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JC658 U.S. PTO 03/07/03

JC498 U.S. PTO 10/382577 03/07/03

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

RULE 60 APPLICATION

Atty. Dkt. PAICE201.DIV

Hon. Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

This is a request for filing a **divisional** application under 37 CFR § 1.60 of pending prior application Serial No. 09/822,866 filed on April 2, 2001 entitled Hybrid Vehicles

Full Name of first joint inventor: Alex J. Severinsky

Residence: Washington, DC Citizenship: U.S.

Post Office Address: 4704 Foxhall Crescent, Washington DC 20007

Full Name of second joint inventor: Theodore Louckes

Residence: Holly, Michigan Citizenship: U.S.

Post Office Address: 10398 Appomattox, Holly, MI 48442

X Enclosed is a copy of the prior application including the Declaration as originally filed. I hereby verify that the attached papers are a true copy of the prior application Serial No. 09/822,866, as originally filed on April 2, 2001.

X The filing fee is calculated below: Claims as filed, less any claims canceled:

									LARGE ENTITY
CLAIMS						Filing Fee:			$750
Total	7	-	20	=	0	x	$18		$0
Indep.	3	-	3	=	0	x	$84		$0
									$750

_X_ The Commissioner is hereby authorized to charge fees under 37 CFR § 1.16 and § 1.17 which may be required, or credit any overpayment of Deposit Account No. 04-0401. A duplicate copy of this sheet is enclosed.

___ Status as a "small entity" under 37 CFR 1.9 is claimed by way of the attached declaration.

___ A preliminary amendment is enclosed.

_X_ An information disclosure statement is enclosed.

_X_ Cancel the following claims before calculating filing the fee: 1 - 9.

_X_ A check in the amount of $ 750.00 is enclosed.

___ Priority of application Serial No. _________ filed on _____ in (country) ___________ is claimed under 35 U.S.C. § 119.

a) ____ Certified copy is on file in prior application Serial No. _________ filed ____________________.

b) ____ Certified copy filed herewith.

_X_ Amend the specification by rewriting lines 4 - 10 to read as follows:

This is a **divisional** application of application Serial No. 09/822,866 filed April 2, 2001, which was a continuation-in-part of Ser. No. 09/264,817, filed March 9, 1999, now U.S. patent 6,209,672, issued April 3, 2001, which in turn claims priority from provisional application Ser. No. 60/100,095, filed Spetember 14, 1998, and was also a continuation-in-part of Ser. No. 09/392,743, filed September 9, 1999, now U.S. patent 6,338,391 issued January 15, 2002, which in turn claims priority from provisional application Ser. No. 60/122,296, filed March 1, 1999.

___ Transfer the drawings for the prior application to this application, and abandon said prior application as of the filing date accorded this application. A duplicate copy of this sheet is enclosed for filing in the prior application file.

_X_ New formal drawings are enclosed.

_X_ The prior application is assigned of record to PAICE Corporation via a document dated May 18 and May 25, 2001 and recorded by the U.S. Patent and Trademark Office on June 26, 2001 at Reel 011932, Frame 0488.

X The power of attorney in the prior application is to Michael de Angeli, Reg. No. 27,869. The power was filed June 26, 2001.

X Address all future communications to:

Michael de Angeli
60 Intrepid Lane
Jamestown RI 02835
401-423-3190

X The undersigned declare further that all statements made herein of his own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Respectfully submitted,

3/5/03
Dated

Michael de Angeli
Reg. No. 27,869
60 Intrepid Lane
Jamestown RI 02835
401-423-3190

HYBRID VEHICLES

Inventors: Alex J. Severinsky
Theodore N. Louckes

Cross-Reference to Related Applications

This application is a continuation-in-part of Ser. No. 09/264,817, filed March 9, 1999, now U. S. patent 6,209,672, issued April 3, 2001, which in turn claims priority from provisional application Ser. No. 60/100,095, filed September 14, 1998, and is also a continuation-in-part of Ser. No. 09/392,743, filed September 9, 1999, which in turn claims priority from provisional application Ser. No. 60/122,296, filed March 1, 1999.

Field of the Invention

This application relates to improvements in hybrid vehicles, that is, vehicles in which both an internal combustion engine and one or more electric motors are provided to supply torque to the driving wheels of the vehicle. More particularly, this invention relates to a hybrid electric vehicle that is fully competitive with presently conventional vehicles as regards performance, operating convenience, and cost, while achieving substantially improved fuel economy and reduced pollutant emissions.

Discussion of the Prior Art

For many years great attention has been given to the problem of reduction of fuel consumption of automobiles and other highway vehicles. Concomitantly very substantial attention has been paid to reduction of pollutants emitted by automobiles and other vehicles. To a degree, efforts to solve these problems conflict with one another. For example, increased thermodynamic efficiency and thus reduced fuel consumption can be realized if an engine is operated at higher temperatures. Thus there has been substantial interest in engines built of ceramic materials withstanding higher combustion temperatures than those now in use. However, higher combustion temperatures in gasoline-fueled engines lead to increase in certain undesirable pollutants, typically NO_x.

Another possibility for reducing emissions is to burn mixtures of gasoline and ethanol ("gasohol"), or straight ethanol. However, to date ethanol has not become economically competitive with gasoline, and consumers have not accepted ethanol to any great degree. Moreover, to make an alternate fuel such as ethanol available to the extent necessary to achieve appreciable improvements in nationwide air quality and fuel conservation would require immense costs for infrastructure improvements; not only the entire nation's motor fuel production and delivery system, but also the vehicle manufacture, distribution, and repair system, would have to be extensively revised or substantially duplicated.

One proposal for reducing pollution in cities is to limit the use of vehicles powered by internal combustion engines and instead employ electric vehicles powered by rechargeable batteries. To date, all such "straight electric" cars have had very limited range, typically no more than 150 miles, have insufficient power for acceleration and hill climbing except when the batteries are substantially fully charged, and require substantial time for battery recharging. Thus, while there are many circumstances in which the limited range and extended recharging time of the batteries would not be an inconvenience, such cars are not suitable for all the travel requirements of most individuals. Accordingly, an electric car would have to be an additional vehicle for most users, posing a substantial economic deterrent. Moreover, it will be appreciated that in the United States most electricity is generated in coal-fired power plants, so that using electric vehicles merely moves the source of the pollution, but does not eliminate it. Furthermore, comparing the respective net costs per mile of driving, electric vehicles are not competitive with ethanol-fueled vehicles, much less with conventional gasoline-fueled vehicles. See, generally, Simanaitis, "Electric Vehicles", *Road & Track*, May 1992, pp. 126-136; Reynolds, "AC Propulsion CRX", *Road & Track*, October 1992, pp. 126-129.

Brooks et al U.S. patent 5,492,192 shows such an electric vehicle; the invention appears to be directed to incorporation of antilock braking and traction control technologies into an otherwise conventional electric vehicle.

Much attention has also been paid over the years to development of electric vehicles including internal combustion engines powering generators, thus eliminating the defect of limited range exhibited by simple electric vehicles. The simplest such vehicles operate on the same general principle as diesel-electric locomotives used by most railroads. In such systems, an internal combustion engine drives a generator providing electric power to traction motors connected directly to the wheels of the vehicle. This system has the advantage that no variable gear ratio transmission is required between the engine and the wheels of the vehicle.

More particularly, an internal combustion engine produces zero torque at zero engine speed (RPM) and reaches its torque peak somewhere in the middle of its operating range. Accordingly, all vehicles driven directly by an internal combustion engine (other than certain single-speed vehicles using friction or centrifugal clutches, and not useful for normal driving) require a variable-ratio transmission between the engine and the wheels, so that the engine's torque can be matched to the road speeds and loads encountered. Further, some sort of clutch must be provided so that the engine can be mechanically decoupled from the wheels, allowing the vehicle to stop while the engine is still running, and to allow some slippage of the engine with respect to the drive train while starting from a stop. It would not be practical to provide a diesel locomotive, for example, with a multiple speed transmission, or a clutch. Accordingly, the additional complexity of the generator and electric traction motors is accepted. Electric traction motors produce full torque at zero RPM and thus can be connected directly to the wheels; when it is desired that the train should accelerate, the diesel engine is simply throttled to increase the generator output and the train begins to move.

The same drive system may be employed in a smaller vehicle such as an automobile or truck, but has several distinct disadvantages in this application. In particular, and as discussed in detail below in connection with Figs. 1 and 2, it is well known that a gasoline or other internal combustion engine is most efficient when producing near its maximum output torque. Typically, the number of diesel locomotives on a train is selected in accordance with the total tonnage to be moved and the grades to be overcome, so that all the locomotives can be operated at nearly full torque production. Moreover, such locomotives tend to be run at steady speeds for long periods of time. Reasonably efficient fuel use is thus achieved. However, such a direct drive vehicle would not achieve good fuel efficiency in typical automotive use, involving many short trips, frequent stops in traffic, extended low-speed operation and the like.

So-called "series hybrid" electric vehicles have been proposed for automotive use, wherein batteries are used as energy storage devices, so that an internal combustion engine provided to power a generator can be operated in its most fuel-efficient output power range while still allowing the electric traction motor(s) powering the vehicle to be operated as required. Thus the engine may be loaded by supplying torque to a generator charging the batteries while supplying electrical power to the traction motor(s) as required, so as to operate efficiently. This system overcomes the limitations of electric vehicles noted above with respect to limited range and long recharge times. Thus, as compared to a conventional vehicle, wherein the internal combustion engine delivers torque directly to the wheels, in a series hybrid electric vehicle, torque is delivered from the engine to the wheels via a serially connected generator used as a battery charger, the battery, and the traction motor. However, energy transfer between those components consumes at least approximately 25% of engine power. Further, such components add substantially to the cost and weight of the vehicle; in particular, an electric motor capable of providing sufficient torque to meet all expected demand, e.g., to allow reasonable performance under acceleration, during hill-climbing and the like, is rather heavy and expensive. Thus, series hybrid vehicles have not been immediately successful.

A more promising "parallel hybrid" approach is shown in U.S. Patent Nos. 3,566,717 and 3,732,751 to Berman et al. In Berman et al an internal combustion engine and an electric motor are matched through a complex gear train so that both can provide torque directly to the wheels, the vehicle being operated in several different modes. Where the output of the internal combustion engine is more than necessary to drive the vehicle ("first mode operation") the engine is run at constant speed and excess power is converted by a first motor/generator ("speeder") to electrical energy for storage in a battery. In "second mode operation", the internal combustion engine drives the wheels directly, and is throttled. When more power is needed than the engine can provide, a second motor/generator or "torquer" provides additional torque as needed.

Berman et al thus show two separate electric motor/generators separately powered by the internal combustion engine; the "speeder" charges the batteries, while the "torquer" propels the vehicle forward in traffic. This arrangement is a source of additional complexity, cost and difficulty, as two separate modes of engine control are required. Moreover, the operator must control the transition between the several modes of operation. Such a complex vehicle is unsuited for the automotive market. Automobiles intended for mass production can be no more complicated to operate than conventional vehicles, and must be essentially "foolproof", that is, resistant to damage that might be caused by operator error. Further, the gear train shown by Berman et al appears to be quite complex and difficult to manufacture economically. Berman et al also indicate that one or even two variable-speed transmissions may be required; see, e.g., col. 3, lines 19 - 22 and 36 - 38 of patent 3,566,717, and col. 2, lines 53 - 55 of patent 3,732,751.

Lynch et al patent 4,165,795 also shows an early parallel hybrid drive. Lynch argues that maximum fuel efficiency can be realized when a relatively small internal combustion engine is provided, such that when the engine is operated at an efficient speed, it produces approximately the average power required over a typical mission. The example given is of an engine producing 25 hp maximum and 17 hp at its most efficient speed, about 2500 rpm. This is to be combined with an electric motor-generator of about 30 peak hp. This vehicle requires a variable-ratio transmission to achieve reasonable performance. It appears that the engine is to be run continuously, at a steady speed, with additional torque provided by the motor when needed and excess torque produced by the engine being used to charge the batteries. In a first embodiment, torque provided by the motor is transmitted to the drive wheels through the engine, while in a second embodiment their respective positions are reversed.

Nishida U.S. patent 5,117,931 shows a parallel hybrid vehicle where torque from an electric motor may be combined with torque from an internal combustion engine in a "torque transmission unit" comprising paired bevel gears and means for controlling the relative rates of rotation of the motor and engine, so that the motor can be used to start the engine, absorb excess torque from the engine (by charging a battery), or provide additional propulsive torque. A variable-speed transmission is coupled between the torque transmission unit and the propelling wheels. Both the torque transmission unit and the variable-speed transmission are complex, heavy, and expensive components, the use of which would preferably be avoided.

Helling U.S. patent 3,923,115 also shows a hybrid vehicle having a torque transmission unit for combining torque from an electric motor and an internal combustion engine. However, in

Helling the relative rates of rotation of the motor and engine input shafts are fixed; a flywheel is provided to store excess mechanical energy as well as a battery to store excess electrical energy. Albright, Jr. et al patent 4,588,040 shows another hybrid drive scheme using a flywheel in addition to batteries to store excess energy; various complicated mechanical connections are provided between the various components. Capacitors have also been proposed for energy storage; see Bates et al U.S. patent 5,318,142.

Fjällström U.S. patent 5,120,282 shows a parallel hybrid drive train wherein torque from two electric motors is combined with torque produced by an internal combustion engine; the combination is performed by a complex arrangement of paired planetary gearsets, and unspecified control means are alleged to be able to allow variation of road speed without a variable-ratio transmission.

Hunt U.S. Patent Nos. 4,405,029 and 4,470,476 also disclose parallel hybrids requiring complex gearing arrangements, including multiple speed transmissions. More specifically, the Hunt patents disclose several embodiments of parallel hybrid vehicles. Hunt indicates (see col. 4, lines 6 - 20 of the '476 patent) that an electric motor may drive the vehicle at low speeds up to 20 mph, and an internal combustion engine used for speeds above 20 mph, while "in certain speed ranges, such as from 15 - 30 mph, both power sources may be energized... Additionally, both power sources could be utilized under heavy load conditions." Hunt also indicates that "the vehicle could be provided with an automatic changeover device which automatically shifts from the electrical power source to the internal combustion power source, depending on the speed of the vehicle" (col. 4, lines 12 - 16).

However, the Hunt vehicle does not meet the objects of the present invention, as discussed in detail below. Hunt's vehicle in each embodiment requires a conventional manual or automatic transmission. See col. 2, lines 6 - 7. Moreover, the internal combustion engine is connected to the transfer case (wherein torque from the internal combustion engine and electric motor is combined) by a "fluid coupling or torque converter of conventional construction". Col. 2, lines 16 - 17. Such transmissions and fluid couplings or torque converters are very inefficient, are heavy, bulky, and costly, and are to be eliminated according to one object of the present invention, again as discussed in detail below.

Furthermore, the primary means of battery charging disclosed by Hunt involves a further undesirable complexity, namely a turbine driving the electric motor in generator configuration. The turbine is fueled by waste heat from the internal combustion engine. See col. 3, lines 10 - 60. Hunt's internal combustion engine is also fitted with an alternator, for additional battery charging capability, adding yet further complexity. Thus it is clear that Hunt fails to teach a hybrid vehicle meeting the objects of the present invention - that is, a hybrid vehicle competitive with conventional vehicles with respect to performance, cost and complexity, while achieving substantially improved fuel efficiency.

Kawakatsu U.S. Patents Nos. 4,305,254 and 4,407,132 show a parallel hybrid involving a single internal combustion engine coupled to the drive wheels through a conventional variable-ratio transmission, an electric motor, and an alternator, to allow efficient use of the internal combustion engine. As in the Hunt disclosure, the engine is intended to be operated in a relatively efficient range of engine speeds; when it produces more torque than is needed to propel the vehicle, the excess is used to charge the batteries; where the engine provides insufficient torque, the motor is energized as well.

A further Kawakatsu patent, No. 4,335,429, shows a hybrid vehicle, in this case comprising an internal combustion engine and two motor/generator units. A first larger motor/generator, powered by a battery, is used to provide additional torque when that provided by the engine is insufficient; the larger motor-generator also converts excess torque provided by the engine into electrical energy, to be stored by the battery, and is used in a regenerative braking mode. The second smaller motor/generator is similarly used to provide additional torque and additional regenerative braking as needed.

More particularly, the latter Kawakatsu patent asserts that a single electric motor sized to provide sufficient torque to propel the vehicle would not be capable of providing sufficient regenerative braking force; see col. 1, line 50 - col. 2 line 8. Accordingly, Kawakatsu provides two separate motor/generators, as noted; a separate engine starting motor is also provided. See col. 6, lines 22 - 23. In the embodiment shown, the larger motor/generator is connected to the wheel drive shaft, while the engine and the smaller motor/generator are connected to the wheels through a complex mechanism comprising three separately-controllable clutches. See col. 5, lines 50 - 62.

Numerous patents disclose hybrid vehicle drives tending to fall into one or more of the categories discussed above. A number of patents disclose systems wherein an operator is required to select between electric and internal combustion operation; for example, an electric motor is provided for operation inside buildings where exhaust fumes would be dangerous, and an internal combustion engine provided for operation outdoors. It is also known to propose a hybrid vehicle comprising an electric motor for use at low speeds, and an internal combustion engine for use at higher speed. The art also suggests using both when maximum torque is required. In several cases the electric motor drives one set of wheels and the internal combustion engine drives a different set. See generally Shea (4,180,138); Fields et al (4,351,405); Kenyon (4,438,342); Krohling (4,593,779); and Ellers (4,923,025).

Many of these patents show hybrid vehicle drives wherein a variable speed transmission is required, as do numerous additional references. A transmission as noted above is typically required where the internal combustion engine and/or the electric motor are not capable of supplying sufficient torque at low speeds. See Rosen (3,791,473); Rosen (4,269,280); Fiala (4,400,997); and Wu et al (4,697,660). Kinoshita (3,970,163) shows a vehicle of this general type wherein a gas turbine engine is coupled to the road wheels through a three-speed transmission; an electric motor is provided to supply additional torque at low speeds.

For further examples of series hybrid vehicles generally as discussed above, see Bray (4,095,664); Cummings (4,148,192); Monaco et al (4,306,156); Park (4,313,080); McCarthy (4,354,144); Heidemeyer (4,533,011); Kawamura (4,951,769); and Suzuki et al (5,053,632). Various of these address specific problems arising in the manufacture or use of hybrid vehicles, or specific alleged design improvements. For example, Park addresses certain specifics of battery charging and discharge characteristics, while McCarthy shows a complex drive system involving an internal combustion engine driving two electric motors; the torque generated by the latter is combined in a complex differential providing continuously variable gear ratios. Heidemeyer shows connecting an internal combustion engine to an electric motor by a first friction clutch, and connecting the motor to a transmission by a second friction clutch.

Other patents of general relevance to this subject matter include Toy (3,525,874), showing a series hybrid using a gas turbine as internal combustion engine; Yardney (3,650,345), showing use of a compressed-air or similar mechanical starter for the internal combustion engine of a series hybrid, such that batteries of limited current capacity could be used; and Nakamura (3,837,419), addressing improvements in thyristor battery-charging and motor drive circuitry. Somewhat further afield but of general interest are the disclosures of Deane (3,874,472); Horwinski (4,042,056); Yang (4,562,894); Keedy (4,611,466); and Lexen (4,815,334); Mori (3,623,568); Grady, Jr. (3,454,122); Papst (3,211,249); Nims et al (2,666,492); and Matsukata (3,502,165). Additional references showing parallel hybrid vehicle drive systems include Froelich (1,824,014) and Reinbeck (3,888,325). U.S. Patent No. 4,578,955 to Medina shows a hybrid system wherein a gas turbine is used to drive a generator as needed to charge batteries. Of particular interest to certain aspects of the present invention is that Medina discloses that the battery pack should have a voltage in the range of 144, 168 or 216 volts and the generator should deliver current in the range of 400 to 500 amperes. Those of skill in the art will recognize that these high currents involve substantial resistance heating losses, and additionally require that all electrical connections be made by positive mechanical means such as bolts and nuts, or by welding. More specifically, for reasons of safety and in accordance with industry practice, currents in excess of about 50 amperes cannot be carried by the conventional plug-in connectors preferred for reasons of convenience and economy, but must be carried by much heavier, more expensive and less convenient fixed connectors (as used on conventional starter and battery cable connections). Accordingly, it would be desirable to operate the electric motor of a hybrid vehicle at lower currents.

U.S. patent 5,765,656 to Weaver also shows a series hybrid wherein a gas turbine is used as the internal combustion engine; hydrogen is the preferred fuel.

U.S. Patent No. 4,439,989 to Yamakawa shows a system wherein two different internal combustion engines are provided, so that only one need be run when the load is low. This arrangement would be complex and expensive to manufacture.

Detailed discussion of various aspects of hybrid vehicle drives may be found in Kalberlah, "Electric Hybrid Drive Systems for Passenger Cars and Taxis", SAE Paper No. 910247 (1991). Kalberlah first compares "straight" electric, series hybrid, and parallel hybrid drive trains, and concludes that parallel hybrids are preferable, at least when intended for general use (that is, straight electric vehicles may be useful under certain narrow conditions of low-speed, limited range urban driving). Kalberlah then compares various forms of parallel hybrids, with respect to his Fig. 4, and concludes that the most practical arrangement is one in which an internal combustion engine drives a first pair of wheels, and an electric motor the second; more particularly, Kalberlah indicates that mechanical combination of the torque from an internal combustion engine and an electric motor is impractical.

Gardner U.S. patents 5,301,764 and 5,346,031 follow Kalberlah's teachings, in that Gardner shows separately driving at least two pairs of wheels; one pair is driven by a first electric motor, and the second by a second electric motor or alternatively by a small internal combustion engine. Three different clutches are provided to allow various sources of drive torque to be connected to the wheels, and to a generator, depending on the vehicle's operation mode. The internal combustion engine is run continuously, and provides the driving torque when the vehicle is in a cruise mode; at other times it is used to charge the batteries powering the electric motors.

Bullock, "The Technological Constraints of Mass, Volume, Dynamic Power Range and Energy Capacity on the Viability of Hybrid and Electric Vehicles", SAE Paper No. 891659 (1989) provides a detailed theoretical analysis of electric vehicles in terms of the loads thereon, and a careful analysis of the various battery types then available. Bullock concludes that a vehicle having two electric motors of differing characteristics, driving the wheels through a variable-speed transmission, would be optimal for automotive use; see the discussion of Fig. 8. Bullock also suggests the use of an internal combustion engine to drive battery charging, but does not address combining the engine's torque with that from the motors; see pp. 24 - 25.

Further related papers are collected in Electric and Hybrid Vehicle Technology, volume SP-915, published by SAE in February 1992. See also Wouk, "Hybrids: Then and Now"; Bates, "On the road with a Ford HEV", and King et al, "Transit Bus takes the Hybrid Route", all in IEEE Spectrum, Vol. 32, 7, (July 1995).

Urban et al U.S. patent 5,667,029 shows two embodiments of parallel hybrids; a first embodiment is shown in Figs. 1 - 9 and 11, and a second in Figs. 12 - 17. Both embodiments have numerous common features, including similar operating modes. Referring to the first embodiment, an internal combustion engine provides torque to the road wheels or to a generator; two electric motors can provide torque to the road wheels, or charge batteries during regenerative braking. Torque from the engine and motors is combined at the input shaft to a variable-ratio transmission. Overrunning clutches are provided, e.g., to allow the engine's torque to be applied to the road wheels without also rotating the motors.

As indicated at col. 6, lines 25 - 54, certain transitions between various operating modes are made automatically, responsive to the position of the accelerator pedal; for example, if the operator does not depress the pedal beyond a given point, only the internal combustion engine is employed to propel the vehicle; if the operator depresses the pedal more fully, the electric motors are also energized. Other changes in the operational mode must be made by the operator directly; for example, the vehicle may be operated as a "straight electric" vehicle, e.g. for short duration trips, by the operator's making an appropriate control action. See col. 7, lines 49 - 56.

The Urban et al design appears to suffer from a number of significant defects. First, the internal combustion engine is stated to provide all torque needed to accelerate the vehicle to cruising speed under normal circumstances (see col. 5, lines 3 - 10), and also to propel the vehicle during cruising (see col. 6, lines 48 - 54). The electric motors are to be used only during rapid acceleration and hill-climbing; col. 5, lines 10 - 13. A 20 horsepower engine, operated through a continuously variable-ratio transmission and a torque converter, is stated to be adequate for this purpose. Such components are clearly complex and expensive; further, torque converters are notoriously inefficient. Moreover, using the internal combustion engine as the sole source of power for low-speed running would require it to be run at low speeds, e.g., at traffic lights, which is very inefficient and highly polluting. (Various additional references suggest that excess torque can be used to charge batteries; if this were incorporated in the Urban system, the engine might be run at a reasonably efficient output level while the vehicle was stationary, but this would lead to high levels of noise and vibration. In any event Urban does not appear to consider this possibility.)

On the other hand, Urban does suggest that the vehicle can be operated as a "straight electric" under low-speed conditions, but this requires the operator to provide an explicit control input; this complexity is unacceptable in a vehicle intended to be sold in quantity, as would be required in order to reach Urban's stated goals of reduction of atmospheric pollution and reduced energy consumption. As noted, hybrid vehicle operation must be essentially "foolproof", or "transparent" to the user, to have any chance of commercial success.

Urban's second embodiment is mechanically simpler, employing but a single "dynamotor", through which torque is transmitted from the engine to the variable-ratio transmission, but suffers from the same operational deficiencies.

A second Urban et al patent, 5,704,440, is directed to the method of operation of the vehicle of the '029 patent and suffers the same inadequacies.

Various articles describe several generations of Toyota Motor Company hybrid vehicles, believed to correspond to that available commercially as the "Prius". See, for example, Yamaguchi, "Toyota readies gasoline/electric hybrid system", Automotive Engineering, July 1997, pp. 55 - 58; Wilson, "Not Electric, Not Gasoline, But Both", Autoweek, June 2, 1997, pp. 17 - 18; Bulgin, "The Future Works, Quietly", Autoweek February 23, 1998, pp. 12 and 13; and "Toyota Electric and Hybrid Vehicles", a Toyota brochure. A more detailed discussion of the Toyota vehicle's powertrain is found in Nagasaka et al, "Development of the Hybrid/Battery ECU for the Toyota Hybrid System", SAE paper 981122 (1998), pp. 19 - 27. According to the Wilson article, Toyota describes this vehicle as a "series-parallel hybrid"; regardless of the label applied, its powertrain appears to be similar to that of the Berman patents described above, that is, torque from either or both of an internal combustion engine and an electric motor are controllably combined in a "power-split mechanism" and transmitted to the drive wheels through a planetary gearset providing the functionality of a variable-ratio transmission. See the Nagasaka article at pp. 19 - 20.

Furutani U.S. patent 5,495,906 describes a vehicle having an internal combustion engine driving a first set of wheels through a variable-ratio transmission and an electric motor driving a second set of wheels. The engine is apparently intended to be run continuously; at low speeds, it drives a generator to charge batteries providing energy to the motor, and at higher speeds the engine or both engine and motor propel the vehicle. In some circumstances the transmission may not be required; compare, for example, col. 3, lines 4 - 8 with col. 5, lines 59 - 64.

U.S. patent 5,842,534 to Frank shows a "charge depletion" control method for hybrid vehicles; in this scheme, the internal combustion engine is essentially used only when the state of the batteries is such that the vehicle cannot otherwise reach a recharging point. See col. 3, lines 50 - 55. In normal operation, the batteries are recharged from an external power source. Frank also discusses two-mode brake pedal operation, wherein mechanical brakes are engaged in addition to regenerative braking when the pedal is depressed beyond a preset point.

U.S. patent 5,823,280 to Lateur et al shows a parallel hybrid wherein the shafts of an internal combustion engine and first and second electric motors are all coaxial; the engine is connected to the first motor by a clutch, and the first motor to the second by a planetary gearset, allowing the speeds of the motors to be varied so as to operate them in their most efficient range. See col. 4, line 57 - col. 5, line 60.

U.S. patent 5,826,671 to Nakae et al shows a parallel hybrid wherein torque from an internal combustion engine is combined with that from a motor in a planetary gearset; a clutch is provided therebetween. The specific invention relates to sensing of engine warmup conditions, so as to limit emission of unburnt fuel and thus lower emissions.

U.S. patent 5,846,155 to Taniguchi et al shows a parallel hybrid wherein torque from an internal combustion engine and a motor is again combined in a planetary gearset; the specific improvement appears to be the use of a continuously-variable transmission.

It will be appreciated by those of skill in the art that there are significant limitations inherent in the use of planetary gearsets as a means for connecting different sources, e.g., an internal combustion engine and an electric motor, to the drive wheels of a vehicle, namely, that unless the planetary gearset is effectively locked (anathematic to its use as a continuously-variable transmission, e.g., in the Toyota vehicle) it is capable of additive combination of shaft speeds, but not of output torque. Hence, the principal advantage of the parallel hybrid drivetrain, additive combination of the output torque of both the electric motor and the internal combustion engine, is only available when the planetary gearset is locked. This fact is acknowledged by Lateur, for example, at col. 6, line 27.

Additional disclosures of possible interest include U.S. patent 5,845,731 to Buglione et al; this patent issued December 8, 1998, and therefore is not necessarily available as a reference against the claims of the present application. The basic powertrain shown by Buglione et al includes an internal combustion engine 12, coupled through a first clutch 18 to a first electric motor 20, coupled to a second electric motor 26 through a second clutch 24; the wheels are (apparently; see col. 3, line 8) driven by the second motor 26. The overall hybrid operational scheme provided by Buglione et al is illustrated in Fig. 4. At low speeds one or both motors may be used to propel the vehicle, with the engine off, idling, or running to drive one motor as a generator. During low-speed cruising the second motor propels the vehicle, while during high-speed cruising, the engine propels the vehicle. When acceleration is required at high speed, the engine and both motors may be used to propel the vehicle. Buglione et al also indicates that a variable-ratio transmission may be unnecessary, col. 3, line 9, and that the first motor can be used to start the engine, col. 4, lines 8 - 15.

U.S. patent 5,586,613 to Ehsani, showing an "electrically peaking hybrid" vehicle is also of interest. Ehsani's vehicle is shown in several embodiments; in each, an engine is apparently to be run continuously, with excess torque used to charge the batteries, and one or more motors used to provide additional propulsive torque when the engine's output torque is inadequate. A transmission is provided in some embodiments of the Ehsani vehicle. An embodiment involving two motors is shown in Fig. 7, and can be modified as discussed in the text at col. 9, lines 4 - 5. Fig. 7 itself shows driving a first set of wheels by a first "electric machine", i.e., a motor capable of operation as a generator. This drive arrangement is independent of a second drive arrangement, whereby a second set of wheels is driven by an engine connected through a first clutch to a second electric machine, connected to the second set of wheels by a second clutch. Ehsani suggests at col. 9, lines 4 - 5 that the drive shaft otherwise coupled to the first electric machine could also be driven by the engine. Although it is not made explicit that the first electric machine is to be retained, this seems likely; otherwise, the modified Fig. 7 embodiment would be the same as Ehsani's Fig. 1, modified to have all four wheels driven by a common driveshaft.

This application discloses a number of improvements over and enhancements to the hybrid vehicles disclosed in U.S. patent 5,343,970 (the "'970 patent"), to one of the present inventors, which is incorporated herein by this reference. Where differences are not mentioned, it is to be understood that the specifics of the vehicle design shown in the '970 patent are applicable to the vehicles shown herein as well. Discussion of the '970 patent herein is not to be construed to limit the scope of its claims.

Generally speaking, the '970 patent discloses hybrid vehicles wherein a controllable torque transfer unit is provided capable of transferring torque between an internal combustion engine, an electric motor, and the drive wheels of the vehicle. The direction of torque transfer is controlled by a microprocessor responsive to the mode of operation of the vehicle, to provide highly efficient operation over a wide variety of operating conditions, and while providing good performance. The flow of energy - either electrical energy stored in a substantial battery bank, or chemical energy stored as combustible fuel - is similarly controlled by the microprocessor.

For example, according to the operating scheme of the hybrid vehicle disclosed in the '970 patent, in low-speed city driving, the electric motor provides all torque needed responsive to energy flowing from the battery. In high-speed highway driving, where the internal-combustion engine can be operated efficiently, it typically provides all torque; additional torque may be provided by the electric motor as needed for acceleration, hill-climbing, or passing. The electric motor is also used to start the internal-combustion engine, and can be operated as a generator by appropriate connection of its windings by a solid-state, microprocessor-controlled inverter. For example, when the state of charge of the battery bank is relatively depleted, e.g., after a lengthy period of battery-only operation in city traffic, the internal combustion engine is started and drives the motor at between 50 and 100% of its maximum torque output, for efficient charging of the battery bank. Similarly, during braking or hill descent, the kinetic energy of the vehicle can be turned into stored electrical energy by regenerative braking.

The hybrid drive train shown in the '970 patent has many advantages with respect to the prior art which are retained by the present invention. For example, the electric drive motor is selected to be of relatively high power, specifically, equal to or greater than that of the internal combustion engine, and to have high torque output characteristics at low speeds; this allows the conventional multi-speed vehicle transmission to be eliminated. As compared to the prior art, the battery bank, motor/generator, and associated power circuitry are operated at relatively high voltage and relatively low current, reducing losses due to resistive heating and simplifying component selection and connection.

It can thus be seen that while the prior art, including the '970 patent, clearly discloses the desirability of operating an internal combustion engine in its most efficient operating range, and that a battery may be provided to store energy to be supplied to an electric motor in order to even out the load on the internal combustion engine, there remains substantial room for improvement. In particular, it is desired to obtain the operational flexibility of a parallel hybrid system, while optimizing the system's operational parameters and providing a substantially simplified parallel hybrid system as compared to those shown in the prior art, again as including the '970 patent.

As noted above, the present application is a continuation-in-part of Ser. No. 09/264,817, filed March 9, 1999 (the '817 application), which discloses and claims several distinct improvements over the hybrid vehicles shown in the '970 patent, as discussed in further detail below. Similarly, the present application is a continuation-in-part of Ser. No. 09/392,743, filed September 9, 1999 (the '743 application), which discloses and claims several distinct improvements over the hybrid vehicles shown in the '970 patent and the '817 application, as discussed in further detail below. The present application discloses and claims further improvements over the vehicles of the '817 and '743 applications.

As discussed in detail below, the '817 and '743 applications (which are not to be limited by this brief summary) disclose a new "topology" for a hybrid vehicle, wherein an internal combustion engine and a first electric "starting" motor, which can be operated as a starter, to start the engine, a generator, to charge the battery bank responsive to torque from the engine or the wheels (i.e., during regenerative braking) or as a source of torque, to propel the vehicle, are connected to the road wheels of the vehicle through a clutch, so that the engine can be decoupled from the wheels during starting and battery charging, but can be connected to the wheels to propel the vehicle. A second "traction" motor is directly connected to the road wheels to propel the vehicle. The vehicle operating mode is determined by a microprocessor responsive to the "road load", that is, the vehicle's instantaneous torque demands. The '743 application further discloses that a turbocharger may be provided, and operated when needed to increase the torque output of the engine when torque in excess of its normally-aspirated capacity is required for more than a minimum time. The present application builds further on these concepts.

Koide U.S. patent 5,934,395 and Schmidt-Brücken U.S. patent 6,059,059 were addressed during the prosecution of the '817 application. Tsuzuki 6,018,198 and Werson 5,986,376 were also each applied against one claim. As indicated, the '817 application discloses a hybrid vehicle comprising a controller, a battery bank, an internal combustion engine, and two electric motors, a starting motor and a traction motor. The starting motor and engine are connected to the road wheels through a clutch, while the traction motor is connected directly and permanently to the road wheels for torque transmission therebetween, i.e., without a clutch therebetween. Koide does not show this "topology" for a hybrid vehicle; although Koide does show a hybrid vehicle having first and second motors along with an engine, the components are not connected as described. Specifically, in Koide, both motors and the engine are connected to the road wheels by way of a variable-ratio transmission and a clutch, while, as noted, in the '817 application only the combination of the engine and starting motor is connected to the wheels through a clutch, while the traction motor is connected directly to the wheels for torque transmission therebetween, that is, without a clutch or variable-ratio transmission. More specifically, Koide's entire disclosure is premised on being able to vary the ratios between the torque-producing components of his system and the road wheels, in order that the engine can be smoothly started when needed. According to the '817 application, only the starter motor and engine need to be disconnectible from the wheels for smooth starting, while the traction motor can be connected to the road wheels at all times. This represents a substantial simplification with respect to the system shown by Koide.

The Schmidt-Brücken patent also fails to show the topology shown in the '817 application. Schmidt-Brücken shows an engine 1 in combination with a starting motor 7, connected to the road wheels through a first clutch 11, and a traction motor 19 connected to the road wheels through a second clutch 23.

The '817 and '743 applications also disclose that the vehicle operating mode is determined by a microprocessor responsive to the "road load", that is, the vehicle's instantaneous torque demands, i.e., that amount of torque required to propel the vehicle at a desired speed. The operator's input, by way of the accelerator or brake pedals, or a "cruise control" device, indicates that continuing at steady speed is desired, or that a change in vehicle speed is called for. For example, the operator's depressing the accelerator pedal signifies an increase in desired speed, i.e., an increase in road load, while reducing the pressure on the accelerator or depressing the brake pedal signifies a desired reduction in vehicle speed, indicating that the torque being supplied is to be reduced or should be negative. More particularly, it is important to note that the road load can vary between wide limits, independent of vehicle speed, and can be positive or negative, i.e., when decelerating or descending a hill, in which case the negative road load (that is, torque available at

[redacted]

the wheels in excess of that required to propel the vehicle) is usually employed to charge the battery bank.

More particularly, it is important to recognize that road load is not the same thing as vehicle velocity. Indeed, as noted, road load can be negative while vehicle velocity is positive, as during deceleration or descent. Moreover, widely differing road loads may be encountered during operation at the same velocity; for example, operation at 50 mph on a flat road may involve a road load of only 30 - 40% of the engine's maximum output torque (MTO), while accelerating from the same speed while climbing a hill may involve a road load of well over 100% of MTO.

By the same token, control of the vehicle's operating mode in response to monitoring of road load is not the same as controlling its operating mode in response to vehicle speed. Numerous prior art references, including the Koide and Schmidt-Brücken patents, teach the latter, i.e., indicate the vehicle operating mode should be controlled in response to vehicle speed. See Koide at col. 12, lines 45 - 48, and Schmidt-Brücken at col. 5, line 56 - col. 6 line 29. Neither Koide nor Schmidt-Brücken, nor any other reference of which the inventors are aware, recognizes that the desired vehicle operational mode should preferably be controlled in response to the vehicle's actual torque requirements, i.e., the road load. Doing so according to the invention provides superior performance, in terms of both vehicle response to operator commands and fuel efficiency, under the widely-varying conditions encountered in "real world" driving situations, than is possible according to the prior art.

Moreover, as set forth in the '817 and '743 applications, in order to provide maximum efficiency in use of fuel, it is essential to operate the internal combustion engine of a hybrid vehicle only under circumstances where the engine will be loaded so as to require at least 30% of its maximum torque output ("MTO") (it being understood throughout this specification and the appended claims that this 30% figure is arbitrary and can be varied). If the vehicle is controlled to shift into an engine-only mode whenever it exceeds some arbitrary road speed, as in Koide and Schmidt-Brücken, it is apparent that the engine will be operated at various times when the road load is less than 30% of MTO, for example, during deceleration or during descents. Moreover, as noted above, the torque actually required can vary widely irrespective of vehicle speed. For example, 30% of MTO may be sufficient to maintain steady speed on a flat road, but 150% of MTO may be required for acceleration from the same speed. If the vehicle's operational mode is selected based solely on speed, as taught by Koide and Schmidt-Brücken, it will be incapable of responding to the operator's commands, and will ultimately be unsatisfactory.

By comparison, according to the invention of the '817 and '743 applications, and as further disclosed and claimed herein, the vehicle's operating mode -- that is, the selection of the source of torque needed to propel the vehicle -- is determined based on the amount of torque actually required. In this way the proper combination of engine, traction motor, and starting motor is always available. This apparently-simple point has evidently been missed entirely by the art.

Moreover, according to this aspect of the invention, the engine is used to propel the vehicle only when it is efficient to do so. This is in accordance with another aspect of the invention, wherein the engine is operated only at high efficiency, leading directly to improved fuel economy. For example, the engine is also used as needed to charge the battery bank, e.g., in low-speed city driving, where the battery bank may become depleted. The starter motor, which is operated as a generator in these circumstances, is accordingly sized so as be able to accept at least 30% of MTO as input torque; the battery bank is likewise sized so as to be able to accept a corresponding amount of charging current. Therefore the engine is never operated at less than 30% of MTO, and is thus never operated inefficiently. Koide and Schmidt-Brücken, because they teach switching the vehicle's operational mode based on vehicle speed and not its torque requirements, would inherently operate the engine under less efficient conditions.

Furutani patent 5,495,906 discloses selection of operating mode based on a combination of vehicle speed and "vehicle load"; see, e.g., col. 2, lines 39 - 47: "It is preferable that the running state detection means detects vehicle speed and vehicle load...[and] that the control means transfers the driving force generated by the engine to the power generator and changes the electric power generated by the power generator [i.e., more of the engine power is used to charge the batteries] in accordance with the vehicle load if the vehicle speed is the predetermined value or less. Moreover, it is preferable to change the predetermined value of the vehicle speed in accordance with the vehicle load." It thus appears that Furutani determines the vehicle operating state based on vehicle speed, although the change-over speed can be varied responsive to the vehicle load. Furutani's "vehicle load" thus apparently includes the torque required to charge the battery, as distinguished from applicants' "road load", i.e., the torque required to propel the vehicle. Even assuming that Furutani's "vehicle load", which is not defined, were suggestive of "road load" as used by applicants, Furutani clearly does not suggest determining the operating mode based on road load. More specifically, although Furutani recognizes a distinction between differing vehicle loads, and that the vehicle load can vary independent of vehicle speed, the vehicle operating mode is nonetheless selected based on vehicle speed; see col. 3, line 62 - col. 4, line 32. Instead of varying the operating mode of the vehicle based on road load, Furutani directs more or less of the engine's torque to battery charging; see col. 4, lines 24 - 32.

Frank 6,054,844 shows several embodiments of hybrid vehicles. In those where an engine is used to provide torque to the vehicle wheels, a continuously-variable transmission is employed, and the ratio R is considered in determining the response to be made to operator input, e.g., accelerator and brake pedal positions. Frank's control strategy is to operate the engine along a line of optimal efficiency and use an electric motor to add to or subtract from the engine's output torque as appropriate. See col. 6, line 49 - col. 7, line 7 and col. 10, line 33 - col. 11, line 22. Frank thus does not suggest control of the vehicle operating mode responsive to road load.

Patent 6,018,694 to Egami et al shows a controller for a hybrid vehicle comprising an internal combustion engine and first and second "rotary electric units". Although the question is not free from doubt, it appears from a detailed review of Egami's disclosure that torque from the engine is not supplied directly to the road wheels, but instead is used to drive one of the rotary electric units as a generator, in turn supplying the second with current to provide torque for propelling the vehicle. Hence Egami does not show selection of the operational mode of the vehicle (that is, the determination whether propulsive torque is to be provided from the engine, one or both of the motors, or all three) in response to the road load, since it does not appear that propulsive torque is ever supplied from the engine to the wheels. Moreover, despite making reference to a "vehicle driving torque demand Mv*", which might be misunderstood to be equivalent to applicant's road load, Egami in fact does not determine the road load. More specifically, Mv* is determined by consulting a "map", using "the vehicle speed V, the accelerator lift ACC, the brake state BRK, and the shift position SFT as the input parameters". See col. 22, lines 23 - 26. The same point, i.e., that the "vehicle driving torque demand Mv*" is not equivalent to applicant's claimed road load, is made throughout Egami's extensive specification; see, for example, col. 10, lines 28 - 32 and col. 27, lines 58 - 65.

Deguchi patent 5,993,351 refers to decision-making regarding the vehicle mode of operation "based on the vehicle speed detected value and the required motive force detected value" (Abstract; see also col. 1, line 41); the latter might be misunderstood to be equivalent to the road load. Deguchi also states (col. 2, lines 7

- 9) that the vehicle "runs on the motor at times of low load and runs on the internal combustion engine at times of high load". However, Deguchi makes it clear that in fact the operational-mode decision is made "based on the accelerator aperture detected value θ which represents the required driving force of the vehicle and the detected vehicle speed" (col. 5, lines 19 - 21). The accelerator position and vehicle speed signals are the only relevant inputs to the vehicle controller shown in Fig. 2. Hence Deguchi does not show controlling the vehicle operating mode responsive to road load as defined by applicants.

Along generally similar lines, Boll patent 5,327,992 teaches a hybrid vehicle comprising a diesel engine and a motor on a common shaft, and intended to be operated such that the engine is only operated efficiently, i.e., under relatively high load. The torque required to overcome the "instantaneous tractive resistance" is determined responsive to the deflection of the accelerator pedal, i.e., in response to operator command (see col. 3, line 13 and line 35); when this is less than the minimum amount of torque that can be produced efficently by the engine, the excess torque is used to power the motor as a generator. Boll also suggests that both the motor and engine can be used to propel the vehicle when needed, e.g., during acceleration, and that the vehicle can be operated in four different modes: (a) engine alone powering the vehicle; (b) motor only powering the vehicle, with the engine "generally switched off"; (c)engine and motor both powering the vehicle; and (d) engine powering vehicle, with excess torque powering motor in generator mode. Boll also teaches that a second motor can be provided, operable as a generator and then driven either by the engine directly or by exhaust gas, and that the resulting current can be used to charge the battery or to power the other motor.

Other references of interest are directed to the braking systems of hybrid vehicles, see for example German patent 19 05 641 to Strifler, discussing a method of control of a braking system providing both regenerative and mechanical braking, and the powering of ancillary systems, such as power steering pumps, see U.S. patent 5,249,637 to Heidl. These references are discussed in further detail below with reference to improvements provided in these areas by the present application.

Objects of the Invention

It is an object of the invention to provide an improved hybrid electric vehicle realizing substantially increased fuel economy and reduced pollutant emissions as compared to present day internal combustion and hybrid vehicles while suffering no significant penalty in performance, operating convenience, cost, complexity, or weight, which can be operated efficiently by an operator accustomed to conventional vehicles without special training, and which does not require modification of the existing infrastructure developed over the years to support conventional vehicles.

More specifically, it is an object of the invention to provide such an improved vehicle that operates on fuel now widely available and uses batteries already well understood and widely available, so that the operator need not learn new driving techniques, deal with new fuel supply arrangements, nor be obliged to be attentive to maintenance of batteries employing complex new technologies.

It is a more particular object of the present invention to provide an improved series-parallel hybrid electric vehicle wherein an internal combustion engine and two separately-controlled electric motors can separately or simultaneously apply torque to the driving wheels of the vehicle, controlled to realize maximum fuel efficiency at no penalty in convenience, performance, or cost.

It is a further object of the invention to provide a series-parallel hybrid electric vehicle comprising two electric motors together providing output power equal to at least 100 percent of the rated output power of the internal combustion engine, and more preferably up to about 150 - 200 percent thereof, so that the engine operates under substantially optimum conditions in order to realize substantial fuel economy and reduced emission of undesirable pollutants in operation.

More particularly, it is an object of the invention to provide a series-parallel hybrid electric vehicle wherein the internal combustion engine is sized to efficiently provide the average power required for operation at moderate and highway speeds, with two)or more) separately-controlled electric motors together sized to deliver the additional power needed for acceleration and hill climbing.

Still another object of the invention is to provide a series-parallel hybrid electric vehicle wherein the electric motor and battery charging circuits operate at no more than about 30 - 50 amperes continuous current (although significantly greater currents may flow for short periods, under peak load conditions), whereby resistance heating losses are greatly reduced, and whereby inexpensive and simple electrical manufacturing and connection techniques can be employed.

It is a more specific object of the present invention to provide a hybrid drive system for vehicles that does not require the controllable torque-transfer unit shown in the '970 patent, while providing the functional advantages of the hybrid vehicle shown in the '970 patent.

It is a more specific object of the invention to employ the control flexibility provided by the improved hybrid drive train of the invention to allow starting of the engine at comparatively high RPM, while controlling the fuel/air mixture supplied during starting, throttling the engine, and providing a preheated catalytic converter, minimizing emission of unburned fuel and further improving fuel economy.

It is a more specific object of the invention to employ the control flexibility provided by the improved hybrid drive train of the invention to allow employment of a motor producing substantially constant torque up to a base speed, and substantially constant power thereafter, as the engine starting motor, so that torque produced thereby can also be used to propel the vehicle.

In addition to the above objects of the invention, which are similar to those listed in the '817 and '743 applications, the invention of the present continuation-in-part application has as objects the broadening of the useful ranges of loading of vehicles according to the invention, e.g., to provide highly efficient hybrid operation for a vehicle that may weigh 7,000 pounds empty but which can be loaded to weigh 10,000 pounds or more, and may be expected to pull a trailer also weighing 10,000 pounds or more.

A further object of the present invention is to provide further improvements in methods of control of internal combustion engines for hybrid vehicles, to obtain very efficient use of fuel.

Another object of the present invention is to provide an optimal HVAC system for hybrid vehicles.

Still a further object of the invention is to provide a braking system for hybrid vehicles including regenerative braking that provides optimal operator feedback despite changes in operation responsive to the state of charge of the battery bank.

Other aspects and objects of the invention will become clear as the discussion below proceeds.

Summary of the Invention

As discussed above, the '970 patent discloses hybrid vehicles wherein a controllable torque transfer unit is provided capable of transferring torque between an internal combustion engine, an electric motor, and the drive wheels of the vehicle. See Figs. 3 - 11 thereof. The direction of torque transfer is controlled by a microprocessor responsive to the mode of operation of the vehicle, to provide highly efficient operation over a wide variety of operating conditions, and while providing good performance. The flow of energy - either electrical energy stored in a substantial battery bank, or chemical energy stored as combustible fuel - is similarly controlled by the microprocessor.

According to one aspect of the invention of the '817 and '743 applications, which is also employed according to the present continuation-in-part application, the controllable torque-transfer unit shown in the '970 patent is eliminated by replacing the single electric motor shown therein by two separate motors, both operable as generators and as traction motors when appropriate. See Figs. 3 and 4 hereof. As in the '970 patent, an internal combustion engine is provided, sized to provide sufficient torque to be adequate for the range of cruising speeds desired, and is used for battery charging as needed. The internal combustion engine is connected to the drive wheels by a clutch operated by the microprocessor responsive to its selection of the vehicle's mode of operation in response to evaluation of the road load, that is, the vehicle's instantaneous torque demands and input commands provided by the operator of the vehicle. A relatively high-powered "traction" motor is connected directly to the output shaft of the vehicle; the traction motor provides torque to propel the vehicle in low-speed situations, and provides additional torque when required, e.g., for acceleration, passing, or hill-climbing during high-speed driving.

According to the invention of the '817 and '743 applications, a relatively low-powered starting motor is also provided, and can be used to provide torque propelling the vehicle when needed. This second motor is connected directly to the internal combustion engine for starting the engine. Unlike a conventional starter motor, which rotates an internal combustion engine at low speed (e.g., 60 - 200 rpm) for starting, necessitating provision of a rich fuel/air mixture for starting, the starter motor according to the invention spins the engine at relatively high speeds, e.g., 300 - 600 rpm, for starting; this allows starting the engine with a much less fuel-rich fuel/air mixture than is conventional, significantly reducing undesirable emissions and improving fuel economy at start-up. A catalytic converter provided to catalytically combust unburnt fuel in the engine exhaust is preheated to an effective working temperature before starting the engine, further reducing emissions.

In the embodiment discussed in detail, the starting motor is connected directly to the engine, and this combination is connected to the traction motor by a clutch for transfer of torque; the output shaft of the traction motor is then connected to the road wheels of the vehicle. In other embodiments, the engine/starting motor combination may be connected to a first set of road wheels through a clutch, with the traction motor connected to another set of road wheels directly; in a further embodiment, plural traction motors may be provided. In each case, the engine is controllably disconnected from the road wheels by control of the clutch. Engagement of the clutch is controlled by the microprocessor, e.g., controlling an electrical or hydraulic actuator as part of controlling the state of operation of the vehicle in response to the road load.

For example, during low-speed operation, the clutch will be disengaged, so that the engine is disconnected from the wheels; the vehicle is then operated as a "straight" electric car, i.e., power is drawn from the battery bank and supplied to the traction motor. Should the batteries become relatively depleted (e.g., become discharged to 50% of full charge), the starter motor is used to start the internal combustion engine, which then runs at relatively high torque output (e.g., at least about 30% of its maximum torque), for efficient use of fuel, and the starting motor is operated as a high-output generator to recharge the battery bank.

Similarly, when the operator calls for more power than available from the traction motor alone, e.g., in accelerating onto a highway, the starter motor starts the internal combustion engine; when it reaches an engine speed at which it produces useful torque, the clutch is engaged, so that the engine and starter motor can provide additional torque. As noted above, the engine is rotated at relatively high speed for starting, so that the engine rapidly reaches a useful speed.

As in the '970 patent, the engine is sized so that it provides sufficient power to maintain the vehicle in a range of suitable highway cruising speeds, while being operated in a torque range providing good fuel efficiency; if additional power is then needed, e.g., for hill-climbing or passing, the traction and/or starter motors can be engaged as needed. Both motors can be operated as generators, e.g., to transform the vehicle's kinetic energy into electrical power during descent or deceleration. Also as in the '970 patent, the peak power of the two motors together at least equals the rated power of the engine, as is necessary to provide good performance without employment of a variable-speed transmission or the equivalent.

In each of these aspects of the operation of the vehicle, and as in the '970 patent, the operator of the vehicle need not consider the hybrid nature of the vehicle during its operation, but simply provides control inputs by operation of the accelerator and brake pedals. The microprocessor determines the appropriate state of operation of the vehicle based on these and other inputs and controls the various components of the hybrid drive train accordingly.

It is also within the scope of the invention to operate one or both of the motors at differing rotational speeds than the engine, so that each can be optimized for the demands thereon. More specifically, motors can in general be made smaller if they can be operated at relatively high RPM. Motors operating at up to 9000 - 18,000 RPM appear appropriate for the present application. However, operating the internal combustion engine at this speed would likely lead to undesirable levels of noise and vibration, and might constrain its performance characteristics in an undesirable manner. Accordingly, for example, the starter motor might drive the engine through a pinion geared to a larger toothed flywheel, as conventional. Similarly, it might be desirable to provide the traction motor as a relatively high-speed unit, driving the road wheels through a chain, belt, or gear reduction unit. The starter motor may be configured as a "faceplate" or "pancake" motor, essentially forming the flywheel of the engine, and rotating at engine speed, while the traction motor is a much higher speed induction motor connected to the vehicle driveshaft by a chain drive reduction unit. It is also within the scope of the invention, as noted above, to operate the engine and the two motors at the same speed when the clutch is engaged, avoiding intermediate gear trains or like mechanical components and the attendant cost, complexity, weight, audible noise, and frictional losses occasioned by their use.

Other improvements provided according to the invention include providing the batteries in two series-connected battery banks, with the vehicle chassis connected to the batteries at a central point, between the banks. This "center-point-chassis" connection reduces the voltage between various circuit components and the vehicle chassis by half, significantly reducing the electrical insulation required and simplifying such issues as heat-sinking of power semiconductors used in the inverter circuitry. Providing dual battery banks and dual electric motors, as above, also provides a degree of redundancy, permitting certain component failures without loss of vehicle function.

In the preferred embodiment, both the traction and starting motors are AC induction motors of four or more phases and the accompanying power circuitry provides current of more than three, preferably five, phases, allowing the vehicle to function even after failure of one or more components. These motors, and the inverter/chargers driving them, should be chosen and operated such that the motors have torque output characteristics varying as a function of rpm as illustrated in Fig. 14 of the '970 patent; that is, the motors should produce substantially constant torque up to a base speed and should produce substantially constant power at higher speeds. The ratio of the base to maximum speed can vary between about 3 to 1 and about 6 to 1. By comparison, the series-wound DC motors conventionally used as engine starting motors provide very high torque, but only at very low speeds; their torque output drops precipitously at higher speeds. Such conventional starter motors would be unsatisfactory in the present system.

During substantially steady-state operation, e.g., during highway cruising, the control system operates the engine at varying torque output levels, responsive to the operator's commands. The range of permissible engine torque output levels is constrained to the range in which the engine provides good fuel efficiency. Where the vehicle's torque requirements exceed the engine's maximum efficient torque output, e.g., during passing or hill-climbing, one or both of the electric motors are energized to provide additional torque; where the vehicle's torque requirements are less than the minimum torque efficiently provided by the engine, e.g., during coasting, on downhills or during braking, the excess engine torque is used to charge the batteries. Regenerative charging may be performed simultaneously, as torque from the engine and the vehicle's kinetic energy both drive either or both motors in generator mode. The rate of change of torque output by the engine may be controlled in accordance with the batteries' state of charge.

The vehicle is operated in different modes, depending on its instantaneous torque requirements, and the state of charge of the battery, and other operating parameters. The mode of operation is selected by the microprocessor in response to a control strategy discussed in detail below; the values of the sensed parameters in response to which the operating mode is selected may vary depending on recent history, or upon analysis by the microprocessor of trips repeated daily, and may also exhibit hysteresis, so that the operating mode is not repetitively switched simply because one of the sensed parameters fluctuates around a defined setpoint.

None of the implementations of the invention shown in the '970 patent or the '817 and '743 applications include a conventional multi-speed transmission between the motors and engine and the road wheels, and it was stated that a desirable aspect of the invention was to avoid such transmissions, so that the rotational speeds of the two motors and the engine were fixed with respect to one another, and to the speed of the road wheels. However, it now appears that in some circumstances a two-speed transmission may be desired in some cases to broaden the range of utility of the vehicles of the invention (principally to extend their load-carrying capabilities) while still providing highly efficient operation, and to include such a two-speed transmission is accordingly part of the invention of the present continuation-in-part application. Such a two-speed transmission could be operated infrequently as a two-speed "range selector", or could be operated essentially as a conventional automatic transmission, that is, be repetitively shifted during acceleration, upon "kick-down" and the like.

More specifically, it is of great present interest to optimize the hybrid power train of the invention for use with relatively heavy vehicles, such as vans, pickup trucks and "sport-utility vehicles" (SUVs). Such vehicles have become increasingly popular in recent years, despite their generally poor fuel mileage; it would be highly desirable to provide vehicles with generally similar load-carrying abilities and performance with better fuel economy. Still more particularly, heretofore large classes of such vehicles have not been subject to certain emission regulations; however, such regulations are expected to take effect shortly. Accordingly, it would be very desirable to provide such vehicles with hybrid power trains that will allow their owners to enjoy the load-carrying and performance abilities of the existing vehicles with improved fuel economy and reduced emissions.

One of the aspect of SUVs and similar vehicles that must be considered in design of a suitable hybrid powertrain is that their owners use them to carry and tow widely-varying loads. That is, a conventional SUV might weigh 5,500 pounds, and might typically be used during the week to transport a 140 pound person, up to 300 pounds of children, and 50 pounds of groceries. However, on the weekend the family might load the vehicle with half a ton of camping gear and the like and set off for the mountains towing a

7,500 pound trailer. The vehicle must provide adequate acceleration, passing, and hill-climbing performance in both uses. In order to have sufficient power at times of maximum loading, the vehicle is grossly overpowered under all different circumstances; that is, only when the vehicle is laden to near-maximum capacity and pulling up a long hill does the engine deliver near maximum torque for any length of time. Under all other circumstances, it is run very inefficiently, as noted in connection with Figs. 1 and 2 (reproduced herein from the '970 patent).

An important aspect of the invention as described by the present continuation-in-part application as well as the predecessor applications and the '970 patent lies in controlling the operation of the internal combustion engine of a hybrid vehicle so that it is only operated at high efficiency, that is, only when is it loaded to require a substantial fraction e.g., 30% of its maximum torque output. That is, the engine is never run at less than 30% of maximum torque output ("MTO"). As discussed in the '970 patent and the '817 application, this can be accomplished by sizing the engine so that it can efficiently propel the vehicle unassisted at highway speeds; if additional torque is required for passing or hill-climbing, the traction motor is operated. Application Ser. No. 392,743 further adds the idea of providing a turbocharger, controlled by the microprocessor only to operate when torque in excess of the engine's rated normally-aspirated maximum torque output (MTO) is needed for an extended period of time, for example in towing a trailer. By employing the turbocharger only when actually needed, many of the drawbacks inherent in conventional turbocharger uses are eliminated. Typically the turbocharger may be sized such that the engine provides up to 150% of MTO when turbocharged.

According to one aspect of the invention of the present continuation-in-part application, the range of efficient use of the hybrid vehicle of the invention is further broadened by providing a two-speed transmission between the engine and road wheels, so as to allow variation in the overall gear ratio and therefore vary the amount of torque available at the wheels. As noted above, this could be a manually- or automatically-operated "range shifting" gearbox akin to those presently provided on SUVs and the like, to allow shifting into a "low range", for example, when a heavy trailer is be towed, or could be operated similarly to a conventional multispeed transmission, that is, to provide a sequence of effective overall gear ratios each time the vehicle is accelerated.

A further improvement made according to the present continuation-in-part application has to do with the braking system. As noted above, the '970 patent (as well as numerous other prior art references) disclose regenerative braking, that is, employing the microprocessor to control the operation of inverter/chargers connected between the motor and battery bank so that when the operator desires to slow the vehicle, its momentum is used to drive the motor in generator mode, charging the battery. There are certain limitations on this as a method of vehicle braking, which must be addressed by any useful vehicle. In particular, a hydraulic braking system of generally conventional design must be provided for several reasons: first, for safety, in the event that the regenerative system fails for any reason; second, to provide braking in the event the battery bank is fully charged and cannot accept further charge (since overcharging is highly detrimental to battery life); and to provide braking when regenerative braking is not available, e.g., when at a standstill. The present application discloses certain improvements in hydraulic braking systems desired to optimize their design for use with hybrid vehicles, as well as a mechanism providing optimized brake "feel" to the driver, regardless whether conventional, regenerative, or both braking systems are in use.

The present application also discloses certain problems inherent in application of conventional vehicles' heating, ventilation and air conditioning systems to hybrid vehicles, and describes preferred solutions to these problems.

A further improvement according to the present invention includes the provision of an auxiliary 12 volt supply system, allowing the hybrid vehicle of the invention to "jumpstart" another vehicle, or likewise to be jumpstarted as might be necessary after a long hiatus, and to allow use of conventional 12 volt accessories, such as radios and other electronic items.

The present application also discloses further useful modifications and enhancements to the hybrid vehicles of the predecessor applications.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of a specific embodiment thereof, especially when taken in conjunction with the accompanying drawings, wherein like reference numerals in the various figures are utilized to designate like components.

Brief Description of the Drawings

The invention will be better understood if reference is made to the accompanying drawings, in which:

Fig. 1 is a plot of output power versus rotational speed (RPM) for a typical internal combustion engine, illustrating the relative fuel consumption of the engine as used in a conventional automobile in gallons/horsepower-hour;

Fig. 2 is a similar plot describing operation of a relatively small internal combustion engine used in the present invention under circumstances similar to those depicted in Fig. 1;

Fig. 3 shows a schematic diagram of the principal components of a first embodiment of the hybrid vehicle drive system according to the invention;

Fig. 4 shows a block diagram of the principal components of the drive system of the invention in a second embodiment, differing in certain mechanical arrangements from that of Fig. 3, and illustrating various control signals provided in both embodiments;

Fig. 5 shows a partial schematic diagram of the battery bank, inverter, and motor circuitry;

Fig. 6 is a diagram illustrating differing modes of vehicle powertrain operation, plotted on a three dimensional chart, illustrating that the mode of vehicle operation is a function of the state of charge of the battery bank, the instantaneous road load, and time;

Fig. 7, comprising Figs. 7 (a)-(c), and extending over two sheets, is a timing diagram showing road load, engine torque output, the state of charge of the battery bank, and engine operation as functions of time, thus illustrating a typical control strategy employed during low-speed city driving, highway cruising, and extended high-load driving;

Fig. 8, comprising Figs. 8 (a)-(d), are diagrams indicating the flow of torque and of energy among the components of the hybrid powertrain of the invention, in various modes of operation;

Fig. 9 is a simplified flow chart of the algorithm employed by the microprocessor to implement the control strategies provided by the vehicle according to the invention;

Fig. 9(a) is a flow chart of an engine starting subroutine employed in the flowchart of Fig. 9;

Fig. 9(b) is an alternate version of one of the steps of the flowchart of Fig. 9, implementing a modification to the vehicle control strategy;

Fig. 9(c) is an alternate version of another of the steps of the flowchart of Fig. 9, similarly implementing a modification to the vehicle control strategy;

Fig. 10 illustrates the preferred torque versus speed characteristics of the electric starting and traction motors, and of the internal combustion engine;

Fig. 11 is a schematic diagram similar to Fig. 3, illustrating an alternative embodiment of the hybrid vehicle powertrain according to the invention, wherein the engine is provided with a turbocharger which is controllably operable, so as to be employed only when needed;

Fig. 12 is a three-dimensional diagram comparable to Fig. 6, showing the modes of operation of the turbocharged hybrid vehicle of Fig. 11;

Fig. 13 is a timing diagram similar to Fig. 7, again comprising Figs. 13(a) - (c), extending over two sheets, and illustrating typical operation of the turbocharged hybrid vehicle of Fig. 11;

Fig. 14 is a schematic diagram similar to Figs. 3 and 11, illustrating a further alternative embodiment of the hybrid vehicle powertrain according to the invention, wherein a second traction motor is connected to a second set of road wheels, providing a particularly convenient way of providing four-wheel drive;

Fig. 15 is a schematic diagram of the preferred brake system of a hybrid vehicle according to the invention; and

Fig. 16 is a is a schematic diagram of the preferred heating, ventilation and air conditioning system of a hybrid vehicle according to the invention.

Description of the Preferred Embodiments

Referring specifically to Fig. 1, which is reproduced here from the '970 patent for convenience, curve 10 represents the output power versus engine speed (RPM) of a typical spark ignition gasoline-fueled internal combustion engine as used with an automatic transmission in a typical sedan of 3,300 pounds. As can be seen, the maximum engine power available is about 165 horsepower at about 5,000 RPM. Also shown in Fig. 1 by the curve labeled "Large Car Average Power Requirements" are the average power requirements of such a vehicle. Points C, S, and H on this curve show average fuel consumption in city, suburban, and highway driving, respectively; in particular, point C shows that the average power required in typical city driving is less than 5 hp. Point S shows that the average power consumed in suburban driving is 10 hp, and point H shows that the power needed for steady-speed highway driving is only about 30 hp. Thus, the vehicle is vastly overpowered at all times except during acceleration or hill-climbing.

Fig. 1 also includes dashed-line curves indicating the relative fuel consumption of the engine. As can be seen, reasonable fuel efficiency, that is, at least about 105 percent relative fuel consumption (100% being ideal), is reached only when the engine is operated at between about 2,000 and 4,000 RPM, and when producing between about 75 and 150 horsepower. Fig. 1 thus indicates that the typical internal combustion engine is operated with reasonable efficiency only when producing between about 50 and about 90% of its maximum output power. The typical automobile only requires such substantial power under conditions of extreme acceleration or hill climbing.

Accordingly, it will be appreciated that the typical engine is operated efficiently only during relatively brief intervals; more specifically, at lower power outputs, losses due to friction and pumping consume larger fractions of the engine's total torque, so that a lower fraction is available to propel the vehicle. As can be seen, during typical highway driving, shown by point H, the relative fuel consumption is on the order of 190 percent of that required during the most efficient operation of the engine. The situation is even worse in suburban driving, where the relative fuel consumption is nearly 300 percent of the most efficient value, and in city driving, where the relative fuel consumption is almost 350 percent of that required at most efficient operation.

Fig. 1 thus demonstrates that an internal combustion engine having sufficient horsepower for adequate acceleration and hill climbing capability must be so oversized with respect to the loads encountered during most normal driving that the engine is grossly inefficient in its consumption of fuel. As noted, Fig. 1 further shows that only about 30 horsepower is needed to cruise on the highway even in a relatively large car.

Fig. 2 (again reproduced from the '970 patent for convenience) is similar to Fig. 1, and illustrates the operational characteristics of the same 3,300 pound car if driven by a relatively small engine having a maximum horsepower rating of about 45 horsepower at 4,000 RPM. The power requirement of the vehicle during highway cruising, shown by point H on the curve marked "Large Car Average Power Requirements", is in the center of the most efficient region of operation of the engine. However, even with this small engine thus optimized for highway cruising, there is a substantial gap between the "Engine Operating Power" curve and the Average Power Requirement curve 14. That is, even this small engine produces substantially more power at low RPM than needed for city driving (point C) or for suburban driving (point S). Accordingly, even with a small engine sized appropriately for highway cruising, substantial inefficiencies persist at lower speeds. Moreover, of course, such a vehicle would have unsatisfactory acceleration and hill climbing ability. Therefore, the answer is not simply to replace large internal combustion engines with smaller internal combustion engines.

The prior art recognizes that there are substantial advantages to be gained by combining the virtues of a gasoline or other internal combustion engine with those of an electric motor running from a battery charged by the internal combustion engine. However, the prior art has failed to provide a solution which is directly price- and performance-competitive with vehicles now on the market; moreover, in order that such a vehicle can be commercially successful, it must also be no more complex to operate than existing vehicles.

As indicated above, "straight" electric vehicles, that is, vehicles having electric traction motors and batteries requiring recharge at the end of each day's use, do not have sufficient range and require too much time to recharge to fully replace conventional automobiles. Further, the operational costs of such vehicles are not competitive with internal combustion vehicles operated on fuels derived from renewable resources such as ethanol, and are even less competitive with gasoline-fueled automobiles.

A first type of series hybrid vehicles, involving a gasoline engine driving a generator charging a battery powering an electric traction motor, are limited in acceleration and hill climbing ability unless the electric motor is made very large, costly, and bulky. The alternative series hybrid approach, involving a transmission between a relatively smaller electric motor and the wheels to provide the torque needed to accelerate quickly, loses the virtue of simplicity obtained by elimination of a multi-speed transmission. These vehicles fail to realize the advantages provided by the parallel hybrid system in which both an internal combustion engine and an electric motor provide torque to the wheels as appropriate.

However (apart from the '970 patent) the prior art relating to parallel hybrid vehicles fails to disclose a system sufficiently simple for economical manufacture. The art further has failed to teach the optimum method of operation of a parallel hybrid vehicle. Moreover, the art relating to parallel hybrids (again, apart from the '970 patent) does not teach the appropriate operational parameters to be employed, relating to the relative power outputs of the internal combustion engine and the electric motor; the type of electric motor to be employed; the frequency, voltage, and current characteristics of the motor/battery system; the proper control strategy to be employed under various conditions of use; and combinations of these.

As shown in the '970 patent with reference to Figs. 1 and 2 thereof, and again above, typical modern automobiles operate at very low efficiency, due principally to the fact that internal combustion engines are very inefficient except when operating at near peak torque output; this condition is only rarely met. (The same is true, to greater or lesser degree, of other road vehicles powered by internal combustion engines.) According to an important aspect of the invention of the '970 patent, substantially improved efficiency is afforded by operating the internal combustion engine only at relatively high torque output levels, typically at least 35% and preferably at least 50% of peak torque. When the vehicle operating conditions require torque of this approximate magnitude, the engine is used to propel the vehicle; when less torque is required, an electric motor powered by electrical energy stored in a substantial battery bank drives the vehicle; when more power is required than provided by either the engine or the motor, both are operated simultaneously. The same advantages are provided by the system of the present invention, with further improvements and enhancements described in detail below.

According to one aspect of the invention of the '970 patent, the internal combustion engine of a hybrid vehicle is sized to supply adequate power for highway cruising, preferably with some additional power in reserve, so that the internal combustion engine operates only in its most efficient operating range. The electric motor, which is substantially equally efficient at all operating speeds, is used to supply additional power as needed for acceleration and hill climbing, and is used to supply all power at low speeds, where the internal combustion engine is particularly inefficient, e.g., in traffic.

As indicated above, this application discloses certain modifications, improvements, and enhancements of the hybrid vehicles shown in U.S. patent 5,343,970; where not otherwise stated, the design of the vehicle of the present invention is similar to that shown in the '970 patent. Components commonly numbered in this application and the '970 patent are functionally similar, with detail differences as noted. The advantages of the system shown in the '970 patent with respect to the prior art are provided by that of the present invention, with further improvements provided by the latter, as detailed herein.

In the system of the '970 patent, torque from either or both the engine and motor is transferred to the drive wheels of the vehicle by a controllable torque-transfer unit. This unit also allows torque to be transferred between the motor and engine, for starting the engine, and between the wheels and motor, for regenerative battery charging during deceleration of the vehicle. This unit, while entirely practical, comprises gears for power transfer, which are inevitably a source of audible noise and frictional losses. According to one aspect of the present invention, the controllable torque-transfer unit is eliminated. Instead, two electric motors are provided, each separately controlled by a microprocessor controller responsive to operator commands and sensed operating conditions.

In this connection, it will be understood that the terms "microprocessor" and "microprocessor controller" are used interchangeably throughout the present application, and it is to be further understood that these terms as used herein include various types of computerized control devices not always referred to as "microprocessors" per se, such as computers themselves incorporating microprocessors, digital signal processors, fuzzy logic controllers, analog computers, and combinations of these. In short, any controller capable of examining input parameters and signals and controlling the mode of operation of the vehicle according to a stored program, as discussed below in detail, is considered to be a "microprocessor" or "microprocessor controller" as used herein. Furthermore, the electronic fuel injection and electronic engine management devices shown in Figs. 3 and 4 as separate elements might also be integrated within the "microprocessor" or "microprocessor controller" as described herein.

Fig. 3 of the present application shows a first embodiment of the present invention, while Fig. 4, discussed below, shows a second embodiment illustrating certain alternative mechanical arrangements; overall the two embodiments are very similar, and functionally they are substantially identical. Fig. 11, also discussed below, illustrates a further embodiment, and Fig. 14 incorporates still further improvements.

In the Fig. 3 embodiment, a traction motor 25 is connected directly to the vehicle differential 32, and thence to the road wheels 34. A starting motor 21 is connected directly to the internal combustion engine 40. The motors 21 and 25 are functional as motors or generators by appropriate operation of corresponding inverter/charger units 23 and 27, respectively, connected between the motors and battery bank 22. At present, essentially conventional lead-acid batteries are preferred for battery bank 22, since these are widely available and well understood. More advanced batteries may be used if and when they become widely available and economically competitive.

Motors 21 and 25 are controllably connected for torque transfer by a clutch 51, mechanically interlocking the shafts 15 and 16 of motors 21 and 25 respectively. As discussed further below in connection with Fig. 4, microprocessor ("μP") 48 is provided with signals indicative of the rotational speeds of shafts 15 and 16, and controls operation of engine 40, motor 21, and motor 25 as necessary to ensure that the shafts are rotating at substantially the same speed before engaging clutch 51. Accordingly, clutch 51 need not necessarily be an ordinary automotive friction clutch (as illustrated schematically in Fig. 1), as conventionally provided to allow extensive relative slipping before the shafts are fully engaged. More particularly, as slipping of clutch 51 is not required to propel the vehicle initially from rest, as is the case in conventional vehicles, clutch 51 need not allow for extensive slipping when being engaged. In some cases it may be satisfactory to provide clutch 51 as a simple self-aligning mechanical interlock (as shown in Fig. 4), wherein positive mechanical connection is made between the shafts 15 and 16 upon engagement. Such a mechanical interlock is much simpler and less expensive than a friction clutch. In either case, clutch 51 is operated by microprocessor 48, e.g., through a known electric or hydraulic actuator 53, together with the other components of the system, in accordance with the operational state of the vehicle and the operator's input commands.

The respective positions of motor 21 and engine 40 with respect to clutch 51, motor 25, and wheels 34 could be reversed as compared to their positions in Figs. 3 and 4 without affecting the function of the system, although as engine 40 would then require torque transmitting connection at both ends of its crankshaft, some additional complexity would result.

As shown in Fig. 4, shaft encoders 18 and 19 may be mounted on the shafts 15 and 16 of starting motor 21 and traction motor 25, respectively, to provide signals to microprocessor 48 indicative of the relative rotational speeds of the shafts, and their respective rotational positions. Such shaft encoders are well-known and commercially available. Alternatively, signals indicative of the rotational speeds of the shafts may be derived from the inverter control signals, in accordance with well-known principles of control of "sensorless" motor drives (see, for example, Bose, "Power Electronics and Variable Frequency Drives", IEEE, 1996). However, provision of encoders 18 and 19 will allow better low-speed torque characteristics of motor 21 and 25, and thus reduction in cost.

Thus being provided with signals indicative of the rotational speeds of shafts 15 and 16, microprocessor 48 controls operation of engine 40, motor 21, and motor 25 as necessary to ensure that the shafts are rotating at substantially the same speed before engaging clutch 51; therefore, clutch 51 need not be an ordinary automotive friction clutch (as illustrated schematically in Fig. 3), as conventionally provided to allow extensive slipping before the shafts are fully engaged. According to this aspect of the invention, and particularly if microprocessor 48 is made capable of ensuring that shafts 15 and 16 bear a desired relative angular relationship, clutch 51 instead may be a simple, relatively inexpensive self-aligning mechanical interlock (as illustrated schematically in Fig. 4), wherein positive mechanical connection is made between the shafts 15 and 16 upon engagement.

Fig. 4 also shows additional signals provided to microprocessor 48 in both the Fig. 3 and the Fig. 4 embodiments. These include operator input commands, typically acceleration, direction, deceleration, and "cruise mode" commands, as shown. The acceleration and deceleration commands may be provided by position-sensing encoders 71 and 72 (Fig. 3)(which could be configured as rheostats, Hall-effect sensors, or otherwise) connected to microprocessor 48 by lines 67 and 68, to inform the microprocessor of the operator's commands responsive to motion of accelerator and brake pedals 69 and 70 respectively. The microprocessor monitors the rate at which the operator depresses pedals 69 and 70 as well as the degree to which pedals 69 and 70 are depressed. The operator may also provide a "cruise mode" signal, as indicated, when a desired cruising speed has been reached. The microprocessor uses this information, and other signals provided as discussed herein, in accordance with the operational strategy discussed in detail below in connection with Figs. 6 - 9, to properly control operation of the vehicle according to the invention by appropriate control signals provided to its various components.

For example, suppose the vehicle has been operated in city traffic for some time, that is, under battery power only. Typically the operator will only depress the accelerator pedal 69 slightly to drive in traffic. If the operator then depresses accelerator pedal 69 significantly farther than he or she had, for example, the prior few times acceleration was required, this may be taken as an indication that an amount of torque that can efficiently be provided by engine 40 will shortly be required; microprocessor will then initiate the sequence whereby starting motor 21 will be used to start engine 40.

Upon initiation of the engine starting sequence, a heater 63 (Fig. 3) will first be used to preheat a catalytic converter 64 provided in the engine exhaust system 62, so that any fuel that is not combusted during starting and subsequent running of the engine 40 will be catalytically combusted, reducing emission of undesirable pollutants. A temperature sensor 102 is preferably provided, so as to ensure the engine is not started until the catalytic material is heated to effective working temperature. As noted above, engine starting is preferably performed with the engine turning at a higher speed than is conventional, so that a the fuel/air ratio need only be slightly (e.g., 20%) richer than stoichiometric. As a result, only very limited amounts of pollutants are emitted during engine starting. By comparison, in conventional vehicles, a very significant fraction of the total pollutants emitted during any given trip are emitted during the first 30 - 60 seconds of operation, due to the extremely rich mixtures normally supplied during starting, and to the ineffectiveness of the catalyst until it has been heated by the exhaust.

If the operator depresses the pedal 69 rapidly, indicating an immediate need for full acceleration, the preheating step may be omitted; however, a preferable alternative may be to allow the traction and starting motors to be driven at or slightly beyond their rated power, providing adequate torque, for a short time sufficient to allow the catalyst to be warmed and the engine started.

Similarly, if the operator depresses the brake pedal 70 relatively gently, all braking may be provided by regenerative charging of the batteries; if the operator instead presses aggressively on brake pedal 70, and/or presses brake pedal 70 beyond a predetermined point, both mechanical and regenerative braking will be provided. Mechanical braking is also provided on long downhills when the batteries are fully charged, and in case of emergency. Further aspects of the preferred brake system of the hybrid vehicles of the invention are added by the present continuation-in-part application, and are discussed below.

In addition to engine and starting motor speed and traction motor speed, monitored by shaft encoders 18 and 19 as discussed above, battery voltage, battery charge level, and ambient temperature are also either monitored directly or derived from monitored variables. In response to these inputs, and the operator inputs, microprocessor controller 48 operates a control program (see the high-level flowchart of an exemplary control program provided as Fig. 9), and provides output control signals to engine 40, by commands provided to its electronic fuel injection unit (EFI) 56 and electronic engine management system (EEM) 55, and to starting motor 21, clutch 51, traction motor 25, inverter/charger units 23 and 27, and other components.

As indicated in Fig. 4, the control signals provided to inverter/chargers 23 and 27 by microprocessor 48 allow control of the current (represented as *I*), of the direction of rotation of the motor 25 (represented as +/-), allowing reversing of the vehicle, and of the frequency of switching (represented as *f*), as well as control of operation of the motors 21 and 25 in motor or generator mode. Inverter/chargers 23 and 27 are separately controlled to allow independent operation of motors 21 and 25. Inverter/charger operation is discussed further below in connection with Fig. 5.

As noted above, the Figs. 3 and 4 embodiments of the system of the invention differ in certain mechanical arrangements, intended to illustrate variations within the scope of the invention, and Fig. 4 also provides more detail concerning the specific control signals passing between various elements of the system.

Referring to the differing mechanical arrangements, it will be observed that in Fig. 3 the shafts of motors 21 and 25 are illustrated as coaxial with that of engine 40; this is the simplest arrangement, of course, but would require the engine 40 and starter motor 21 to rotate at the same speed at all times, and at the same speed as traction motor 25 when clutch 51 is engaged. As noted above, it may be preferable to design motors 21 and 25 to have maximum speeds of 9000 - 15,000 rpm, so that they could be made smaller, lighter, and less costly than slower-rotating motors. However, it is envisioned that a preferred maximum speed for engine 40 is 6000 rpm, as internal combustion engines running at substantially higher speeds wear rapidly and tend to have limited torque at low speed, and because higher frequency engine noise and vibration can also be difficult to absorb. It is within the scope of the invention to provide the motors coaxial with the engine shaft, as illustrated in Fig. 3, but to provide a planetary gearset(s) between the shafts of either or both of traction motor 25 and starting motor 21 and the output shaft to permit differing engine and motor speeds. Further alternatives to this aspect of the invention are again added by the present continuation-in-part application, and are discussed below.

Fig. 4 illustrates an alternative construction, also permitting differing engine and motor speeds. In this case, the output shaft of starting motor 21 is shown connected to that of engine 40 by spur gears 52, and traction motor 25 is connected to the output shaft 55 by chain drive indicated at 54. Numerous other arrangements will occur to those of skill in the art. However, in each case there is no variable-ratio transmission between the sources of torque -- that is, the motors 21 and 25, and the engine 40 -- and the road wheels 34. Again, further alternatives to this aspect of the invention are added by the present continuation-in-part application, and are discussed below.

It is also within the scope of the invention to connect the traction motor to one set of wheels, and to connect the combination of the engine 40 and starting motor 21 to another set of wheels through clutch 51, thus providing a four-wheel drive vehicle with differing power sources for the alternate pairs of wheels. In this embodiment, the torque from the traction motor 25 is effectively combined with that from engine 40 (and from starting motor 21, when used as a source of propulsive torque) by the road surface, rather than by mechanical connection, as in the Figs. 3 and 4 embodiment. A further alternative would be to provide a complete system as in Fig. 3 driving one pair of road wheels, and a separate traction motor driving a second pair of road wheels.

Both embodiments are within the scope of the invention, and the control strategy is essentially the same as to both. See Fig. 14 and the related text below for further discussion.

Other elements of the system as illustrated in Figs. 3 and 4 are generally as discussed in the '970 patent, including supply of fuel 36 from tank 38, air filter 60, and throttle 61.

Control of engine 40 by microprocessor 48 is accomplished by way of control signals provided to electronic fuel injection (EFI) unit 56 and electronic engine management (EEM) unit 55, responsive to throttle operation; preferably, the throttle in turn is operated electronically responsive to the opertor's depression of the accelerator pedal. Control of starting of engine 40, and using either or both of starting motor 21 and traction motor 25 as motors, providing propulsive torque, or as generators, providing recharging current to battery bank 22, is accomplished by microprocessor 48 by way of control signals provided to inverter/charger units 23 and 27.

Under deceleration, for example, during descents, or as needed for braking, or when the engine's instantaneous torque output exceeds the vehicle's current torque requirements, either or both of motors 21 and 25 are operated as generators, providing regenerative recharging of battery bank 22. Fig. 7, discussed below, illustrates this aspect of the operation of the vehicle of the invention in further detail.

Thus, as indicated above, when microprocessor 48 detects a continued operator requirement for additional power, such as during transition from slow-speed to highway operation, or by measuring the rate at which the operator depresses accelerator pedal 69, engine 40 is started using starter motor 21 and brought up to speed before clutch 51 is engaged, to ensure a smooth transition. As cruising speed is reached (as determined by monitoring the operator's commands), power to traction motor 25 (and to starter motor 21, if also used to accelerate the vehicle) is gradually reduced. Provision of the clutch 51 and separate starter motor 21, as compared to using the single traction motor to start engine 40 while simultaneously accelerating the vehicle, that is, as in the '970 patent, simplifies the control arrangements somewhat.

In one possibly preferred embodiment, both motors 21 and 25 and clutch 51 may be provided in a single sealed housing, possibly bathed in oil for cooling and protection from dust and the like. It is also known to control auxiliary motors, such as conventional starter motors, to absorb or add torque to that provided by an associated internal combustion engine, to damp out vibration caused by fluctuation of the torque provided by the engine; doing so herein using either or both of motors 21 and 25 is within the scope of the invention, and is simplified by virtue of the direct connection of the engine 40 to the drive wheels through motors 21 and 25 according to the invention.

Provision of the clutch 51 and separate starter motor 21 also allows another important improvement to be provided according to the present invention, namely starting engine 40 at high speed, e.g., about 300 -600 rpm, as compared to the 60 - 200 rpm starts conventionally provided. As is generally known in the art (see Simanaitis, "What goes around comes around", *Road & Track*, November 1998, p. 201) high-rpm starting allows substantial elimination of the usual necessity of providing a fuel-rich air/fuel mixture to start engine 40, reducing emission of unburned fuel and improving fuel economy at start-up, particularly from cold.

More particularly, in conventional low-rpm starts, a rich mixture comprising up to on the order of 6 to 7 times the stoichiometric amount of fuel is provided, to ensure that some fraction of the fuel is in the vapor phase, as only fuel in the vapor phase can be ignited by a spark. Most of the excess fuel condenses as liquid on the cold cylinder walls, and thus does not burn efficiently, if at all, and is immediately emitted unburned. By comparison, at high starting speeds according to the invention, turbulence in the combustion chamber is sufficient to ensure the presence of vapor, so that a near-stoichiometric mixture, typically including only 1.2 times the stoichiometric amount of fuel, can be provided to engine 40 during the starting phase. The avoidance of rich mixtures at starting significantly reduces emission of unburned fuel - since most of the fuel provided to a conventional engine at starting is immediately exhausted unburnt - and provides some improvement in overall fuel efficiency.

Furthermore, as noted above, whenever possible - that is, whenever the engine is started except when immediate full torque is required by the operator - a catalytic converter 64 is preheated to an effective working temperature of at least about 350° C before starting the engine, to prevent even this relatively small emission of unburned fuel.

Thus, the primary consideration in selecting the torque of starting motor 21 is that it be capable of rotating the engine 40 at about 300 - 600 rpm for starting, and that it be capable of accepting at least about 30% of the engine's maximum torque output when operated as a generator, so that the engine can be efficiently employed when charging the battery bank during extended low-speed operation; the main consideration in specification of the torque of engine 40 is that it provides sufficient power for highway cruising while being operated at high efficiency, i.e., that its maximum power output be sufficent to cruise in a range of desired cruising speeds; and the principal consideration defining the power required of the traction motor 25 is that it be sufficiently powerful to provide adequate acceleration in combination with the engine 40 and starting motor 21. Stated differently, the total power available provided by all of these torque-producing components should be at least equal to and preferably exceeds the peak power provided by the internal combustion engines of conventional vehicles of similar intended use, both as measured at the wheels. Moreover, as set forth in the '970 patent, the total torque provided by motors 21 and 25 should be at least equal to that produced by engine 40, in order to provide adequate low-speed performance under motor alone, and without necessity of a variable-ratio transmission.

At the same time, motors 21 and 25 are also sized to be capable of recovering almost all of the vehicle's kinetic energy when operated as generators in the regenerative braking mode. A particularly high fraction of the vehicle's kinetic energy can be recovered during low-speed operation; as compared to high-speed operation, where air resistance and road friction consume a relatively large fraction of the total energy required, in low speed operation much energy is lost by conventional vehicles as heat released during braking.

Given the above considerations, the following are typical power specifications for the engine 40, starting motor 21 and traction motor 25 of a 3000 pound vehicle having performance approximately equivalent to that of a "mid-size" sedan of United States manufacture. It should be understood that in these specifications, reference is made to the rated power produced continuously by the engine, not to the rated peak power of the motors, as is generally conventional in the art. Further, the motors are specified assuming the direct-drive embodiment of Fig. 3; if the motors run at higher speeds, their ratings would be determined accordingly.

Engine 40: 40 to 50 horsepower at 6000 rpm

Starting motor 21: 10 - 15 horsepower at approximately 1500 rpm and higher speeds

Traction motor 25: 50 - 75 horsepower from 1500 to 6000 rpm.

The same starting motor would be satisfactory for a larger, 4000 pound sedan, but the engine would typically provide 70 - 90 horsepower at 6000 rpm and the traction motor 75 - 100 horsepower.

In both cases, the total power available from the electric motors together should equal, and preferably exceeds, the maximum power available from the engine.

In the hybrid vehicle of the invention, which as noted does not require a complex, heavy, and costly variable-ratio transmission, these components would provide acceleration much superior to that of typical similarly-sized automobiles of United States manufacture, together with far better fuel economy and substantially reduced emission of pollutants. It will be apparent that these specifications may vary over relatively wide ranges depending on the intended use of the vehicle of the invention, and should not be construed to limit the scope of the invention.

As indicated above, in the preferred embodiment, both the starting and traction motors are AC induction motors, although other types may also be employed. These motors, and the inverter/chargers controlling them in response to control signals from the microprocessor (as discussed further below), should be chosen and operated such that the motors have torque output characteristics varying as a function of rpm as illustrated by curve A in Fig. 10. That is, the motors are operated by the inverter/chargers, in response to control signals from the microprocessor, so as produce constant torque up to a base speed C, typically 1500 rpm for a motor having a top speed of 6000 rpm, as employed in the direct-drive embodiment of Fig. 3, and should produce constant power at higher speeds; accordingly, the torque drops off at speeds above the base speed C, as shown. The ratio of the base to maximum speed, 4 : 1 in this example, can vary between about 3 to 1 and about 6 to 1. This torque output characteristic essentially allows the vehicle of the invention to provide quite acceptable performance, especially acceleration, without the weight, complexity and cost of a variable-ratio transmission.

By comparison, the series-wound DC motors conventionally used as automotive engine starting motors provide very high torque, but only at very low speeds; their torque output drops precipitously at higher speeds. Such conventional starter motors would be unsatisfactory in the present system.

Fig. 10 also shows the torque curve of a typical internal combustion engine at B; as noted, the torque is zero at zero rpm, so that a clutch allowing slippage is required to allow the engine to move the vehicle from rest. Fig. 10 shows at D typical curves for torque as measured at the wheels of a vehicle propelled by a typical internal combustion engine driving the vehicle through a four-speed transmission, used to provide additional torque at low speeds; the vertical spaces between sections of curve D represent changes in gear ratio, that is, the vehicle will be shifted to move between the sections of curve D. As shown by Fig. 10, the desired torque characteristics of the starting and traction motors discussed above allow the vehicle of the invention to provide low-speed performance comparable to or better than a conventional vehicle, while eliminating the necessity of a variable-ratio transmission. However, as discussed further below, it is within the invention of the present continuation-in-part application to extend the load-carrying capabilities of the hybrid vehicle of the invention by also providing a variable-ratio, e.g., two-speed, transmission, where not excluded by the appended claims. This should not be necessary with respect to passenger cars.

The ratio between the base speed and maximum speed of the motors as used according to the invention is thus comparable to the ratio between the lowest and highest gears of a conventional transmission; for passenger cars, the latter ratio is typically between 3 and 4 : 1, so that the engine's torque is relatively well matched to the road load over a reasonable range of road speeds.

As discussed above, while it is within the scope of the invention to operate the motors 21 and 25 and the internal combustion engine 40 at the same maximum speed, so that no gearing is required to couple these elements, it is presently preferred that at least traction motor 25 have a maximum speed substantially higher than that of the internal combustion engine 40; the output shaft of motor 25 can be connected to the road wheels by a chain-drive reduction unit, as indicated in Fig. 4. The maximum speed of the internal combustion engine is preferably limited to on the order of 6000 rpm to limit wear, noise and vibration, which increase with higher operating speeds, and because engines capable of higher-rpm operation tend to have narrow ranges of rpm within which they produce substantial torque; the latter characteristic would be undesirable in a vehicle not having a variable-ratio transmission and intended to cruise powered solely by the internal combustion engine, according to the invention.

By comparison, operating the motors 21 and 25 at maximum speeds of 9000 - 18,000 rpm allows them to be made smaller, lighter, and less costly; whether this advantage overcomes the added complexity of chain, gear, or belt drives, or other mechanical means allowing combination of torque from the motors with that from the engine, is a matter of engineering choice that may vary from one model of vehicle to the next. Both are accordingly within the present invention. If each of the torque-producing components (that is, engine 40 and starting and traction motors 21 and 25) is to be operated at the same speed, a maximum speed of approximately 6000 rpm is preferred, as this represents a good compromise between cost, weight, and size of the key components.

As discussed above, it is preferred that motors 21 and 25 have more than two poles, and be operated by current applied over more than three phases, so that failure of some components - such as the power semiconductors used in the inverter/charger units, as discussed below - can be tolerated without total failure of the vehicle. It is also desired that the battery bank be divided into two, with the vehicle chassis connected between them, halving the voltage between given components and the vehicle chassis, and thus simplifying their construction, insulation, and connection. Fig. 5 shows a partial schematic diagram of a circuit providing these attributes.

The functions of the inverter/chargers 23 and 27 (separate inverter/chargers being required to allow independent operation of motors 21 and 25) include control of motors 21 and 25 to operate as motors or as generators; operation of traction motor 25 in the opposite direction for reversing the vehicle; conversion of DC stored by the battery bank to AC for motor operation; and conversion of AC induced in the motors when operated as generators to DC for battery charging. Essentially similar functions were provided by the solid-state switching AC/DC converter 44 in the '970 patent; where not specified to the contrary, the discussion thereof is applicable to the inverter design shown in Fig. 5 hereof.

As illustrated in Fig. 5, traction motor 25 is embodied as a five-phase AC induction motor; starting motor 21, which is not fully illustrated, as indicated, can be but is not necessarily generally similar. Other motor types, such as permanent magnet brushless DC motors or synchronous motors, might also be employed. The motors are operated as multiphase devices, having three phases or more, permitting employment of smaller and overall less costly semiconductors, and allowing operation even if some of the semiconductors fail. Use of motors operated at relatively high frequency, e.g., more than 60 Hz, also permits motors of a given power output to be smaller. As shown in Fig. 5, it is currently preferred that at least traction motor 25 be wired in the "wye" arrangement shown, rather than the known "delta" arrangement; it is found that certain undesirable harmonics are reduced by the "wye" arrangement. Both are well known in the art, and within the scope of the invention.

As illustrated in Fig. 5, each of the windings 78 of motor 25 is connected to a pair of semiconductor switching elements 80 collectively making up inverter/charger 27. Inverter/charger 27 is correspondingly configured as a set of ten power semiconductors 80 controlled by switching signals A through J provided by a pulse generator 88 responsive to frequency, polarity and current signals received from microprocessor 48 (Figs. 3 and 4). Typical operating frequencies can be up to 200, 400 or 600 Hz; the transfer of power between the battery bank 22 and motors 21 and 25 is then controlled by pulse-width modulation, that is, by controlling the semiconductors 80 to conduct during portions of the power waveform, the duration of the conducting portions varying in accordance with the power required. Semiconductors 80 may be any type suitable for handling relatively high voltages and currents; satisfactory insulated-gate bipolar transistors (IGBTs) are currently available and are presently preferred. As conventional, each of the semiconductors 80 is paralleled by a freewheeling rectifier diode 82.

Design of the inverter/chargers 23 and 27 and of pulse generator 88 to provide suitable control signals A through T so that the inverter/chargers perform the functions listed above is within the skill of the art; again, see, for example, Bose, "Power Electronics and Variable Frequency Drives", IEEE, 1996.

The current drawn from the battery bank 22 during long-term operation of the traction and starting motor(s) to propel the vehicle should be limited to 30 - 50 amperes, to reduce the size of the conductors and other components required, as discussed in the '970 patent; these components are satisfactory to carry currents of up to 200 amperes, as may be encountered during full-power acceleration, as this condition will not persist for more than about 30 seconds.

As indicated, the battery bank 22 comprises two substantially similar battery assemblies 84; in one embodiment, each battery assembly will comprise eight 48-volt batteries, such that 384 volts is provided by each. The battery assemblies 84 are connected in series, so that 768 volts are provided across the circuit "rails" 86, 88. However, the vehicle chassis connection is taken from between the series-connected battery assemblies, so that only 384 volts is present between any given circuit component and the vehicle chassis; this "center-point-chassis" connection significantly reduces various insulation and heat-sinking requirements. More specifically, the conductors, connectors, relays, switches and like elements can be as approved by the National Electrical Manufacturers' Association (NEMA) for 600 volt service; such elements are widely available, and are much more easily employed and much less expensive than those needed for continuously carrying current at, for example, 300 volts and 300 amperes.

Preferably, as indicated by Fig. 5(a), illustrating a detail of a portion of one of the battery assemblies 84, the 48-volt batteries 85 are connected by normally-open relays 87, so that the batteries 85 are isolated from one another under fail-safe conditions; for example, if the vehicle is involved in an accident, power to the relays is cut off, so that the maximum open voltage anywhere in the vehicle is 48 volts, reducing the danger of fire. Similarly, the relays open when the vehicle's "ignition" is shut off by the operator.

The present continuation-in-part application adds to the above from the '817 application that an auxiliary 12-volt system may also be provided, as shown at 223 in Fig. 14, discussed further below. This would be a DC-to-DC converter, allowing the vehicle to provide "jumping" current to start other vehicles having conventional 12-volt electrical systems, and would also allow the vehicle of the invention to be jumpstarted similarly, if necessary. Provision of a 12-volt system also allows convenient employment of conventional automotive accessories, such as radios and the like. The 12-volt system could perhaps most conveniently be implemented by a separate semiconductor-implemented voltage conversion circuit, transforming the 48 volts from one of the batteries to 12 volts for jumping others, and providing the inverse 12 to 48 volt transformation as needed. It should also be understood that the individual batteries could be 42 volt units, conforming to the apparent trend toward 42 volt systems for new vehicles. Further preferably, the entire battery bank assembly, including the relays, is enclosed in a rugged container, significantly reducing the danger of electrical shock and the like.

Turning now to detailed discussion of the inventive control strategy according to which the hybrid vehicles of the invention are operated: as in the case of the hybrid vehicle system shown in the '970 patent, and as discussed in further detail below, the vehicle of the invention is operated in different modes depending on the torque required, the state of charge of the batteries, and other variables. Throughout, the object is to operate the internal combustion engine only under circumstances providing a significant load, thus ensuring efficient operation. In the following, the relationships between these modes are illustrated using several different techniques, to ensure the reader's full understanding of various aspects of the vehicle control strategy; some of these are seen more clearly in one form of illustration than another.

Fig. 6 illustrates the several modes of vehicle operation with respect to the relationship between the vehicle's instantaneous torque requirements or "road load", the state of charge of the battery bank 22, and time, while Fig. 7 shows variation in, and the relationship between, road load, engine torque output, and the state of charge of the battery bank over time, that is, during an exemplary trip. Figs. 8(a) - (d) show simplified schematic diagrams of the vehicle of the invention in its principal modes of operation, showing the flow of energy, in the form of electricity or combustible fuel, by dot-dash lines, and the flow of torque by dashed lines. Finally, Fig. 9 provides a high-level flowchart, showing the principal decision points in the algorithm according to which the microprocessor operates the various components of the hybrid vehicle drivetrain according to the invention, and Figs. 9 (a)-(c) show details and modifications thereof.

As noted, the preferred control strategy of the invention is illustrated in several different ways by Figs. 6 - 9. The same specific numerical examples for various significant control variables, data items, and the like are used throughout for clarity. It will be understood that these examples would normally be expressed as ranges; although ranges are not used in the following, to simplify the discussion, it should be understood throughout that these numerical examples are exemplary only, and that the invention is not to be limited to the exact values of the control variables mentioned herein.

Further, it should be realized that certain of these control variables need not be restricted to specific numbers; in some cases, the decision points may be "fuzzy", i.e., so-called "fuzzy logic" may be employed, so that while the operating scheme retains its overall characteristics, the specific values against which the control variables and data items are tested in implementation of the control strategy according to the invention may vary from time to time. Examples of this practice -- amounting in many circumstances to modifying certain specific values depending on other data items not discussed in detail, or by monitoring the vehicle's actual usage patterns over time -- are given below.

Given these several different explanations of the relationship between the various operating modes of the vehicle of the invention, and specifically these different illustrations of the combinations of conditions in response to which the microprocessor controls mode selection, one of ordinary skill in the art would have no difficulty in implementing the invention.

As noted, during low-speed operation, such as in city traffic, the vehicle is operated as a simple electric car, where all torque is provided to road wheels 34 by traction motor 25 operating on electrical energy supplied from battery bank 22. This is referred to as "mode I" operation (see Fig. 6), and is illustrated in Fig. 8(a). The same paths of energy and torque may also be employed under emergency circumstances, referred to as mode III operation, as discussed below.

While operating at low speeds, e.g., when the vehicle's torque requirements ("road load", or "RL") are less than 30% of the engine's maximum torque output ("MTO"), engine 40 is run only as needed to charge battery bank 22. Starting motor 21 is first used to start engine 40, and is then operated as a generator by appropriate operation of inverter/charger 23, so that charging current flows to battery bank 22. Accordingly, clutch 51 is disengaged, so that the road speed of the vehicle is independent of the speed of engine 40; engine 40 can thus be operated at relatively high output torque level, for fuel efficiency. This "mode II" operation is illustrated in Fig. 8(b); as indicated, clutch 51 is disengaged, so that engine operation to charge battery bank 22 through starting motor 21, and propulsion of the vehicle by traction motor 25, are completely independent of one another.

As in the '970 patent, engine 40 is sized so that its maximum torque is sufficient to drive the vehicle in a range of desired cruising speeds; this requirement ensures that the engine is operated at high efficiency during normal highway cruising. Therefore, when a sensed increase in the road load (e.g., by a continued operator request for more power) indicates that the preferred operating mode is changing from low-speed to highway cruising operation, the microprocessor controls starting motor 21 by way of inverter/charger 23 to start engine 40. When engine 40 is essentially up to speed, clutch 51 is engaged, so that engine 40 drives road wheels 34 through the shafts of motors 21 and 25. When the operator releases pressure on the accelerator pedal, indicating that a desired cruising speed has been reached, traction motor 25 is accordingly depowered. The highway cruising mode is referred to as "mode IV" operation, and the flow of energy and torque are as illustrated in Fig. 8(c).

If extra torque is needed during highway cruising, e.g., for acceleration or hill-climbing, either or both of motors 21 and 25 can be powered. This "mode V" operation is illustrated in Fig. 8(d); energy flows from tank 38 to engine 40, and from battery bank 22 to traction motor 25, and possibly also to starting motor 21; torque flows from either or both motors and engine to wheels 34.

The flow of energy during battery charging is not illustrated *per se* in Fig. 8, but will be understood by those of skill in the art, and is further described below. For example, when the engine's instantaneous output torque exceeds the road load, the starter motor 21 is operated as a charger, supplying recharging current to the battery bank. Similarly, when the road load is trending downwardly or is negative, either the traction motor or the starter motor, or both, can be operated as a regenerative battery charger, supplying recharging current to the battery bank; braking can be accomplished similarly in response to an appropriate operator command.

Fig. 6, as indicated above, is a diagram illustrating differing modes of operation of the hybrid vehicle powertrain of the invention; the modes of operation, indicated by numerals I - V, are plotted on a three dimensional chart, illustrating that the mode of vehicle operation as controlled by microprocessor 48 is a function of the state of charge of the battery bank, the instantaneous road load, and time. Fig. 7, discussed below, further illustrates the inventive mode of vehicle operation.

Fig. 6 shows on one axis the state of battery charge extending from 70% at the origin outwardly to a minimum value shown of 30%. Normally the batteries are maintained at least 30% of full charge. Preferably, the battery bank is not charged to more than 70% of its theoretical full capacity; if a number of series-connected batteries were all charged to 100% of their nominal full charge, some would likely be overcharged due to manufacturing variation, local temperature variation and the like, which would significantly shorten their service life. Moreover, frequently recharging any individual battery to 100% of its theoretical capacity is deleterious to battery life as well.

The road load is shown in Fig. 6 on a second axis as varying from 0 at the origin to 200% of the engine's maximum torque output. (Negative road load, occurring during descents or under braking, is not shown in Fig. 6 due to the difficulty of illustration. This circumstance is discussed in connection with Fig. 7, below.) Time is shown on the third axis extending from an arbitrary point at the origin; that is, Fig. 6 shows the mode of the vehicle's operation over the next short period of time (on the order of 30 - 60 seconds) from a present instant at the origin. Stated differently, according to one aspect of the invention, the microprocessor 48 controls the vehicle's mode of operation at any given time in dependence on "recent history," as well as on the instantaneous road load and battery charge state.

More specifically, Fig. 6 shows that during city driving (mode I), defined in this example as driving where the vehicle's instantaneous torque requirements, or "road load", is up to 30% of the engine's maximum torque, the vehicle is operated as a "straight electric" car, the clutch being disengaged and energy from the battery bank 22 being used to power traction motor 25 to propel the vehicle, as long as the battery remains charged to between 50 and 70% of its full charge. If the charge falls to below a given value, which may vary over time as indicated by the curved line defining the extent of mode II, mode II is entered as indicated, the engine is started, and the starter motor 21 is operated as a generator to charge the battery to substantially full charge. As indicated in mode III, operation of the vehicle as an electric car may also be permitted when the battery falls to below 40% of full charge, for example, if there is a fault in the engine or charging system, but only on an emergency basis; such deep discharge is harmful to battery life.

During highway cruising, region IV, where the road load is between about 30% and 100% of the engine's maximum torque output, the engine alone is used to propel the vehicle. Accordingly, when the microprocessor detects that transition between regions I and IV is required (e.g., the microprocessor can effectively determine the road load by monitoring the response of the vehicle to the operator's command for more power), it causes the starting motor 21 to spin the engine 40 to relatively high speed; when a desired starting speed, typically 300 rpm, is reached, the electronic engine management unit 55 and electronic fuel injection unit 56 are controlled to fire the spark plugs and supply fuel, respectively, starting the engine. Thus starting the engine at relatively high rpm allows a near-stoichiometric fuel/air mixture to be used, as compared to the much richer mixtures normally used for starting.

Emissions of unburned hydrocarbons are thus substantially reduced, and fuel economy improved.

When the speed of the engine output shaft substantially matches that of traction motor 25, clutch 51 is engaged; the power produced by motor 25 is reduced as that produced by engine 40 is increased, so that the transition between modes I and IV is smooth and essentially undetected by the operator. When the operator reduces pressure on the accelerator pedal 69, indicating that the desired cruising speed has been reached, power to motor 25 is reduced to zero.

If the operator then calls for additional power, e.g. for acceleration or passing, region V is entered; that is, when the microprocessor detects that the road load exceeds 100% of the engine's maximum torque output, it controls inverter/charger 27 so that energy flows from battery bank 22 to traction motor 25, providing torque propelling the vehicle in addition to that provided by engine 40. Starting motor 21 can similarly be controlled to provide propulsive torque.

As indicated above, during highway cruising, where the torque required to propel the vehicle varies as indicated by the operator's commands, the control system operates the engine at correspondingly varying torque output levels. The range of permissible engine torque output levels is constrained to the range in which the engine provides good fuel efficiency. Where the vehicle's instantaneous torque requirement exceeds the engine's maximum efficient torque output, e.g., during passing or hill-climbing, one or both of the electric motors are energized to provide additional torque; where the vehicle's torque requirements are less than the torque then being produced by the engine, e.g., during coasting, on downhills or during braking, the excess engine torque is used to charge the batteries. Regenerative charging may occur simultaneously, as torque from the engine and recovery of the vehicle's kinetic energy both drive one or both motors operated in generator mode. The rate of change of torque output by the engine may be controlled to reduce emissions, and in accordance with the state of charge of the battery bank. Fig. 7 illustrates these relationships.

As mentioned above, Fig. 7, comprising Figs. 7(a) - (c), and extending over two sheets, is a timing diagram showing the relationship between road load, engine torque output, the state of charge of the battery bank, and operation of the engine as these vary over time, during low-speed city driving, highway cruising, and extended high-load driving, thus further illustrating the control strategy employed according to the invention.

Fig. 7(a) shows the vehicle's instantaneous torque requirement, that is, the "road load", by a solid line, and the engine's instantaneous output torque by a dashed line, as these vary over time. (The engine's instantaneous output torque is repeated in Fig. 7(c), for clarity, and in order to clearly show certain additional aspects of the inventive control strategy.) The road load is expressed as a function of the engine's maximum torque output. Where the road load exceeds the engine's instantaneous output torque, the cross-hatched areas between these two lines represent torque provided by the traction and or starting motor(s); where the road load is less than the engine's instantaneous output torque, the cross-hatched areas represent charging of the batteries.

It will be appreciated that positive vehicle torque demands correspond to steady-state cruising, acceleration, hill-climbing, or the like, while negative vehicle torque requirements correspond to deceleration or descent. The engine's output torque is constrained to the range of efficient operation; as illustrated in Fig. 7 (a) and (c), this range is controlled to be between 30% and 100% of the engine's maximum torque output ("MTO"). As mentioned above, it will be appreciated that the 30% figure, as well as similar figures mentioned herein, may vary without departure from the scope of the invention.

In the example of vehicle operation shown in Fig. 7, initially the vehicle is operated only at road loads below 30% of MTO, that is, in traffic, as indicated at A. Accordingly, all the torque required is provided by the traction motor 25, and the state of charge of the battery bank 22 ("BSC"), as illustrated by Fig. 7(b), corresponds directly to the road load; when the road load is negative, BSC increases as the battery bank is charged by regenerative braking. (Changes in BSC are significantly exaggerated in order to clearly explain the events shown.)

At point B, the road load exceeds 30% of MTO for the first time on this particular trip. When this is detected by microprocessor 48, starting motor 21 spins the engine 40 at relatively high speed, and the catalytic converter 64 is preheated, causing a short drain on BSC, as shown at C. When the engine reaches the desired starting speed, e.g. 300 RPM, and the catalyst reaches a minimum effective operating temperature, e.g. at least about 350° C, the engine is started by supply of fuel and firing of its spark plugs, and the clutch is then engaged. As the engine is already rotating at relatively high speed, and will have been warmed by compression of air in its cylinders during the starting process, it begins to produce useful torque almost immediately, as indicated at D.

Thereafter, when the vehicle's torque requirement exceeds the instantaneous engine output torque, as at points E - G and P, one or both of the traction and starting motors 25 and 21 are powered to provide additional torque to the road wheels, that is, the vehicle is operated in mode V. While the road load RL remains within the engine's efficient operating range, e.g., while 30% MTO > RL > 100% of MTO, the vehicle is operated in mode IV. During mode IV operation, if the engine's instantaneous torque output exceeds the vehicle's torque requirement, but the battery is relatively fully charged, as at point H, the engine's torque output is reduced to match the road load; when MTO exceeds the road load, and BSC falls below a predetermined level (see Fig. 7(b)), as at I and J, the excess torque available from engine 40 is used to charge the batteries, as indicated at K and L (Fig. 7(c)). When the vehicle's torque requirement is less than the minimum permissible engine torque output, as at M, the engine is again used to charge the batteries, and regenerative braking is also performed, further charging the batteries. If the batteries become substantially fully charged, e.g., during a long descent, as at N, the engine may be shut off entirely, as seen at Q in Fig. 7(c).

More particularly, during deceleration or "coast-down", the engine may be "motored", that is, driven by torque from the wheels, with the clutch engaged, but with at least the fuel supply shut off. In addition to using no fuel, this has the advantage that when the operator next requires torque, e.g., when reaching the point at the bottom of a hill, the engine is rotating and can be immediately restarted by supply of fuel. The exhaust valves might be opened during the motoring of the engine to reduce pumping losses.

The rate of change of the engine's torque output is limited, e.g., to 2% or less per revolution, as indicated by noting that the dashed line in Fig. 7(a), indicating the instantaneous engine output torque, lags the solid line indicating the vehicle's instantaneous torque requirement. Thus limiting the rate of change of engine output torque is preferred to limit undesirable emissions and improve fuel economy; that is, as the stoichiometric fuel/air ratio varies somewhat as the load changes, simply opening the throttle and causing additional fuel to be injected (as is typically practiced) upon the operator's depressing the accelerator pedal would result in non-stoichiometric, inefficient combustion. According to this aspect of the invention, the rate of change of engine torque is limited; this provides sufficient time for the essentially conventional electronic engine management and electronic fuel injection systems, which comprise a "lambda sensor" 47 (Fig. 3) for monitoring the oxygen content of the exhaust gas stream as an indication of stoichiometric combustion, to respond as the load changes, preserving stoichiometric combustion and reducing emission of unburned fuel.

The maximum permissible rate of change of engine output torque also may be varied in accordance with the state of charge of the batteries; more specifically, if the batteries are relatively discharged, it may be preferable to allow the engine's output torque to ramp-up more quickly than otherwise, in order to limit the amount of electrical power drawn from the batteries in response to an acceleration command. More generally, it is preferred to operate the engine so as to limit the amount of power drawn from the batteries, as there are unavoidable losses attendant on conversion of energy stored in the batteries to motor output torque, and during the corresponding recharging period.

As mentioned above, Fig. 9 is a high-level flowchart of the principal decision points in the control program used to control the mode of vehicle operation. Broadly speaking, the microprocessor tests sensed and calculated values for system variables, such as the vehicle's instantaneous torque requirement, i.e., the "road load" RL, the engine's instantaneous torque output ITO, both being expressed as a percentage of the engine's maximum torque output MTO, and the state of charge of the battery bank BSC, expressed as a percentage of its full charge, against setpoints, and uses the results of the comparisons to control the mode of vehicle operation.

As noted above, certain control decisions involved in the inventive control strategy illustrated in Fig. 9, and described therein as being determined in response to precise criteria (in order to clearly present the main features of the inventive operating strategy), may instead be usefully somewhat "fuzzy"; in the present application, this term is intended to indicate that the value of a setpoint (for example) may vary somewhat in response to recent history, or in response to monitored variables not discussed above. As mentioned above, it is also to be understood that the values given above for various numerical quantities may vary somewhat without departing from the invention. Specific alternatives are provided below for steps set forth in Fig. 9 that implement certain of these alternatives.

For example, in the example of the inventive control strategy discussed above, it is repeatedly stated that the transition from low-speed operation to highway cruising occurs when road load is equal to 30% of MTO. This setpoint, referred to in the appended claims as "SP", and sometimes hereinafter as the transition point (i.e., between operation in modes I and IV) is obviously arbitrary and can vary substantially, e.g., between 30 - 50% of MTO, within the scope of the invention.

It is also within the scope of the invention for the microprocessor to monitor the vehicle's operation over a period of days or weeks and reset this important setpoint in response to a repetitive driving pattern. For example, suppose the operator drives the same route from a congested suburban development to a workplace about the same time every morning; typically the road load might remain under 20% of MTO for the first few minutes of each day, then vary between 0 and 50% of MTO for another few minutes as the operator passes through a few traffic lights, and then suddenly increase to 150% of MTO as the operator accelerates onto a highway. It is within the skill of the art to program a microprocessor to record and analyze such daily patterns, and to adapt the control strategy accordingly. For example, in response to recognition of a regular pattern as above, the transition point might be adjusted to 60% of MTO; this would prevent repetitive engine starts as the road load exceeded 30% of MTO for a few hundred yards at a time, as might often occur in suburban traffic. Similarly, the engine starting routine might be initiated after the same total distance had been covered each day.

It is also within the scope of the invention to make the setpoint SP to which the road load is compared to control the transition from mode I to mode IV somewhat "fuzzy", so that SP may vary from one comparison of road load to MTO to the next depending on other variables. For example, as discussed above, if during low-speed operation the operator depresses the accelerator pedal rapidly, this can be treated as an indication that full power will shortly be required, and the engine-starting operation begun before the road load reaches any particular setpoint SP.

The value of the transition point may also vary in dependence on the mode of operation in effect when the road load equals a given setpoint SP. For example, suppose the setpoint at which the mode of operation is controlled to change from the low-speed mode to the highway cruising mode is normally set to 30% of MTO, as in the examples discussed above. If traffic conditions were such that the road load fluctuated around this value, and engine operation were controlled solely in response to road load, the engine would be repeatedly started and shut off as the road load exceeded 30% of MTO for a few hundred yards at a time, and then fell back below 30% of MTO, as might often occur in suburban traffic. Repeated restarts might also occur if the road load averaged over 30% of MTO but occasionally dropped below this value, as might occur in moderate-speed, flat-road cruising.

By monitoring the road load over time, and comparing it to different setpoints accordingly, much of this undesirable repetitive sequence of engine starting and shut-off can be eliminated. It might be preferable to commence mode IV operation upon the occurrence of differing conditions; for example, mode IV might be entered from mode I only after the road load exceeded a first, lower setpoint SP for an extended period of time, so that the engine would be run for extended low-speed cruising, but to start the engine immediately if the road load exceeded a higher setpoint SP2, e.g. 50% of MTO, as during acceleration to highway speed. Similarly, the engine might preferably be shut down only if the road load was less than a minimum setpoint for mode IV operation for an extended period of time. Thus providing "hysteresis" in the mode-switching determination would limit repetitive engine starts in certain types of driving. These limits could be further adjusted as the driving pattern became clear, i.e., as discerned by the microprocessor.

In a further refinement, the setpoint at which the engine is shut off as the road load droppped below the usual minimum value for mode IV operation could vary dependent on BSC; if the batteries were substantially fully charged, the engine might be shut off as road load dropped below 30% of MTO, but if their charge was lower the engine might be controlled to continue to run, even at a stop, i.e., zero road load, to charge the batteries. Of course, the clutch would still have to be disengaged at when the road load fell below 20 - 30% of MTO, in order that the engine could run at an efficient speed for production of torque.

Fig. 9 thus shows the main decision points of the control program run by the microprocessor, with the transition point between mode I, low-speed operation, and mode IV highway cruising, set at a road load equal to 30% of MTO. Examples are then given for some of the various options discussed above, by substituting various of the decision points with alternatives indicated below. Other optional points not specifically shown but discussed herein are within the scope of the invention.

The control program is entered at step 100, where the microprocessor determines whether the road load RL is less than 30% of MTO. If the answer is yes ("Y"), the clutch is disengaged if necessary as indicated at steps 103 and 105. The state of charge of the battery bank BSC is then tested at step 110; if BSC is between 50 and 70% of full charge, the vehicle can operate for some time as a straight electric vehicle, and mode I is accordingly entered, as indicated at 115. A "mode I" loop is then established, including steps 100, 103, and 110; as long as all conditions tested in these steps remain stable, the vehicle continues to be operated in mode I.

However, if at step 110 it was determined that BSC was less than 50% of its maximum value ("N"), the engine should be run, if possible, to charge the battery bank, up to, for example, 75% of its maximum charge, as tested at step 120. If the engine is already running, as tested at step 125, the battery is charged as indicated at 130, and a stable "mode II" loop, as noted at 135, is established including steps 100, 103, 110, 120, 125, and 130. (Normal operation of step 110 would be bypassed or disabled in this mode to prevent battery charging from being stopped when BSC reaches 70%). If the engine is not running, an engine starting subroutine (shown separately, by Fig. 9(a), is entered, as indicated at step 140.

In the engine starting subroutine, beginning with the 'enter' block 141, the clutch is disengaged if necessary at steps 142 - 143, and the catalyst temperature is tested at 145, to determine whether it is at least about 350° C; the catalyst is heated as necessary, as indicated at 150. When the catalyst is heated suitably, the engine is then spun by the starter motor until a desired starting speed is reached, as indicated by the loop including blocks 155 and 160. When the engine reaches its desired starting speed, it is started at step 165, by supply of fuel and firing of its spark plugs, concluding the engine starting subroutine as indicated by 'return' block 170. If the engine starting subroutine was entered from the mode II loop, as above, the battery bank may then be charged as indicated at 130.

If in performance of step 120 it appeared that BSC was less than 40%, which would only occur upon failure of the engine or charging system, step 175 may be performed; thus, if 30% < BSC < 40%, the vehicle may be operated in mode III as an electric car, to provide emergency operation. However, this should be strictly limited to avoid deep discharge of the battery bank, tending to shorten its useful life. As indicated at 177, the vehicle is completely disabled if BSC falls below 30%.

If RL is determined to exceed 30% of MTO in step 100, the program goes to step 180, where the term 30% > RL > 100% is evaluated; that is, the microprocessor determines whether the road load is appropriate for highway cruising in mode IV. If so, and if the engine is running, as tested at step 190, a stable loop including steps 180 and 190 is established; the system remains in mode IV, as indicated at 185, until the state of one of these tests changes.

If in step 190 it is determined that the engine is not running, the engine start subroutine, starting with step 140 as discussed above, is entered as indicated at 195; upon return, at 200, the clutch is engaged at 210, and the loop including steps 180 and 190 is entered.

As noted, in step 180 it is determined whether RL is between 30 and 100% of MTO; if not, it is determined in step 220 whether RL is greater than 100% of MTO. If so, mode V is entered, and the traction motor (and optionally the starting motor) is powered to provide additional torque propelling the vehicle, as indicated at 230. A loop including steps 220 and 230 is thus established, so that mode V remains stable until the state of the test performed in step 220 changes.

When in performance of step 220, it appears that RL is now less than 100% of MTO, it is then determined in step 215 whether RL is less than 30% of MTO. If so, the engine is shut off, as indicated at 240, and the program returns to step 100; if not, the program is returned to step 180.

It will be appreciated that according to the Fig. 9 flowchart, it is possible for the system to proceed directly from mode I to mode V, that is, from step 100 to step 220, if the road load rapidly increases from less than 30% of MTO to more than 100% of MTO. Permitting the operator to thus operate the system is an important safety feature, for example when fast acceleration from a stop is required to merge into highway traffic. In these circumstances the engine would not be running during initial operation in mode V, necessitating a significant drain on the battery bank and overdriving the traction motor. Accordingly, steps equivalent to steps 190, 195, and 210 (including the engine starting subroutine) are to be understood to follow step 220 and precede step 230. That is, in the event mode IV was effectively omitted in passing directly from mode I to mode V, the engine is started and the clutch engaged as soon as possible; these duplicate steps are not shown, for clarity.

In the above discussion of Fig. 9, it was assumed that the transition point between low-speed and highway operation is set so that the transition occurs when the road load is equal to 30% of MTO under all circumstances. However, as discussed above, it may be desirable to operate the system so that the vehicle goes from the low-speed mode I to the highway-cruising mode IV at a higher road load, e.g., 50% of MTO, than the road load at which the low-speed mode is reentered, e.g., when road load in mode IV falls to below 20%. This "hysteresis" of the mode switching point -- for example, allowing the vehicle to accelerate in mode I up to road loads of up to 50% of MTO, but not shutting the engine off, ending mode IV operation, until road load falls below 20% of MTO -- avoids excessive mode-switching during periods of fluctuating road load.

For example, in typical suburban traffic, one might commonly accelerate past 30% of MTO, to what might otherwise be a normal cruising speed, but stop again shortly thereafter; it would be inefficient to thus repetitively stop and restart the engine as the load fluctuates around 30%. Hysteresis might similarly be useful in avoiding needless mode switching in moderate-speed, flat road cruising in mode IV, when the road load might well occasionally drop below 30%; again, it would be inefficient to repeatedly shut off and restart the engine.

Thus providing differing mode switching points depending on the direction of the change in road load can be accomplished readily by monitoring the road load RL as a function of time, and taking appropriate control action. For example, if the system is maintained in mode I until RL exceeds the "normal" 30% of MTO mode switching point for a period of, for example, 30 seconds, and without exceeding 50% of MTO, the excessive mode switching otherwise likely to be encountered in suburban traffic can be largely avoided. Fig. 9(b) shows a step 100' replacing step 100 in Fig. 9 and implementing this "low-speed hysteresis". As indicated, the system remains in the low-speed mode I as long as RL is less than 30% of MTO, or unless RL exceeds 30% of MTO for more than 30 seconds, or exceeds 50% of MTO; if either of the latter conditions occurs, the program goes to step 180, initiating mode IV operation.

Similarly, hysteresis in mode IV cruising, in order to implement excessive mode shifting that might otherwise occur if the road load fluctuates around a fixed mode switching point, can be implemented by simply providing that the system remains in mode IV as long as RL remains between 30 and 100% of MTO, unless RL is less than RL for more than 30 seconds, or exceeds 100% of MTO. This can be implemented as shown in Fig. 9(c); a revised step 215' replaces step 215 of Fig. 9, and provides that, if the system is in mode IV, unless RL is less than 30% of MTO for more than 30 seconds, step 180 is re-entered, thus preserving the "mode IV loop"; when RL is less than 30% of MTO for more than 30 seconds, the engine is shut down, at step 240, control is passed to step 100, and mode I re-entered.

Numerous further modifications to the detailed control strategy of the invention as illustrated in Figs. 6 - 9 will occur to those of skill in the art, and are within the scope of the invention. For example, it may be desirable to vary the operation of the system insofar as responsive to BSC in accordance with monitored variables indicative of battery temperature, ambient temperature, and the like; e.g., on a hot day it may be advisable to avoid charging the battery bank to more than 60% of full charge, as this may cause overheating. Further, as noted above the transition points between modes I, IV, and V in particular may vary in accordance with the operator's commands, so as to provide maximum vehicle responsiveness for safety and ease of consumer acceptance, and over periods of days or weeks, as the microprocessor builds up a detailed historical record of the vehicle's usage pattern, from which an optimized control strategy may be derived.

It may also be possible to provide the microprocessor with useful control information from the operator, without requiring the operator to understand the workings of the system in detail. For example, operators are now well-accustomed to set a "cruise control" when a desired cruising speed is reached; thereafter, existing engine management systems control the instantaneous engine torque output with respect to variation in the road load to maintain vehicle speed substantially constant. It would be a simple matter for the microprocessor to accept a desired cruising speed thus input by the operator, as indicated in Fig. 4. The operator would then be relieved of continuous throttle control, and the microprocessor would similarly control the instantaneous engine torque output with respect to variation in the road load to maintain vehicle speed substantially constant, both as conventional; however, according to the invention, the microprocessor would also reset the transition point so that the system would remain in cruising mode IV until the operator had indicated to the contrary, i.e., by exiting cruise mode.

As discussed above, according to a further embodiment of the invention, additional flexibility is provided to the hybrid vehicle as described above by providing a turbocharger 100, also controlled by the microprocessor 48, so as to be operated when useful in further improving vehicle efficiency and drivability and not at other times. Providing the "turbocharger-on-demand" allows the engine to function efficiently in different torque output ranges, as needed. Essentially, the turbocharger 100 is employed only when the vehicle's torque requirements, the "road load" as above, exceeds the engine's normally-aspirated maximum torque capacity for a relatively extended period T of time, for example, during extended high-speed driving, towing a trailer, or driving up a long hill. Where the road load exceeds the engine's maximum torque for a relatively short period less than T, the traction motor (and possibly also the starting motor) are used to provide additional torque, as in the '970 patent and above. According to a further aspect of the invention, the period T is controlled in response to the state of charge of the battery bank; when the battery bank is relatively depleted, the turbocharger is activated sooner than otherwise, so as to preserve the battery bank.

As is well known to those of skill in the art, a turbocharger 100 (see Fig. 11) typically comprises two turbine wheels 102 and 104 on a common shaft 106, referred to herein as the exhaust-side and air-side wheels respectively. The flow of exhaust gas from engine 40 causes exhaust-side wheel 102 to spin; air-side wheel 104 is driven by shaft 106, drawing air into the body of turbocharger 100 through air filter 110. Waste heat in the exhaust stream is thus effectively recovered by compressing the intake air, which is then ducted to the intake manifold 122 of engine 40. Additional fuel can be burned in the additional air thus provided, so that additional torque is produced. The compressed air may be cooled adiabatically by heat exchange with ambient air in intercooler 117 if desired, further improving thermal efficiency of engine 40.

In typical turbocharger operation, a "wastegate" 114 is provided to limit the exhaust pressure incident on exhaust-side wheel 102, thus limiting the speed of air-side wheel 104 and regulating the "boost" provided by the turbocharger. The waste gate may be spring-loaded to open at a fixed boost pressure (as typically provided to regulate the output of turbocharged racing engines) or may be controlled in a feedback loop using the pressure in the engine intake manifold as the control variable. See <u>Automotive Handbook</u>, <u>2nd Ed.</u>, Robert Bosch GmbH (1986), p. 356. Further, in conventional practice, the turbocharger is used at all times, and the engine's design is optimized accordingly. For example, turbocharged gasoline engines typically have compression ratios of 7 or 8 to 1, as compared to 9 - 11 to 1 for normally-aspirated engines. Neither practice is employed according to the present invention; the turbocharger is controlled by the microprocessor to operate only when needed, and the engine's compression ratio, and other design parameters, are selected based on design criteria relevant when operated in the normally-aspirated mode.

According to the present invention, the waste gate 114 is controlled by the microprocessor 48; except under circumstances when the extra power provided by turbocharging is needed, the waste gate 114 is open (as shown in Fig. 1), so that the engine exhaust essentially bypasses the turbocharger 100. A valve 120, also controlled by microprocessor 48, may also be provided in the duct connecting the air side of the turbocharger 100 and the intake manifold 122 of the engine, so that the engine 40 draws air through the turbocharger only when in use; a second air filter 124 is then also provided.

Commonly, turbocharging for automotive use is employed in order that relatively small-displacement engines will produce high horsepower at the upper end of their operating range; the other design parameters of such engines (e.g., camshaft profiles) are chosen similarly. Engines thus optimized for high-rpm horsepower produce reduced low-speed torque, that is, are "peaky" compared to normally-aspirated engines. A variable-ratio transmission is essential to obtain reasonable acceleration from low speeds. Stated differently, turbocharging as usually implemented for automotive use provides relatively high torque at the upper end of the engine's speed range, but relatively poor torque at lower speeds; such an engine would be unsuitable in practice of the present invention. Moreover, turbocharged engines typically suffer "turbo lag", that is, slow response to sudden increase in torque required. As discussed further below, this particular problem is overcome by use of the turbocharger in a hybrid vehicle according to the invention.

Those of skill in the art will recognize that turbocharged engines are also used in heavy-load road vehicle applications, such as trucks and the like, but these vehicles demand transmissions having 12, 16, or more ratios, so that the engine's narrow power peak can be matched to the load, and exhibit extremely poor acceleration, as well as excessive gear-changing and cost, all of which would be unacceptable to the ordinary motorist. Thus, normally-turbocharged engines, of both the low-speed truck type, or the high-speed automotive type, are not satisfactory in implementation of the present invention.

As also noted above, as conventionally employed, a turbocharger is used at all times. By comparison, according to the present invention, the turbocharger is controlled by the microprocessor 48 to be used only under specified driving conditions, allowing the engine to be operated efficiently in other modes.

Fig. 12, as indicated above, is a diagram comparable to Fig. 6. The differing modes of operation of the hybrid vehicle powertrain of the invention shown thereon are identical to those of the Figs. 3 and 4 vehicle illustrated in Fig. 6, with the addition of turbocharged mode VI. Similarly, Fig. 13 is similar to Fig. 7, but illustrates the operation of a vehicle including a "turbocharger-on-demand" according to this aspect of the invention.

As shown in Fig. 12, according to this aspect of the present invention, a further region VI is provided, wherein the turbocharger 100 is activated by the microprocessor 48 when it detects that the road load has exceeded the engine's maximum output for more than a period of time T. Typically these events will occur when the vehicle is towing a trailer or is otherwise heavily laden, is climbing a long hill, or is operated at high speed for a long period of time.

More specifically, when the road load only exceeds the engine's maximum power for a short time, less than T, as during acceleration onto a highway or during passing, the traction motor is employed to provide the additional torque required, as described above. When the road load exceeds the engine's maximum power for a time greater than T, the turbocharger is energized by closing waste gate 114, and operating valve 120, if provided, to open the duct between the air-side of turbocharger 100 and the intake manifold 122 of engine 40. As the turbocharger "spools up" to its operating speed range, the maximum torque produced by engine 40 increases, and the torque produced by traction motor 25 is gradually reduced. This sequence of events is discussed further below in connection with Fig. 13.

Fig. 12 also shows, by the angle of the line separating regions V and VI with respect to the t = 0 plane, that T can vary with the state of charge of the battery bank 22; when the battery bank is fully charged, T is longer -- that is, energy from the battery bank is used to satisfy road load in excess of the engine's maximum torque output for a longer period -- than when the battery bank is relatively less fully charged. The turbocharger can also be operated to provide additional engine power when full acceleration is needed, e.g., upon detection of the operator's aggressively pressing the accelerator pedal down completely.

As mentioned above, Fig. 13, comprising Figs. 13(a) - (c), and extending over two sheets, is a timing diagram showing the relationship between road load, engine torque output, the state of charge of the battery bank, and operation of the engine in electric car, normally-aspirated and turbocharged modes as these vary over time, during low-speed city driving, highway cruising, and extended high-load driving, thus further illustrating the control strategy employed according to the invention. Fig. 13 is essentially identical to Fig. 7, with the addition of illustration of the operation of turbocharger 100 when the road load exceeds 100% of MTO for more than a period of time T.

Thus, as shown in Fig. 13(a) at t_1, t_2, t_3, and t_4, the microprocessor monitors the length of time t during which road load exceeds 100% of MTO, and compares t continually to a value T preferably varied in accordance with BSC; this is shown by the relative lengths of the arrows marked T on Fig. 13(b). While $t < T$, as at E, F, and G in Fig. 13(a), the excess torque required by the road load is provided by either or both of the traction and starting motors, drawing power from the battery bank. Note that the motors together are rated to be capable of continuously providing torque up to at least 100% of MTO, in accordance with the '970 patent; this allows the motors to provide adequate torque for good vehicle performance without a variable-ratio transmission. The motors may also be overdriven to provide more than their rated torque, well over 100% of MTO, for short periods of time, $t < T$, as at F; as noted, according to an important aspect of the invention, where torque in excess of MTO is needed for a longer period of time, $t > T$, the turbocharger is activated.

Thus, when $t_4 \geq T$, as at P, the microprocessor activates the turbocharger essentially as discussed above, that is, by closing waste gate 114 and valve 120 (if provided). As the turbocharger "spools up", which may take some seconds, and the boost it provides increases, as indicated at Q, the torque provided by the traction motor (and possibly also by the starting motor) is decreased accordingly, as indicated at R. The operator need not be aware of or take any action to initiate the turbocharger's activation; this is controlled by the microprocessor in response to monitoring the road load over time and the state of charge of the battery bank.

As discussed in connection with both Figs. 12 and 13, T is preferably varied in accordance with BSC, so that the turbocharger is activated relatively sooner when BSC is relatively low; this limits the amount of energy drained from the battery during operation of the engine and the traction motor (or both motors) when the road load exceeds 100% of MTO, so that BSC does not fall to an undesirably low value.

Those of skill in the art will recognize that provision of a microprocessor-controlled turbocharger in a hybrid vehicle according to the invention permits operation in an additional mode, providing increased flexibility in the operational scheme provided; essentially the turbocharger provides a larger engine only when needed, at no cost in efficiency at other times. This is particularly significant in meeting the goals of the hybrid vehicle of the invention. More specifically, in addition to the operational advantages noted, provision of a "turbocharger-on-demand" in the hybrid vehicle according to the invention allows the engine to be smaller than otherwise, that is, to provide adequate highway performance in a vehicle of a given weight. As the starting motor/generator must be sized such that when it is operated to charge the batteries (e.g., in extended city driving) it loads the engine adequately that the engine is operated efficiently, employment of a smaller engine allows use of a smaller generator motor. For similar reasons, provision of a smaller engine allows it to be used to efficiently propel the vehicle in highway driving commencing at lower average speeds, resulting in turn in better fuel economy. By providing the "turbocharger-on-demand" according to the invention, all these advantages can be realized without sacrifice in the ultimate performance of the vehicle.

As noted above, one convenient implementation of the "turbocharger-on-demand" according to the invention is to operate the wastegate by a solenoid or the like controlled by the microprocessor, that is, to employ the wastegate as a bypass valve except when turbocharged operations are desired. A separate bypass valve might also or alternatively be provided. The wastegate is still preferably implemented as a spring-loaded relief valve, as illustrated in Fig. 11, and as generally conventional, to limit the "boost" provided. It is also within the invention to operate the waste gate to take intermediate positions, that is, between fully-open and closed positions, so as to limit the torque to limit wheelspin as detected, and to keep the turbocharger wheels spinning at an intermediate speed, to reduce the time necessary to "spool up" to full speed. It is also within the invention to adjust the wastegate responsive to an atmospheric-pressure signal provided by a suitable sensor 107 (Fig. 11) to ensure that adequate boost is provided at higher altitudes to ensure vehicle performance.

It will also be appreciated that a supercharger, that is, a positive-displacement air pump driven by the engine, could be used to implement the differing modes of vehicle operation illustrated in Figs. 12 and 13; for example, the supercharger's operation could be controlled by the microprocessor by driving it through an electrically-controlled clutch, and this is accordingly within the invention. However, this would be less efficient than turbocharger operation, as turbocharging effectively recovers some of the waste heat in the engine exhaust by compressing the air reaching the inlet manifold, while supercharging consumes engine torque. Turbocharging, as discussed in detail, is accordingly preferred.

It will therefore be appreciated that by providing the internal-combustion engine of a hybrid vehicle with a turbocharger controlled by the vehicle's controller to operate only during extended periods of high torque requirements, a number of important advantages are realized, both as compared to a conventional system wherein the turbocharger is continually activated, or as compared to a large engine having the same maximum torque as the smaller turbocharged engine. As to the latter, as explained above all internal combustion engines are extremely inefficient, except when operated at near peak torque output; the larger the engine, the less frequently this will occur. As to the former, employing a conventionally-turbocharged engine, having the typical "peaky" torque curve, would not allow the engine to be used to propel the vehicle during highway driving without a variable-speed transmission. Instead, by providing a "turbocharger-on-demand", that is, which is only employed when it is actually needed, the vehicle of the invention can employ a small engine optimized for its main function of propelling the vehicle efficiently during highway cruising, and which is operable as a much larger engine when needed.

Other advantages provided by the invention include the fact that as the wastegate is normally open, the exhaust temperature will stay high, optimizing catalytic converter performance; as conventionally implemented, cooling of the exhaust gases as their energy is removed in spinning the turbocharger rotor can prevent good catalytic converter performance, especially at low speeds. Further, because the traction motor provides additional torque when needed, the "turbo lag" experienced in conventional turbocharged vehicles as the turbocharger "spools up" when the operator calls for more power is eliminated.

When constructed and operated according to the invention, that is, as a hybrid vehicle having an internal-combustion engine with a turbocharger controlled by the vehicle's controller to operate only during extended periods of high torque requirements, even a heavy vehicle having poor aerodynamic characteristics, such as a sport-utility vehicle or van, can offer good acceleration and hill-climbing and towing ability, while still providing extremely good fuel economy and extremely low emissions.

Another aspect of the invention concerns the method of sizing the various components of the system. Examples were given above of component selection for a vehicle <u>not</u> including a turbocharger according to this aspect of the present invention. Using as a further example a 5,500 pound "sport-utility vehicle" ("SUV") required to have reasonable acceleration and passing performance even while towing a 6,000 pound trailer, sizing of the components of the hybrid drive system of the present invention is preferably accomplished as follows:

1. An internal combustion engine is selected which has sufficient torque to drive the SUV without trailer at medium to high speed along a moderate grade. More specifically, a typical specification will require that the engine be sufficiently powerful to proceed up a 6% grade of unlimited extent at 50 mph. An engine of 100 hp at 6,000 maximum RPM is appropriate to meet this requirement for the SUV described above.

2. If a trailer is to be towed, a turbocharger, operated as above, is added. The turbocharger is sized so that when it is operated the engine provides up to 140 hp.

3. The charger motor is sized so as to provide an engine load

equal to approximately 70% of the engine's maximum torque at a suitable engine speed. In this way fuel is used efficiently during battery charging, as discussed above. In the example, the charger motor is preferably an induction motor of 15 - 30 hp capacity, possibly configured as a "faceplate" or "pancake" type, essentially forming the flywheel of the engine. Such a motor can be operated as a generator requiring 20 - 22 hp, which is 70% of the maximum torque produced by the engine specified above when operated at 1200 - 1500 rpm; battery charging can thus be accomplished in a very fuel-efficient manner. This is essentially equivalent to specifying the starter/generator based on its ability to accept at least about 30% of the engine's maximum torque output (MTO, as above); in this way the engine is operated at a fuel-efficient power level during charging.

4. The traction motor is sized to provide adequate torque at zero speed to overcome the maximum grade specified from rest, with the starter motor assisting as needed. In the example the traction motor may be an induction motor of 100 hp, with a maximum speed of 16,000 rpm, and be connected to the drive wheels through a chain drive providing the appropriate reduction ratio. It will be appreciated that in this example the total torque available from the starting and traction motors combined exceeds that provided by the engine, in accordance with an aspect of the invention of the '970 patent.

5. The torque vs. speed profile of the traction motor is selected to allow city driving, in particular, to provide acceleration sufficient to conform to the Federal urban driving fuel mileage test ("FUDS"), without use of torque from the engine.

6. The battery capacity is then selected to provide sufficient cycle life, i.e., so as not to be overstressed by deep discharge over many repetitive driving cycles. In the example, an 800 v, 8.5 KAH battery pack is provided. The battery bank should be sized and arranged so that the maximum current to be absorbed with the starter/generator being driven at 30% of MTO is no more than 50

amperes.

7. Finally, the controller is provided with software to implement the control scheme described in detail above, that is, to use the traction motor as the only source of drive torque at low speed, to start the engine when the road load increases beyond a setpoint, to operate the turbocharger when the road load exceeds the engine's maximum torque for more than a prescribed time T, which may be varied in accordance with the state of charge of the batteries, and otherwise as described above. Essentially, the controller is operated so that the engine is only operated in a fuel-efficient range, e.g., driving a load at least equal to 30% of MTO.

Simulations show that vehicles configured as above will generally be capable of 80 - 100% improvement in fuel economy with respect to conventional vehicles of similar size, weight and performance characteristics.

Further Improvements according to the Continuation-in-Part

Component Specification

In addition to the methods of sizing the components of the powertrain and ancillary components set forth above, another method of doing so is generally as follows. As set forth above, it is desirable for a number of reasons to operate the system of the invention at relatively high voltages, e.g., 800 V or above, in the case of larger vehicles; this reduces the current flowing throughout the system, which allows use of plug-in rather than bolted connectors, allows use of inexpensive automatic disconnects, and reduces resistance heating losses.

More particularly, suppose that the "average maximum" current (e.g., defined as the maximum current flowing for more than, for example, thirty seconds; under most circumstances, the average current would be much less) is controlled to be 50 A. This allows use of inexpensive mass-produced plug-in connectors, and can be controlled by inexpensive mass-produced power electronic components, as needed to construct the inverter/charger units. These components can be designed to conduct up to approximately 200 A for up to thirty seconds, so that full acceleration can be provided for a time sufficient for the vehicle to reach essentially its maximum speed; according to this aspect of the invention, the peak current can accordingly be set at, for example, 150 A, and the power electronics components then sized based on this value.

More particularly, it appears useful to size the components with respect to one another, in particular, the battery bank with respect to the traction motor(s), so that the peak current is no more than about 150 A, and so that under peak electrical loading (usually under acceleration) a ratio of at least 2.5 : 1 of the battery voltage to the peak current is exceeded.

For example, suppose it is desired to implement the invention with respect to a relatively heavy, e.g., 6000 pound, vehicle having target acceleration capabilities such that a 120 HP electric traction motor, typically drawing 100 kW, will be required. The battery bank for such a vehicle is sized to provide a nominal voltage of 830 V (i.e., when not under load); this will drop to approximately 650 V under load. The battery bank will thus be required to produce 153 A (= 100 kW/650 V) during full acceleration, and the ratio of voltage to peak current is 3.92 (= 650 V/153 A).

In another example, of a much lighter 3000 lb vehicle, a 80 HP, 60 kW motor might be sufficient. To keep the peak current to 115 A, a battery bank of 600 V nominal, 500 V under load would be required. The ratio is then 4.3 (= 500V/115 A).

By comparison, insofar as known to the inventors, the Toyota "Prius" hybrid car now being marketed uses a 30 kW motor, and its battery bank provides approximately 230 V under load; the current required is thus approximately 120 A (= 30 kW/230 V) and the ratio between the voltage under load and the peak current is only about 2 (= 230V/120A). The motor in the Prius is incapable of providing adequate acceleration without assistance; this in turn requires that an internal combustion engine (ICE) be provided, and be connected to the wheels by way of a variable-ratio plantary gearset. Operation of the ICE in the Prius is thus constrained by the vehicle's torque requirements, which unacceptably complicates its operation and renders it incapable of maximally efficient operation.

Applicants assert, therefore, that according to the invention the components of the hybrid vehicles of the invention are to be sized so that the ratio between battery voltage under load to peak current is at least about 2.5, and preferably is at least 3.5 to 4 : 1; this allows adequate acceleration from low speeds without use of torque from the ICE, which in turn allows elimination of any multiple-speed or variable-ratio transmission, and allows the ICE to be declutched from the wheels except when the ICE can be employed efficiently to propel the vehicle (or the ICE is being motored during deceleration or coast-down, as above). In turn this requirement leads to operation at higher voltages than typical, to keep both average maximum and peak currents low, which provides the very significant advantages mentioned above.

Range-Broadening Transmission

As mentioned above, in some embodiments of the invention as disclosed by the present continuation-in-part application, a two-speed transmission may be provided to broaden the range of utility of the vehicle. An exemplary hybrid vehicle powertrain providing this and further additional features is shown in Fig. 14; where not otherwise described, this embodiment of the invention includes features in common with those discussed above in connnection with the '970 patent and the '817 and '743 applications.

More specifically, according to one embodiment of this aspect of the invention of the present continuation-in-part application, the range of efficient use of the hybrid vehicle of the invention is further broadened by providing a two-speed "range shifting" transmission, akin to those presently provided on SUVs and the like to allow shifting into a "low range", so that when the load is expected to be heavy for extended period of time, for example, when a heavy trailer is to be towed, the transmission can be operated to select the low range. As indicated, such a transmission would normally only be operated once per trip, and is accordingly not equivalent to a conventional multiple-speed transmission which is operated to provide a sequence of effective overall gear ratios each time the vehicle is accelerated, as suggested in numerous prior art references dealing with hybrid vehicles. However, in another embodiment, the two-speed transmission thus provided could be operated conventionally, i.e., shifted automatically during acceleration, or in "kick-down" mode responsive to the operator's demand for acceleration.

In one implementation of this aspect of the invention, as shown in Fig. 14, a planetary gearbox 33 is disposed between the output shafts from the traction motor 25 and the combination of engine 40 and starting motor 21. Gearbox 33 may be controlled directly by the operator, as conventional, or by the microprocessor 48, in response to an operator command or responsive to sensing that the road load has exceeded some predetermined value, e.g. 125% of MTO, for an extended time, e.g. several minutes, or conventionally, i.e., shifted under ordinary acceleration. Typically the gearbox 33 will be locked, providing a direct drive, under ordinary circumstances; when a lower ratio is needed, for example, when towing a heavy trailer, the gearbox 33 may be controlled to yield a reduction of 0.5 - 0.8 : 1.

Fig. 14 also shows a second traction motor 222 driving a second set of road wheels 210 through a second differential 211. This is a convenient way of providing a "four-wheel drive" hybrid vehicle, which avoids the fore-and-aft driveshaft and third differential needed by conventional four-wheel drive vehicles. In this embodiment, road wheels 210 are configured as the steering wheels of the vehicle; accordingly halfshaft assemblies 212 incorporating universal joints are employed allowing wheels 210 to pivot, as illustrated. Traction motor 222 is connected to battery bank ("BB" in Figs. 14 and 15) via a further inverter/charger 224, controlled by microprocessor 48 essentially similarly to traction motor 25. As noted above, a DC-to-DC converter 223 may be provided to allow the vehicle of the invention to be connected to vehicles having conventional 12 volt electrical systems for emergency starting purposes, and to provide 12 VDC for operation of conventional accessories.

Provision of separate traction motors 222 and 25 with respect to the corresponding pairs of road wheels 210 and 34 has several advantages with respect to conventional vehicles; as noted above, the fore-and-aft driveshaft and third differential normally required are eliminated, freeing substantial space normally required by these components. Further, "traction control" -- that is, control of the amount of torque directed to each pair of wheels responsive to the traction conditions, which is useful in driving in snow or mud, or on wet or icy pavement -- is conveniently accomplished by the microprocessor, simply by monitoring the wheels' response to given amounts of current and reducing the current to spinning wheels.

As shown by Fig. 14, vehicles according to the invention provided with two traction motors and having a planetary gearbox 33 between one traction motor and its corresponding road wheels may have a similar gearbox 213 between the second traction motor 222 and its wheels; however, this second gearbox 213 is not expected to be commonly required. Similarly, second traction motor 222 can be configured as a high-RPM unit, with its output shaft connected to the road wheels through reduction gears 214. In this implementation starter motor/generator 21 is also shown connected to the road wheels through a reduction device 34, illustrated as a chain drive; as indicated above, providing a mechanical reduction between the various motors 21, 25, and 222 and the respective road wheels is desirable in order that the motors can be selected and optimized to operate at higher speeds than engine 40.

Another possibility not shown specifically by Fig. 14, but within the scope of the invention, is to provide a "torque converter" of essentially conventional design, preferably fitted with a "lock-up" clutch, between the traction motor(s) and the corresponding wheels. As is well known, torque converters are commonly employed as part of automatic transmissions for passenger cars; the torque converter multiplies the input torque at low speeds. Such a torque converter would provide increased acceleration from rest. However, a similar effect can be obtained more simply by overdriving the traction motor(s) beyond their rated power for the first few seconds of acceleration.

Braking System

Numerous patents, including the '970 patent discussed above, recognize that one advantage of hybrid vehicles is that by appropriate control of electric motor/generators connected to the road wheels, a substantial fraction of the energy lost by conventional vehicles to friction can be recovered through regenerative braking, that is, by converting the vehicle's kinetic energy to stored battery power by using torque available at the road wheels to drive the motor(s) in generator mode, and storing the resulting electrical energy in the battery bank for use later. It is commonly estimated that most of the energy expended in accelerating the vehicle in city driving can be recovered in this way, since irrecoverable losses due to air resistance and rolling resistance contribute relatively little to the vehicle's energy demands at low speeds; by comparison, less of the energy expended to drive the vehicle at highway speeds can thus be recovered, although regenerative braking is nonetheless desirable.

More particularly, it is known to operate the motor/generator and cooperating inverter/charger electronics of hybrid vehicles so that electrical power is generated and stored in the battery bank when the operator desires to slow the vehicle. Accordingly "regenerative braking" *per se* is known. It is generally also apparent to those of skill in the art that a conventional mechanical braking system must also be provided, both for safety in the event of a failure in the regenerative braking system and to provide braking in the event the battery bank is fully charged; that is, it is important to avoid overcharging the battery bank in order to maximize its useful life. See Boll U.S. patent 5,788,597 and Frank U.S. patent 5,842,534. Similarly, mechanical braking is also needed when regenerative braking is not possible, e.g., at a stop. However, the art known to the inventors does not address all the concerns relevant to provision of a braking system of a hybrid vehicle, and to do so is another object of the present invention. See, e.g., Mikami et al patent 5,839,533, which suggests employment of engine braking (i.e., retardation of the vehicle using torque due to compression of air in the engine, and friction therein) as well as regenerative braking. The choice between the two is apparently to be made by the operator, at least in part responsive to the battery's state of charge. This would be far too complex for general acceptance.

The disclosure of the Boll patent itself is directed to optimizing the use of regenerative, engine, and mechanical braking. Boll also recognizes the desirability of maintaining a consistent brake pedal "feel" in the various brake modes.

German patent application DT 19 05 641 B2 to Strifler discloses a combined regenerative and mechanical braking system for an electric vehicle, wherein regenerative braking is effected upon the operator's first operating a brake lever, and mechanical braking is further effected upon reaching the maximum regenerative braking effect. If the battery cannot accept further charge, the mechanical braking is triggered relatively earlier, so that the operator experiences substantially the same pedal "feel" regardless whether regenerative or mechanical braking is being implemented.

The present invention also recognizes that providing proper brake "feel" to the operator is important to provision of a satisfactory vehicle, but differs substantially from the teachings of the art, and the Boll and Strifler references in particular, in the type of pedal feel preferred.

More particularly, it will be appreciated that typical vehicle mechanical brake systems provide a relatively linear relationship between the force exerted on the brake pedal and the retarding force exerted on the wheels by the brakes. It is essential that this relatively linear relationship be provided by the brake system of any hybrid vehicle, so that the operator can smoothly and controllably brake the vehicle as desired.

Providing a relatively linear relationship between the force exerted on the brake pedal and the retarding force exerted on the tires by the brakes is substantially straightforward in the case of conventional mechanical braking systems. It is much more complicated in the case of a brake system incorporating regenerative braking as described above, since such a system must provide a linear relationship between the force exerted on the brake pedal and the retarding force exerted on the tires by the brakes and motor/generator(s) under all circumstances. The problem is particularly complicated during transitions from one braking regime to another. For example, if regenerative braking is used to commence deceleration but hydraulic braking must take over, e.g., if the battery bank's state of charge becomes full during a long descent, or if a leisurely stop suddenly becomes abrupt, the braking regime must change smoothly and controllably. Regenerative braking is also not available when the vehicle is moving very slowly or is at rest, and mechanical brakes must be available under these circumstances.

In addition to maintenance of the linear relationship, it is deemed preferable by the present inventors that the operator be made aware by a change in the "feel" of the brake pedal that regenerative braking is not available, typically due to the battery bank's state of charge becoming full. As noted, this is contrary to the teachings of the Boll patent and the Strifler German application. More specifically, it is considered desirable by the inventors that the brake pedal resist depression by the operator to a degree proportional to the amount of regenerative braking actually being effected at all times.

Finally, it will be appreciated that the engine manifold vacuum as conventionally used to produce "power braking", i.e., servo assistance, is not available to a hybrid vehicle if the engine is not running; some other source of power for servo assistance is required in order that brake effort is not unacceptably high.

Fig. 15 shows schematically the principal components of a brake system for a hybrid vehicle that addresses the concerns above. Where common reference numerals are employed, the components are common with those shown in other Figures, while components not important to understanding of the braking system are omitted for simplicity. Thus, Fig. 15 shows traction motors 222 and 25 connected directly to the respective road wheels 210 and 34 respectively, omitting the other components discussed above. (In vehicles where a single traction motor drives a single pair of wheels, the improvements described herein would be provided as to these, while a four-wheel hydraulic braking system would also be provided.) As also discussed above, motors 222 and 25 are connected to battery bank 22 through respective inverter/chargers 224 and 27. Inverter/chargers 224 and 27 are controlled by microprocessor 48 to operate so that the motors can draw power from battery bank 22 and impart torque to the respective wheels to propel the vehicle in the appropriate modes of vehicle operation; during regenerative braking, inverter/chargers 224 and 27 are controlled so that the motors absorb torque from the wheels, slowing the vehicle, and storing the power thus generated in the battery bank 22.

Control of the inverter/chargers and motors to absorb a desired amount of torque from the wheels in response to a braking command from microprocessor 48 is considered to be within the skill of the art. The command itself may be determined by microprocessor 48 responsive to the degree to which brake pedal 70 is depressed, as measured by a potentiometer or similar device, indicated at 71. However, according to the invention, as above, a device is provided which varies the "feel" of the pedal (essentially its resistance to being depressed by the driver) responsive to the degree regenerative braking is in fact being implemented, thereby providing tactile feedback to the driver enabling smooth deceleration and, when appropriate, also providing an indication that regenerative braking is not available.

In the implementation of the invention shown, controllable resistance to the movement of brake pedal 70 is provided by connecting it to a microprocessor-controlled pneumatic cylinder assembly 230. A piston 232 fitting within a pneumatic cylinder 238 is driven by a connecting rod 234 attached to pedal 70 by a clevis 236. As the pedal is depressed, moving from right to left in Fig. 15, i.e., from the position shown in full to that shown in dotted lines, piston 232 expels air from the interior of cylinder 238 via vent 240. The rate at which air is expelled in response to any given pedal pressure is controlled by the spacing of a needle valve 242 from a seat 244; the needle valve 242 is moved closer to its seat 244 to increase the resistance to airflow, or moved away from seat 244 to reduce the resistance. The spacing is controlled by microprocessor 48 in order to vary the feel of the brake pedal 70; in the implementation shown, the needle valve 242 is threaded into the body in which valve seat 244 is formed, and the spacing is controlled by the microprocessor 48 by commands sent to a motor 248 rotating the needle valve 242 through a pair of gears 250. A spring 252 may be provided to return the pedal to its initial position. Thus, for example, if regenerative braking is not available, needle valve 242 is opened, so that the cylinder provides little resistance to the pedal, effectively informing the driver that only hydraulic braking is available. When regenerative braking is initiated, responsive to the microprocessor's detecting a signal from potentiometer 71, the needle valve is closed responsive to the degree of braking provided, resisting motion of the pedal 70, and so that the pedal feel provided to the operator is responsive to the degree of regenerative braking actually being effected. Obviously, numerous other arrangements to thus controllably vary the feel of the brake pedal will occur to those of skill in the art.

The mechanical design of the hydraulic braking system of the hybrid vehicle according to the invention is generally conventional, with two principal exceptions as follows: First, as the engine is not always running during movement of the hybrid vehicle, there is no consistent source of manifold vacuum as conventionally employed to provide servo assistance to braking. Therefore, a motor 254 powered directly by the battery bank BB is provided, and drives a vacuum pump 256, providing vacuum to a conventional servo booster 258, in turn operating conventional wheel brakes 260. The same motor 254 can be used to power other "ancillary" systems that in conventional vehicles are powered by the engine, such as the power steering pump and the air conditioning compressor. (The art does recognize that hybrid vehicles require different sources of power for ancillary devices, such as power steering pumps or power brake pumps. See Heidl patent 5,249,637, at col. 1, lines 7 - 45.) Second, in order that the initial movement of the brake pedal 70 activates only the regenerative braking process (in order to obtain the maximum benefit therefrom), a mechanism is provided so that the rod 262 actuating the piston within master cylinder 264 and thence the wheel brakes 260 moves a distance X before the master cylinder itself is actuated. In the implementation shown, this mechanism simply involves provision of a cross-pin 266 fixed to rod 262 and sliding within a slot 268 formed in the piston rod 270 of master cylinder 264; accordingly, the master cylinder piston(s) do not begin to move until the cross-pin 266 reaches the left end of slot

268. If the overall pedal travel Y is six inches, the distance X defined by slot 268 may be such as to allow pedal 70 to move freely through 1-1/2 inches before the piston(s) of the master cylinder 264 begins to move.

Thus, according to this aspect of the invention, potentiometer 71 provides a signal to the microprocessor 48 when the brake pedal 70 is depressed by the driver. The microprocessor 48 evaluates the battery bank state of charge (SOC) as indicated at 66; unless this is such that further charging is undesirable, the inverter/chargers 224 and 27 are operated such that motors 222 and 25 are operated as generators, so that torque provided to the wheels by the road is converted into electrical power, retarding the vehicle and charging the battery bank. The degree of retardation thus provided depends on the degree to which pedal 70 is depressed. The driver feels resistance to depressing the pedal from air resistance controlled by the opening of needle valve 242; microprocessor 48 controls the opening of valve 242 so that the pedal feel corresponds to the degree of regenerative braking that is provided. In the event regenerative braking is not available for some reason, perhaps because the battery bank is fully charged, because of some flaw in the charging circuits, or because the vehicle is stopped, valve 242 is opened, so that the driver feels little resistance to initial pedal travel, until the hydraulic brake system is activated.

It will be apparent that other types of devices for controlling the resistance to pedal travel to correspond to the amount of regenerative braking being provided, and thus to provide the desired linear relationship between pedal resistance and vehicle retardation, could be substituted for the pneumatic cylinder with microprocessor-controlled vent device shown. For example, a device controllably varying the friction between the pedal pivot and its mounting structure could be provided; a hydraulic system, similarly controlling the resistance to flow of a fluid through an orifice, might be provided; or a device varying the preload of a return spring might be provided. Other equivalent devices for achieving the same goals will occur to those of skill in the art.

HVAC System

The essential components of the heating, ventilation and air conditioning (HVAC) systems of conventional vehicles are a heater core, connected to the engine cooling system, an air conditioning system including an evaporator, and a fan to blow air over the heater core and evaporator and into the passenger cabin. There are several issues to be addressed in adapting the conventional automotive HVAC system to use in a hybrid vehicle. One is that conventionally the air conditioning compressor is driven by the engine through an electrically-controlled clutch; in a hybrid vehicle this is unacceptable, as the engine is not run constantly. Therefore the air conditioning compressor must be powered differently. Similarly, again as the engine is not run constantly, the heater core cannot be relied upon to heat the cabin.

The art does recognize that hybrid vehicles require different sources of power for ancillary devices, such as power steering pumps or power brake pumps. See Heidl patent 5,249,637, at col. 1, lines 7 - 45. Heidl's disclosure is to the effect that a motor/generator used to drive the ancillaries during electric operation can be used as a generator when the vehicle is propelled by an internal combustion engine.

Fig. 16 shows the principal components of an HVAC system for a hybrid vehicle according to the invention. The complex ducting that is typically provided to supply conditioned air throughout the vehicle cabin is represented by a single duct 300. A fan 302 forces air through the duct 300, and in succession past an evaporator 304, a heater core 306, and an electric heater 308. The evaporator 304 is connected to an air conditioning compressor 310 driven by an electric motor 312 powered from the battery bank, so that the air conditioning system can be operated independent of the engine 40.

Motor 312 could be the same motor used to power other ancillaries, such as the vacuum pump 256 (Fig. 15) used to provide servo assistance to the brake system, or could be a separate motor dedicated to powering the compressor 310. The latter may be preferred, as this would allow elimination of the clutch otherwise needed to permit operation of the compressor only when needed; elimination of the clutch would also allow elimination of seals that are a source of leaks. Another advantage of driving the compressor from the battery bank according to the invention is as follows. Conventionally, in order to be useful under all circumstances, the compressor must be sized to provide full cooling with the engine at idle. Such a compressor is very inefficient at higher speeds; by decoupling the compressor from the vehicle drivetrain according to the invention, it can be designed to be driven by motor 312 at a single optimally efficient speed. Cabin temperature can be thermostatically controlled by a throttling valve controlling the flow of refrigerant, or by turning motor 312 on and off as required. The other components of the air conditioning system, including an expansion valve 314 and a condenser 316, are shown schematically, and are generally conventional.

When the engine is running, it is efficient to employ waste heat from the engine cooling system to provide cabin heat, and accordingly an essentially conventional heater core 306 and control elements (not shown) are provided; heater core 306 is downstream of the evaporator 304 with respect to the flow of air through duct 300, as conventional, so that dehumidified air can be heated to provide efficient demisting.

In order to provide heat as may be required when the engine is not running, an electric heating element 308, essentially comprising a coil of Nichrome wire or the like, is provided, again downstream of the evaporator 304. Heating element 308 is provided with conventional controls (not shown) and is powered directly from the battery bank 22, as indicated.

It will be appreciated that according to this aspect of the invention, suitably heated or cooled cabin air is thus available regardless of the mode of operation of the vehicle, as needed in order that the hybrid vehicle of the invention suffers no comfort or convenience drawback with respect to conventional vehicles. Indeed, because ample electrical power is available from the large battery bank of the hybrid vehicle, electric heater 308 can be designed to heat the cabin much more rapidly than does the coolant heat exchanging core of a conventional engine, thus providing a convenience advantage. Similarly, conductors can be embedded in the vehicle windows and windshield and powered by the battery bank for improved electrically-operated de-misting and de-icing.

It will be appreciated that the hybrid vehicle and operational strategy therefor of the invention provide numerous advantages over the prior art discussed herein, and that further improvements and modifications thereto are within the skill of the art. Accordingly, while a preferred embodiment of the invention has been disclosed, and various alternatives mentioned specifically, the invention is not to be limited thereby.

1. In a method of controlling an internal combustion engine of a hybrid vehicle, said engine being operatively connected to drive wheels of said vehicle through a clutch, said vehicle further comprising a traction motor operatively connected to drive wheels of said vehicle, a starter/generator motor operatively connected to said engine for starting said engine and for providing electrical power in response to torque from said engine, a battery bank adapted to store electrical energy to power said traction motor and to start said engine, at least one inverter/charger adapted to cooperate with said traction motor and said starter/generator such that said traction motor can be operated to provide torque to said road wheels responsive to electrical power from said battery bank, or to provide electrical power to said battery bank responsive to torque from said road wheels, and such that said starter/generator can be operated to provide torque to start said engine, or to provide electrical power to said battery bank responsive to torque provided by said engine, and a microprocessor adapted to control operation of said engine, said traction motor, said starter/generator, and said at least one inverter/charger, so as to control flow of torque and electrical power therebetween in response to sensed parameters, the improvement comprising:

establishing at least four vehicle operating modes, including:

a mode I, wherein said engine is not operated and said vehicle is propelled by torque from said traction motor in response to electrical power drawn from said battery bank;

a mode II, wherein said vehicle is propelled by torque from said traction motor in response to electrical power drawn from said battery bank, and said starter/generator is driven by torque provided by said engine to provide electrical power to recharge said battery bank;

a mode III, wherein said vehicle is propelled by torque from said engine;

a mode IV, wherein said vehicle is propelled by torque from said engine and from said traction motor in response to electrical power drawn from said battery bank;

wherein said microprocessor controls operation of said engine, said traction motor, said starter/generator, and said at least one inverter/charger in response to the instantaneous torque demands (RL) of said vehicle, and such that said engine is operated only in response to a load equal at least to a predetermined minimum value of its maximum torque output.

2. The method of claim 1, wherein said starter/generator is sized with respect to said engine such that said starter/generator is capable of being driven by said engine in said mode II while said engine produces at least about 30% of its maximum torque output.

3. The method of claim 2, wherein said battery bank is sized such that the charging current supplied by said starter/generator in response to torque from said engine while producing at least about 30% of its maximum torque output is no more than about 50 amperes.

4. The method of claim 1, wherein said microprocessor controls operation of said vehicle such that said mode III is entered only when RL is at least equal to a predetermined fraction of the engine's maximum torque output (MTO).

5. The method of claim 4, wherein mode III is entered only when RL is substantially equal to at least 30% of MTO.

6. The method of claim 5, wherein said vehicle is operated in mode III while 30% < RL < 100% of MTO.

7. The method of claim 1, wherein mode IV is entered only when RL > 100% of MTO.

8. The method of claim 1, wherein said vehicle further comprises a turbocharger adapted to be controlled by said microprocessor so as to increase the torque output of said engine from its maximum value while normally aspirated (MTO), and wherein a further vehicle operating mode V is established, wherein said turbocharger is controlled to operate when RL is greater than MTO for more than a given period of time T.

9. The method of claim 8, wherein if said vehicle is in said mode IV, with RL between 30 and 100% of MTO, and if RL then exceeds 100% of MTO, torque required in excess of 100% of MTO is initially provided by said traction motor, and if RL continues to exceed 100% of MTO for more than a given period of time T, said turbocharger is activated by said microprocessor such that said engine produces torque in excess of 100% of MTO.

10. A brake system for a hybrid vehicle, said vehicle comprising a drive train including an internal combustion engine operated to provide vehicle propulsive torque only during predetermined modes of operation of said vehicle and at least one traction motor and corresponding inverter/charger adapted to provide vehicle propulsive torque during predetermined modes of operation of said vehicle and to provide electrical energy responsive to torque from wheels of said vehicle during a regenerative braking mode of operation of said vehicle, a battery bank adapted to provide electrical energy to said motor as required and to accept charging energy from said motor when operated as a generator during said regenerative braking mode of operation of said vehicle, and a microprocessor for controlling the mode of operation of said vehicle, said brake system comprising:

a brake pedal adapted to be operated by a driver of said vehicle,

a hydraulic brake system coupled to said brake pedal and comprising at least one master cylinder and a number of wheel brakes operatively connected to said master cylinder for retarding said vehicle upon actuation of said pedal,

a sensor for providing a signal to said microprocessor responsive to motion of said brake pedal,

a sensor for providing a signal to said microprocessor responsive to the state of charge of said battery bank,

a device controllable by said microprocessor to vary the resistance to motion of said pedal during braking responsive to the amount of regenerative braking being provided,

wherein said microprocessor controls the amount of regenerative braking provided upon motion of said pedal responsive to the state of charge of said battery bank, and controls the resistance to motion of said pedal during braking responsive to the amount of regenerative braking being provided.

11. The brake system of claim 10, wherein said device controllable by said microprocessor to vary the resistance to motion of said pedal during braking responsive to the amount of regenerative braking being provided comprises a pneumatic cylinder having a piston sliding therein, said piston being operated by said brake pedal, and comprising a vent passage including an orifice controllable by said microprocessor to control the resistance to motion of said pedal.

12. The brake system of claim 10, wherein said at least one master cylinder is coupled to said brake pedal by an actuating rod arranged so that said pedal can be moved through a predetermined distance before said master cylinder begins to apply pressure to said wheel brakes.

13. The brake system of claim 10, wherein said hydraulic brake system comprises a servo actuator and a vacuum pump driven by a motor responsive to electrical power supplied from said battery bank.

14. A heating, ventilation, and air conditioning (HVAC) system for a hybrid vehicle, said vehicle comprising a drive train including an internal combustion engine run only during predetermined modes of operation of said vehicle and at least one traction motor adapted to provide vehicle propulsive torque during predetermined modes of operation of said vehicle, a battery bank adapted to provide electrical energy to said motor as required, said HVAC system comprising:

a duct having a fan disposed therein for forcing air along said duct;

an evaporator in said duct;

an air conditioning compressor connected to said evaporator, and driven by an electric motor powered by said battery bank;

a heater core in said duct and connected to a cooling system of said engine; and

an electrical heating element in said duct and connected to said battery bank.

15. The HVAC system of claim 14, wherein said evaporator is disposed in said duct upstream of said heater core and said electrical heating element with respect to the direction of air flow through said duct.

16. A method for determining the relative sizes of the internal combustion engine, starting/charging and traction motors, and battery bank of a hybrid vehicle comprising said components, said method comprising the steps of:

a. selecting an internal combustion engine having sufficient torque to drive the vehicle without trailer at medium to high speed along a moderate grade;

b. sizing the starting/charging motor to provide an engine load during battery charging equal to at least approximately 30% of the engine's maximum torque output;

c. sizing the traction motor to provide adequate torque at zero speed to overcome the maximum grade specified from rest, with the starter motor assisting as needed;

d. determining the maximum power drawn by the selected motor under full power conditions;

e. calculating the battery voltage under load that will be required to provide the power to be drawn by the motor(s) under full power conditions, and so that the ratio of the battery voltage under load to the peak current drawn by the motor(s) is at least 2.5:1, and

f. selecting the battery bank to provide the calculated voltage under peak load conditions.

ABSTRACT OF THE DISCLOSURE

A hybrid vehicle comprises an internal combustion engine, a traction motor, a starter motor, and a battery bank, all controlled by a microprocessor in accordance with the vehicle's instantaneous torque demands so that the engine is run only under conditions of high efficiency, typically only when the load is at least equal to 30% of the engine's maximum torque output. In some embodiments, a turbocharger may be provided, activated only when the load exceeds the engine's maximum torque output for an extended period; a two-speed transmission may further be provided, to further broaden the vehicle's load range. A hybrid brake system provides regenerative braking, with mechanical braking available in the event the battery bank is fully charged, in emergencies, or at rest; a control mechanism is provided to control the brake system to provide linear brake feel under varying circumstances.

FIG. 1
(PRIOR ART)

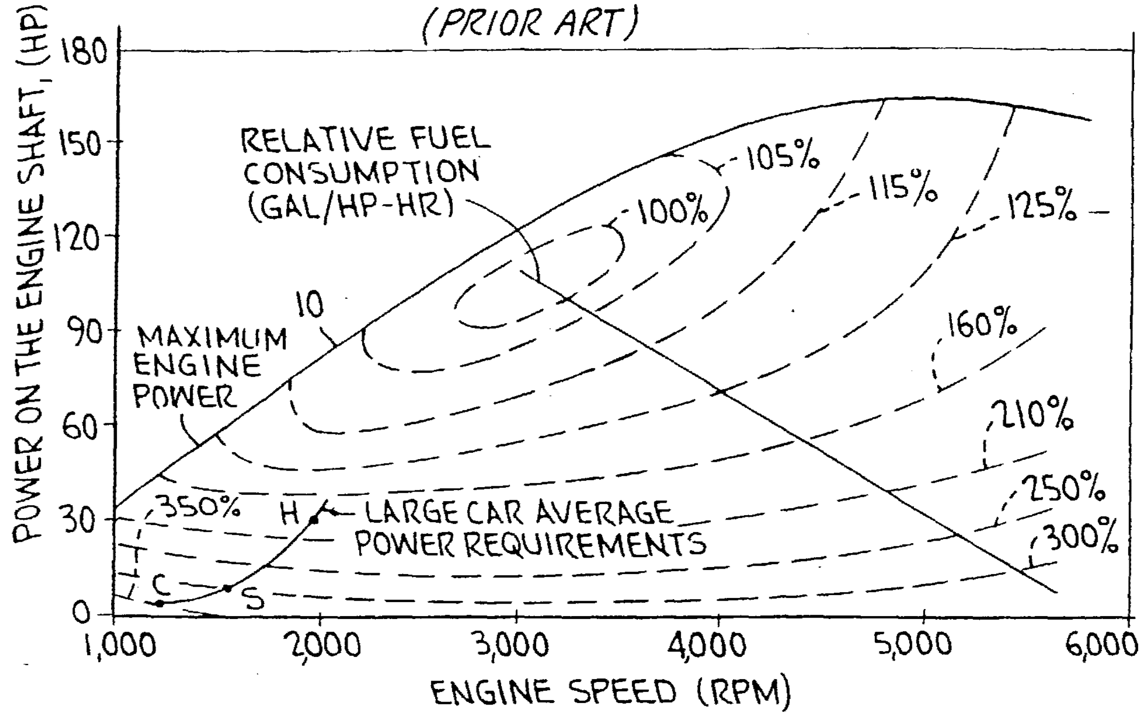

FIG. 2

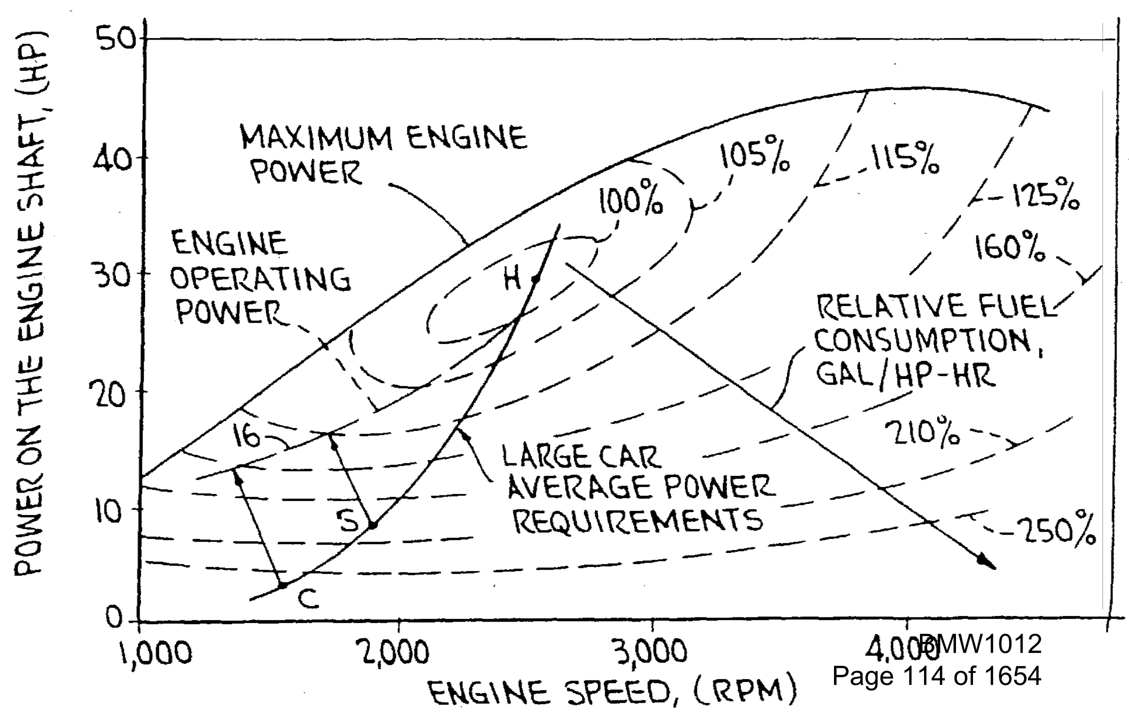

FIG. 3

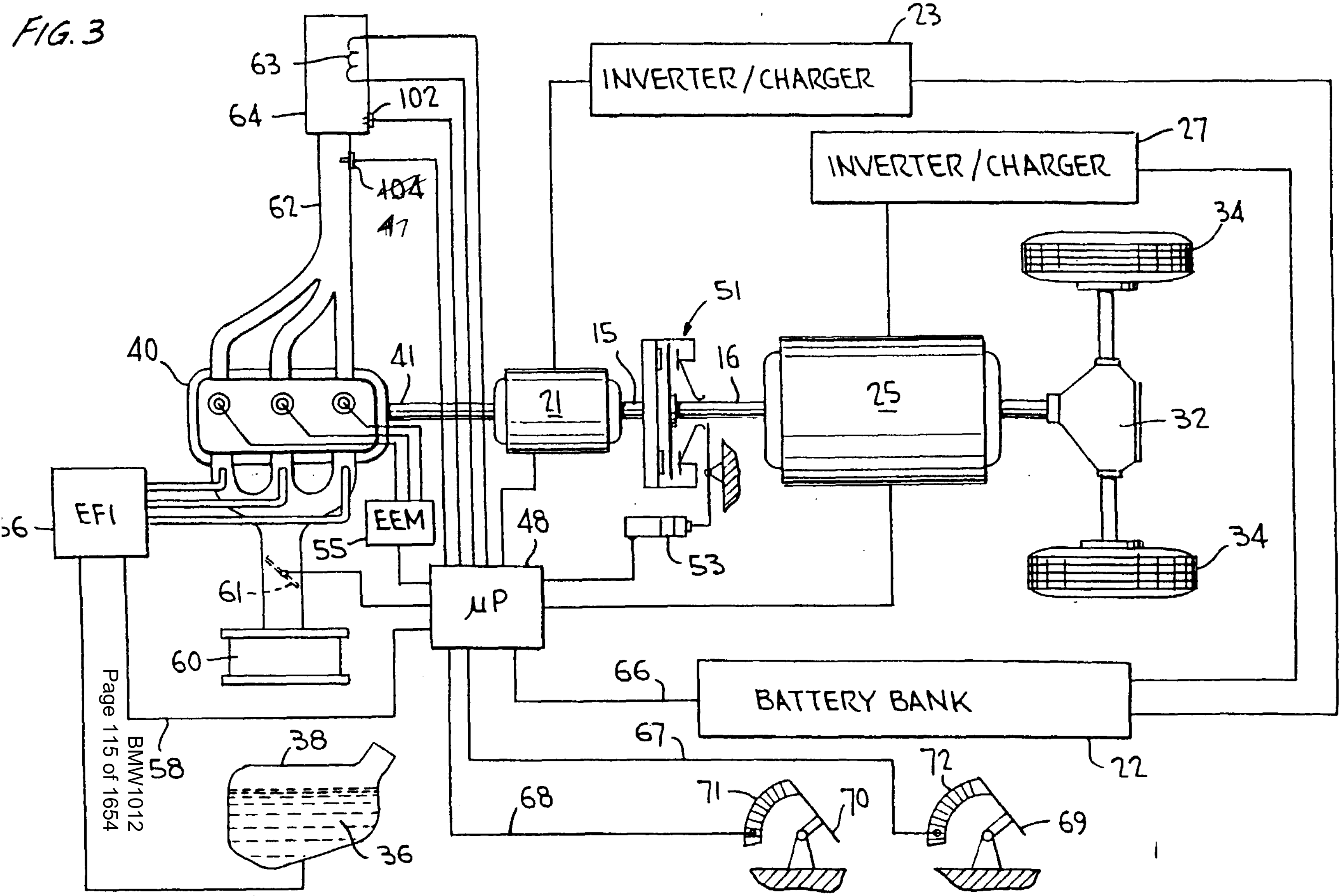

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FIG. 4

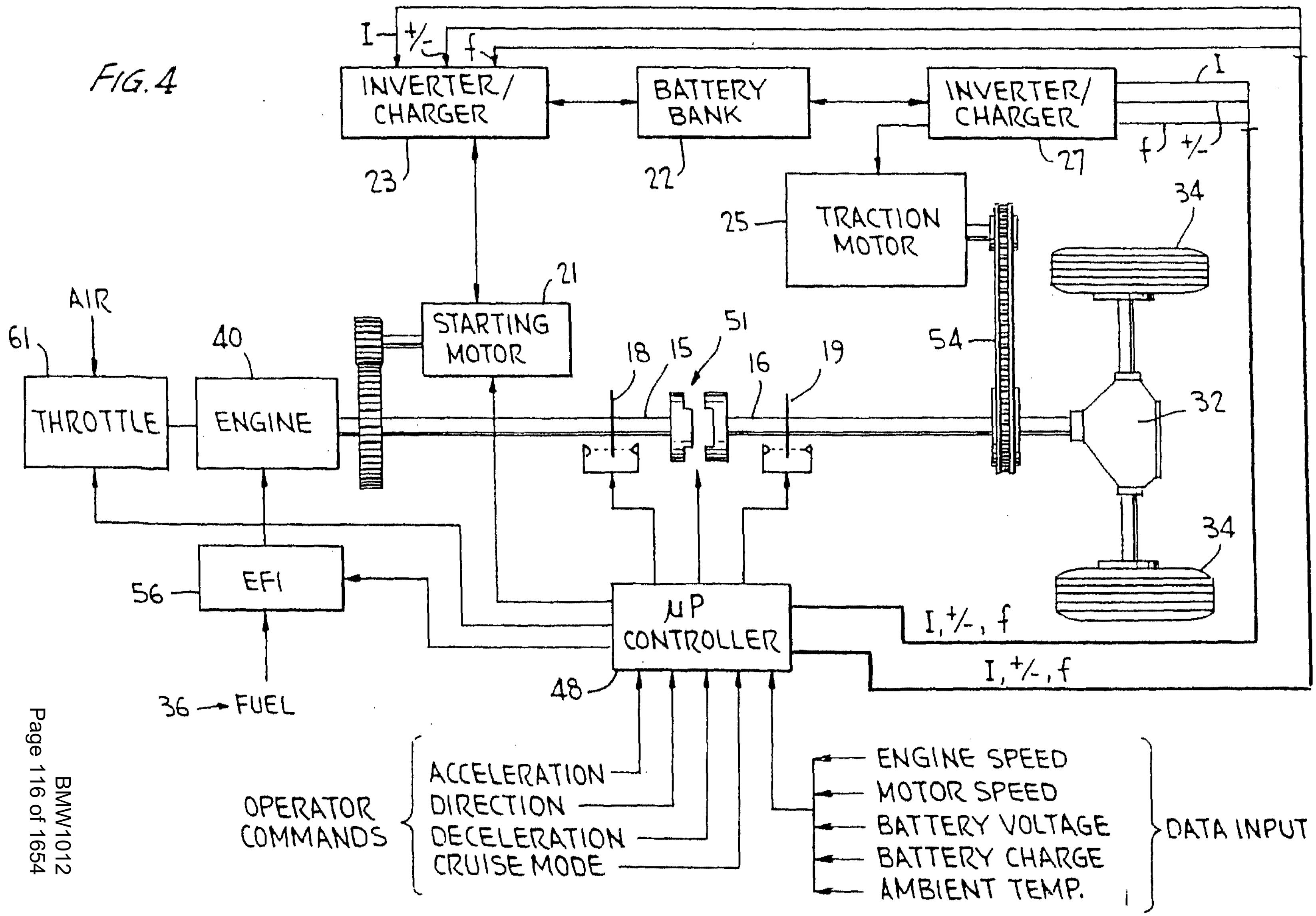

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FIG. 5(a)

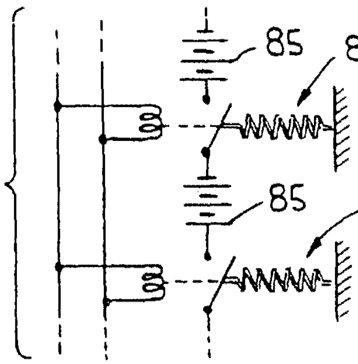

FIG. 5

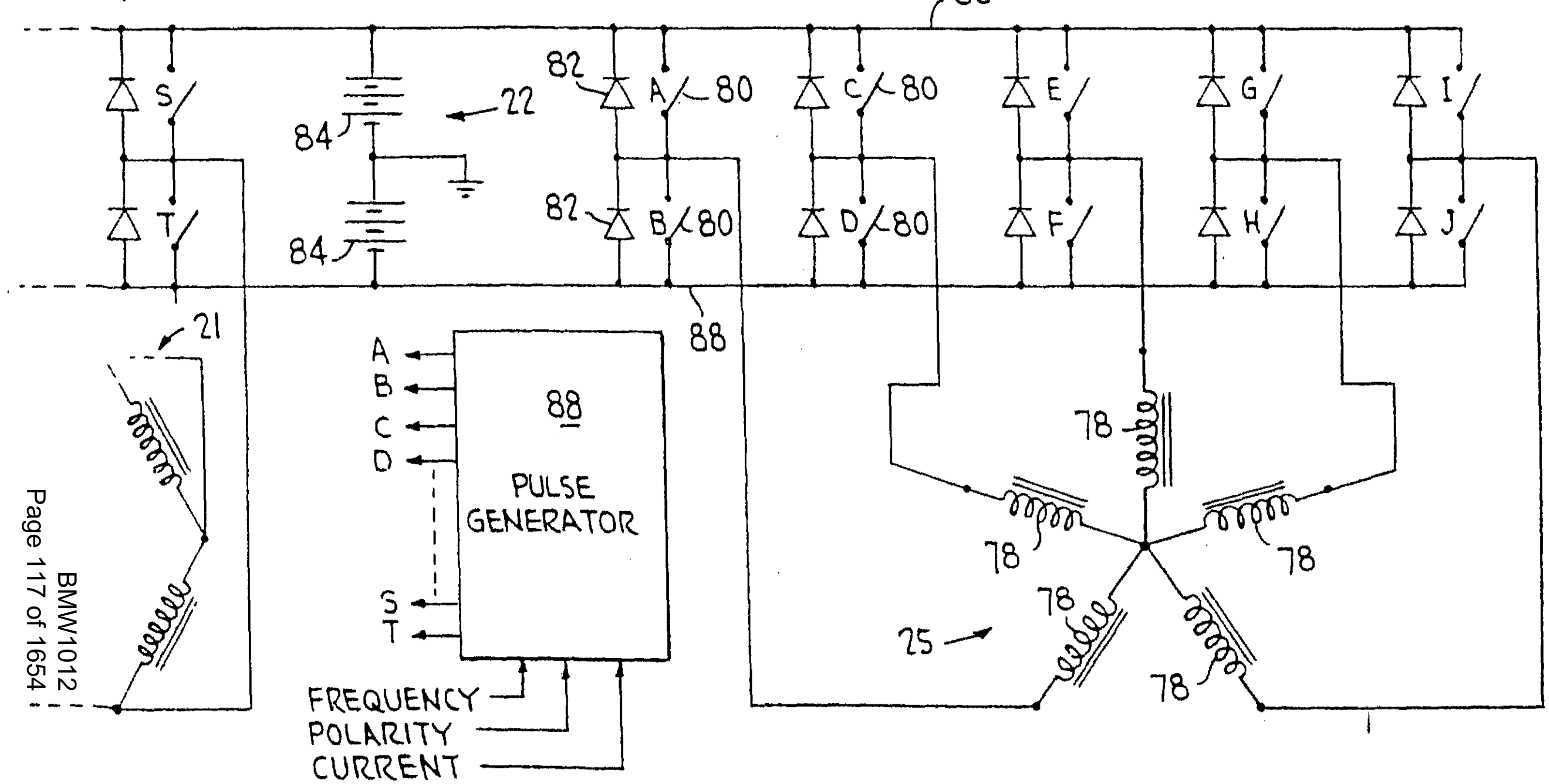

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FIG. 6

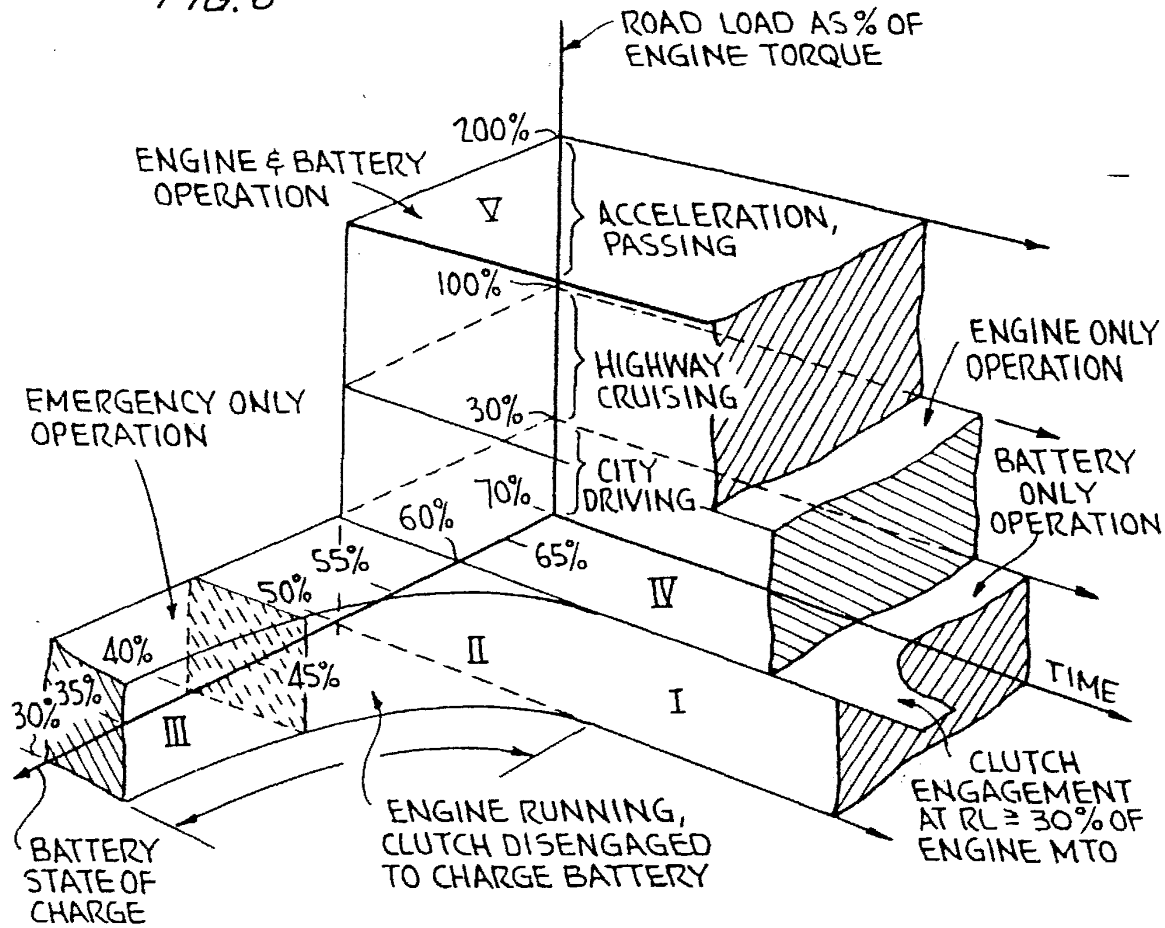
ROAD LOAD AS % OF ENGINE TORQUE
200%
ENGINE & BATTERY OPERATION
V
ACCELERATION, PASSING
100%
HIGHWAY CRUISING
30%
CITY DRIVING
EMERGENCY ONLY OPERATION
ENGINE ONLY OPERATION
BATTERY ONLY OPERATION
70%
60%
55%
65%
50%
40%
35%
30%
45%
IV
II
I
III
TIME
CLUTCH ENGAGEMENT AT RL ≥ 30% OF ENGINE MTO
ENGINE RUNNING, CLUTCH DISENGAGED TO CHARGE BATTERY
BATTERY STATE OF CHARGE

FIG. 10

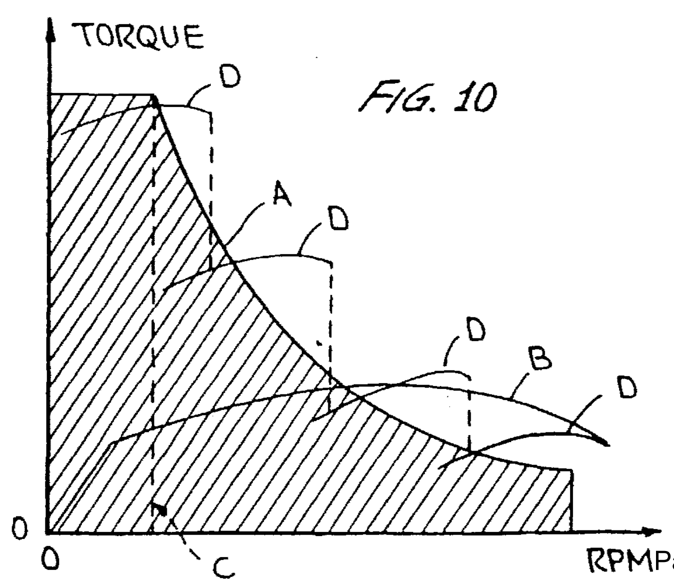
TORQUE
D
A
D
D
B
D
0
0
C
RPM

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FIG. 7(a)

ROAD LOAD AS% OF MAX. ENGINE TORQUE OUTPUT (% MTO)

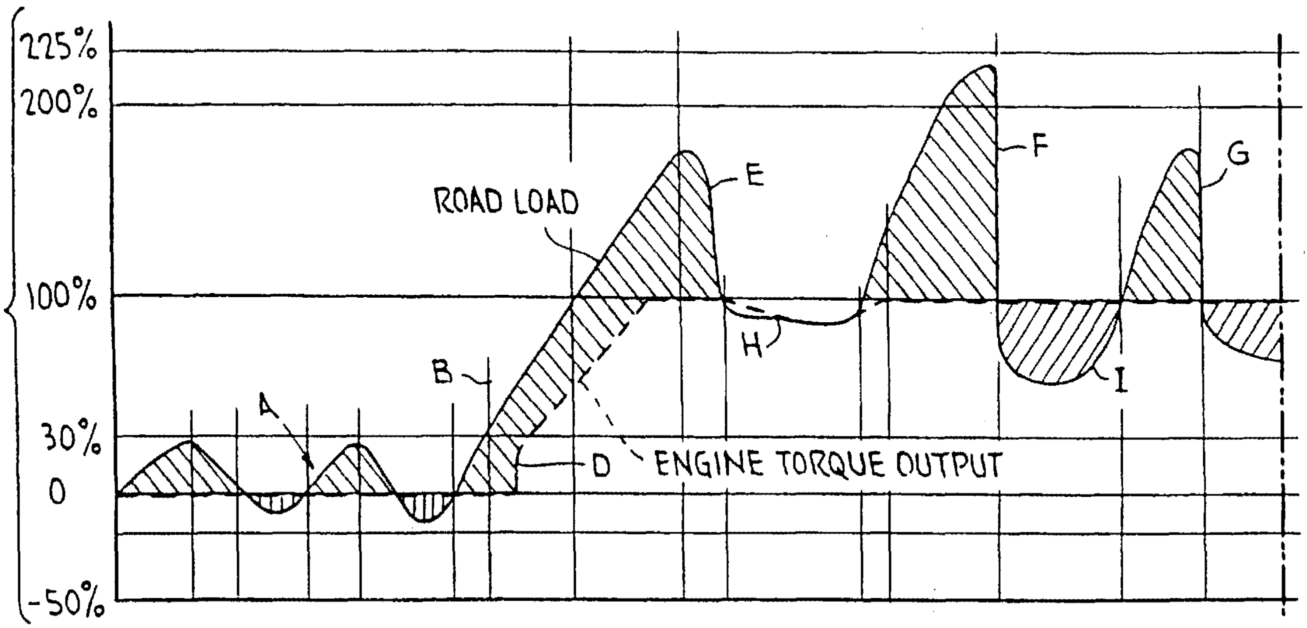


FIG. 7(b)

BATTERY BANK STATE OF CHARGE (BSC)

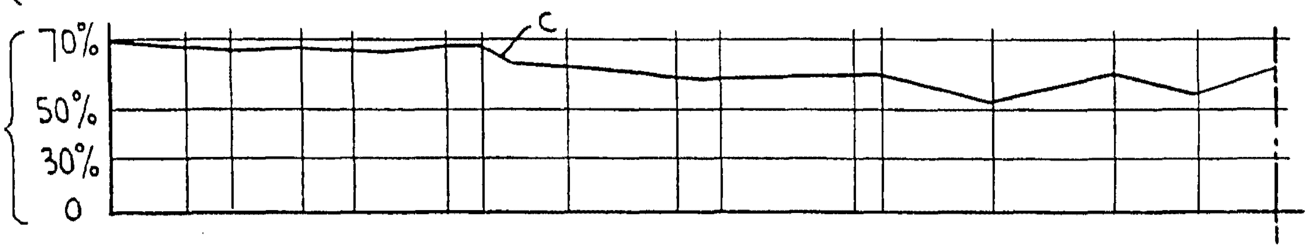
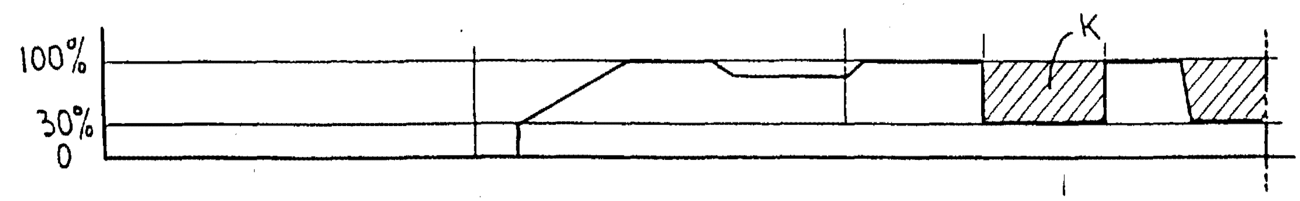


FIG. 7(c)

ENGINE TORQUE OUTPUT



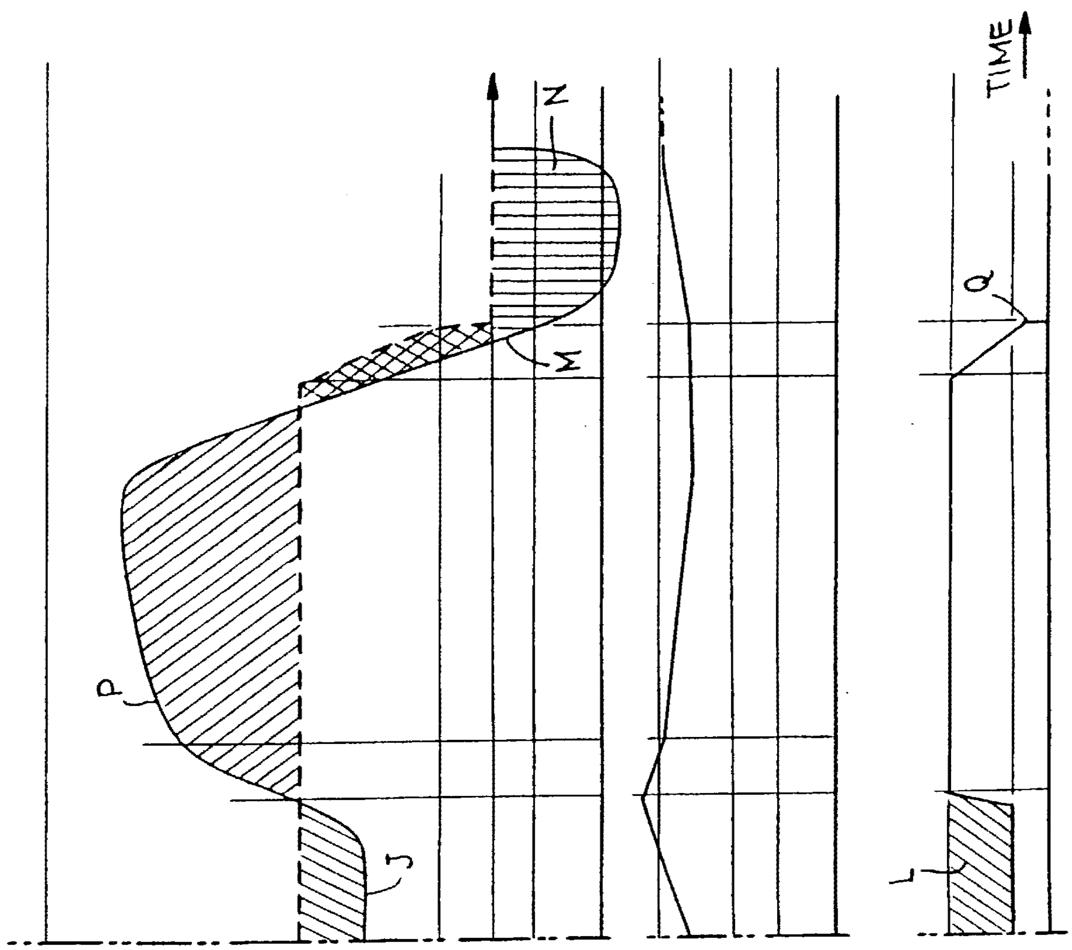


FIG. 7(a) (CONTINUED)

FIG. 7(b) (CONTINUED)

FIG. 7(c) (CONTINUED)

FIG. 8(a)

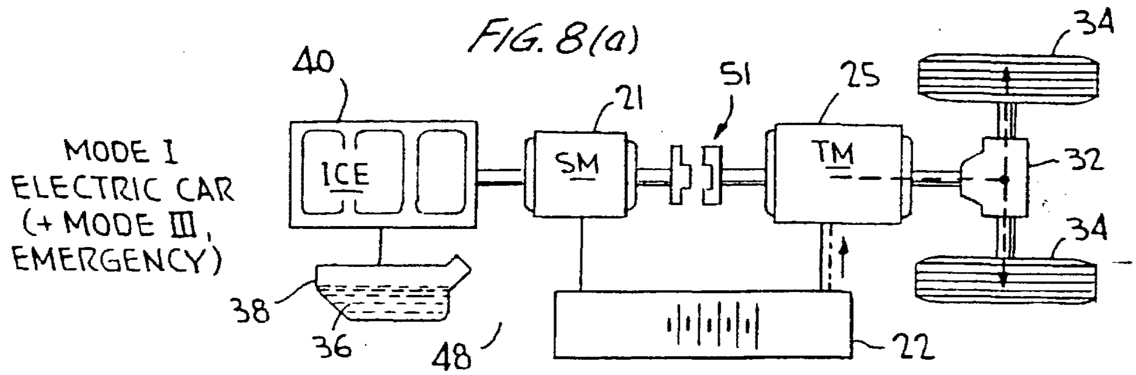


FIG. 8(b)

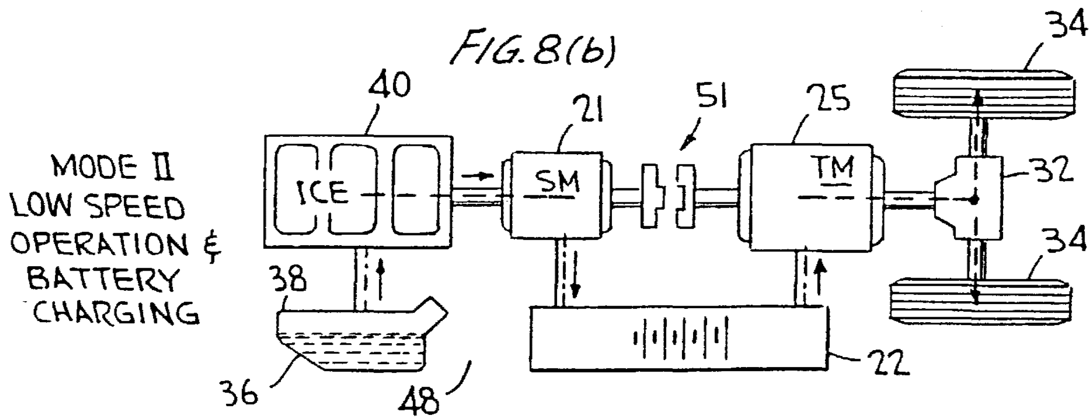


FIG. 8(c)

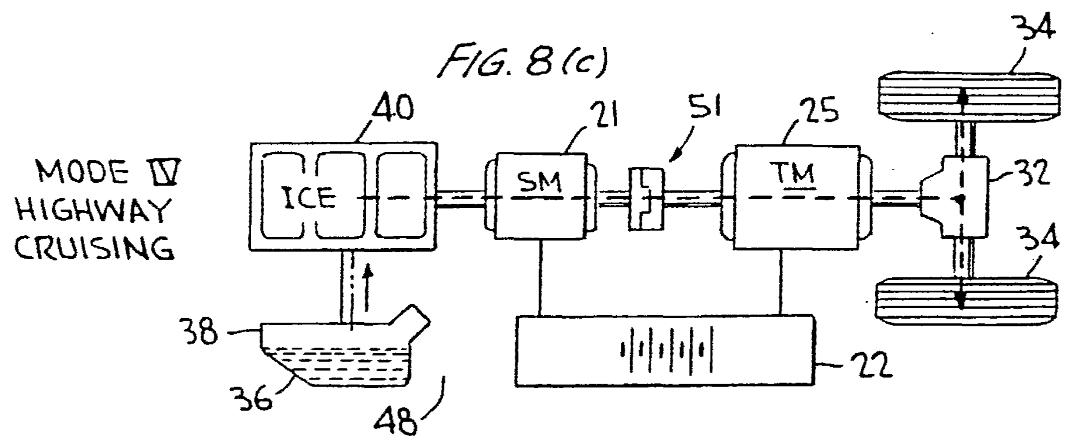


FIG. 8(d)

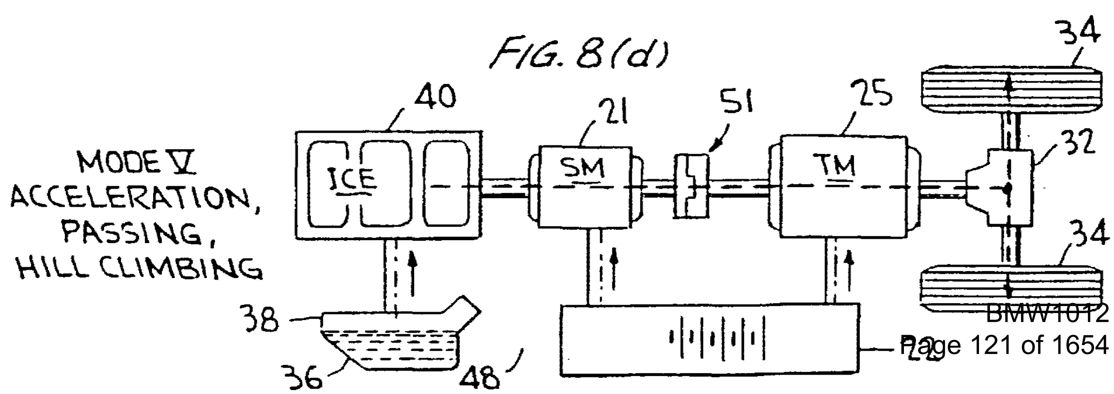


FIG. 9

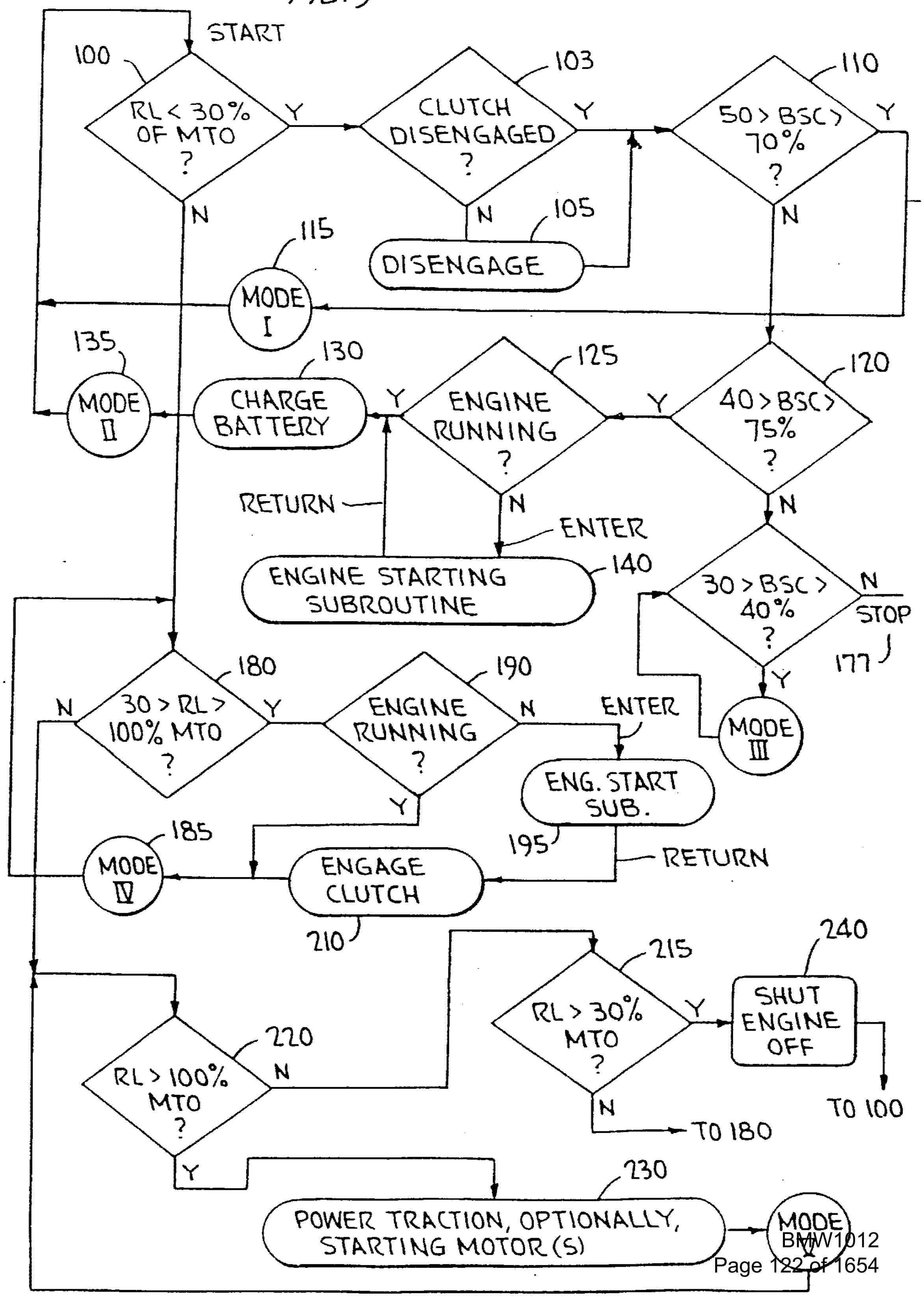

START
100
RL < 30% OF MTO ?
Y
N
103
CLUTCH DISENGAGED ?
Y
N
105
DISENGAGE
110
50 > BSC > 70% ?
Y
N
115
MODE I
135
MODE II
130
CHARGE BATTERY
Y
125
ENGINE RUNNING ?
Y
N
120
40 > BSC > 75% ?
N
RETURN
ENTER
ENGINE STARTING SUBROUTINE
140
30 > BSC > 40% ?
N
STOP
177
Y
MODE III
180
N
30 > RL > 100% MTO ?
Y
190
ENGINE RUNNING ?
N
ENTER
Y
ENG. START SUB.
195
RETURN
185
MODE IV
ENGAGE CLUTCH
210
240
215
RL > 30% MTO ?
Y
SHUT ENGINE OFF
N
TO 180
TO 100
220
RL > 100% MTO ?
N
Y
230
POWER TRACTION, OPTIONALLY, STARTING MOTOR(S)
MODE V

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FIG. 9(a)

ENGINE STARTING SUBROUTINE

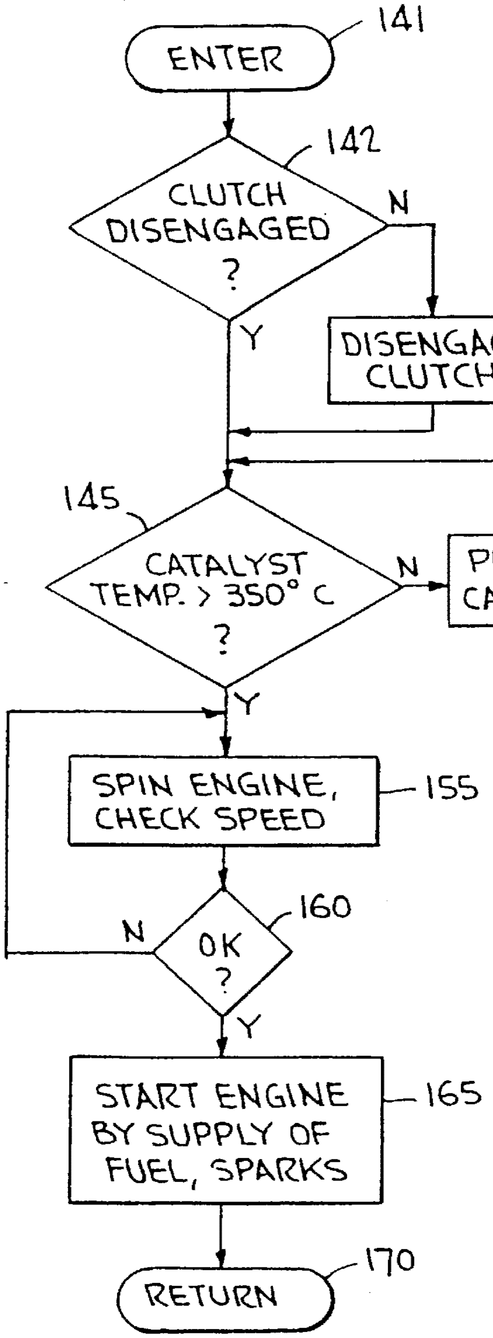


FIG. 9(b)

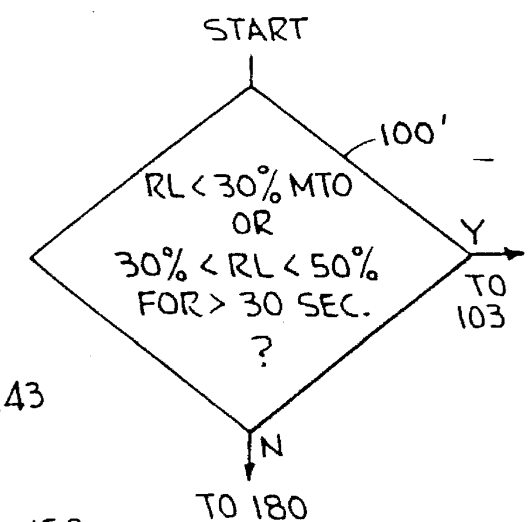


FIG. 9(c)

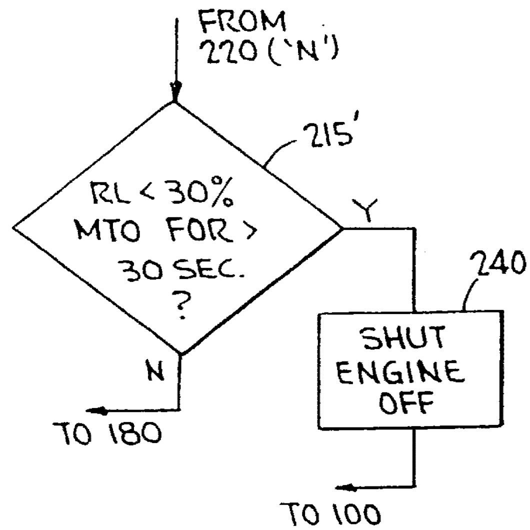
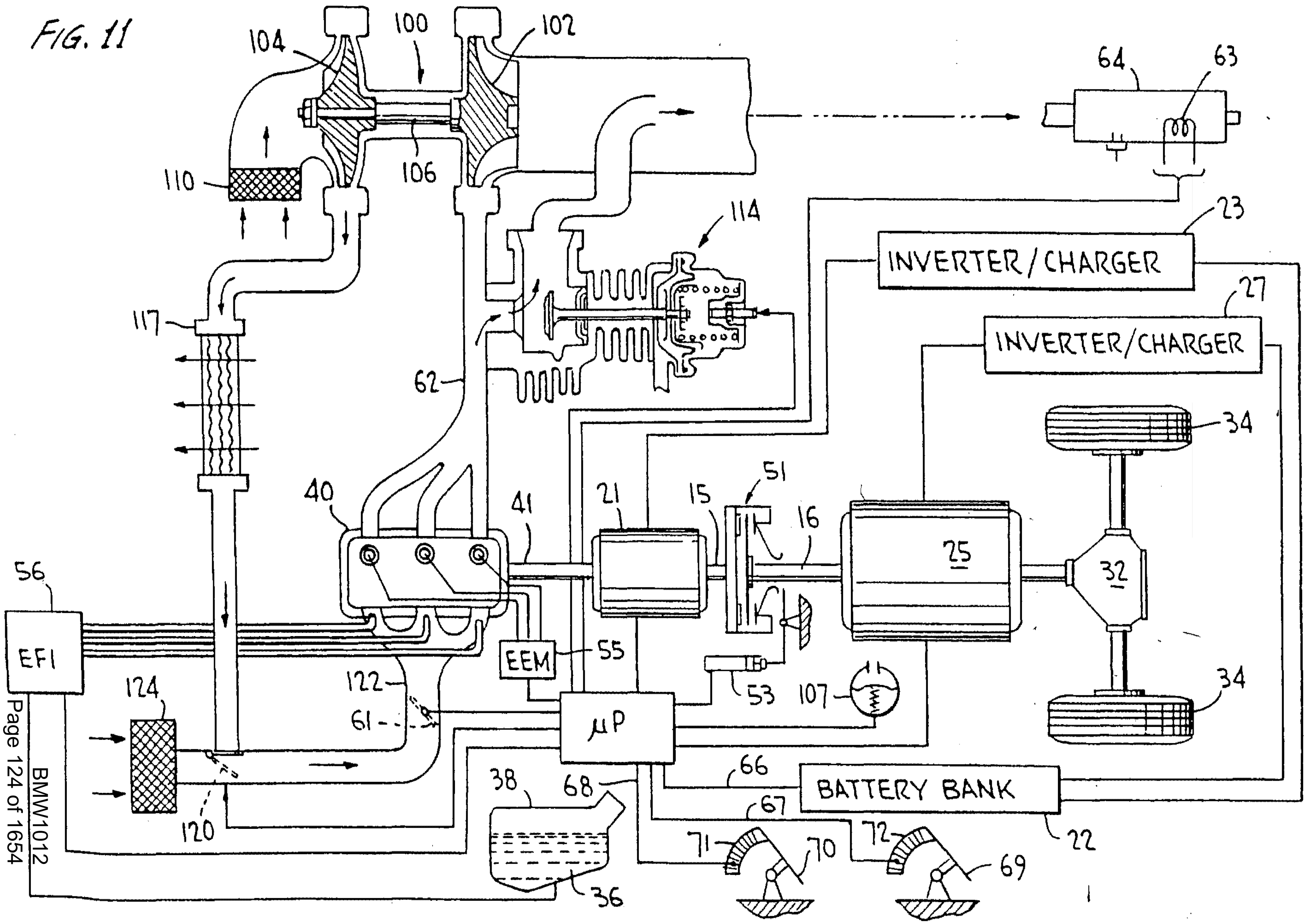


FIG. 11



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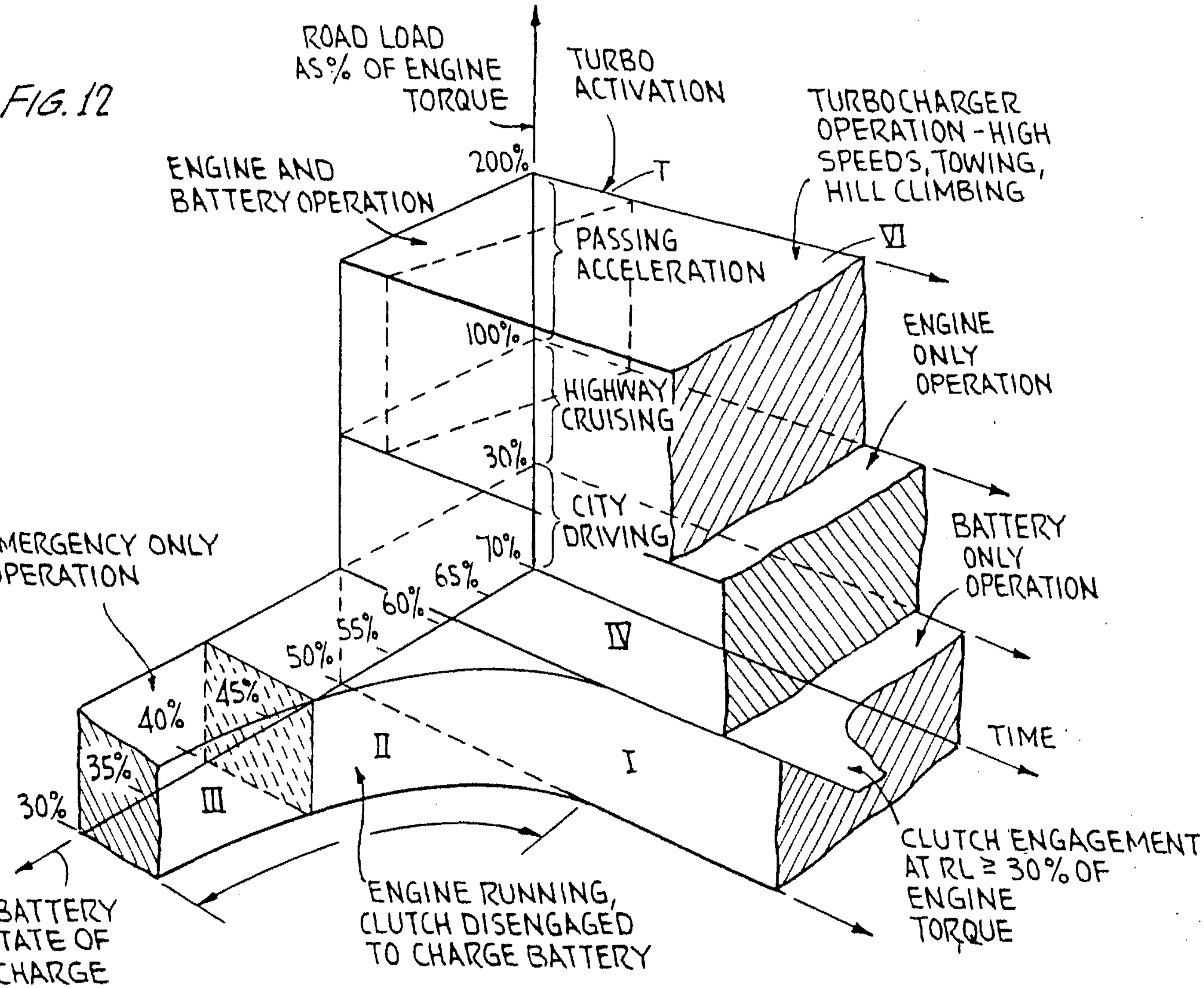
Page 124 of 1654

FIG. 12



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10382577.030703

FIG. 13(a)

ROAD LOAD AS% OF ENGINE'S MAX. TORQUE (NORMALLY ASPIRATED)

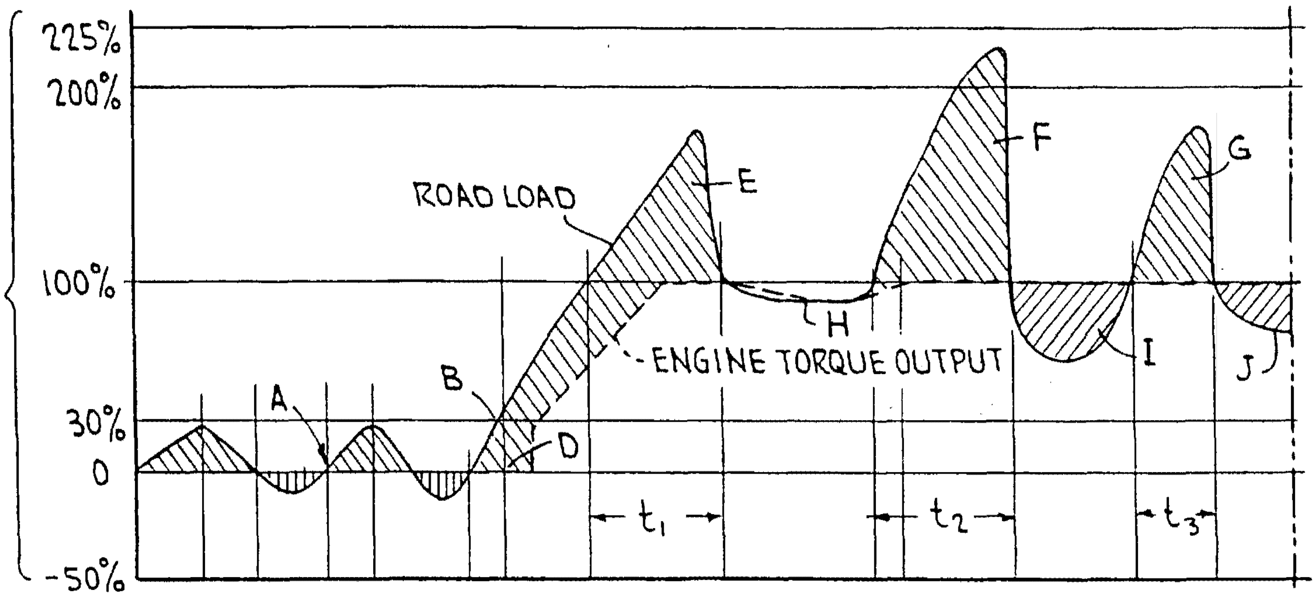


FIG. 13(b)

BATTERY STATE OF CHARGE

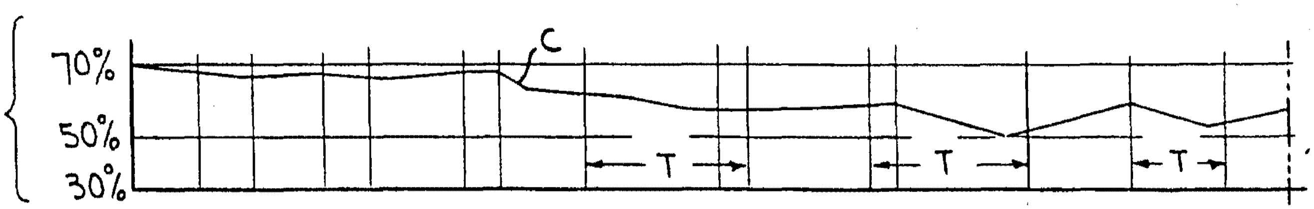
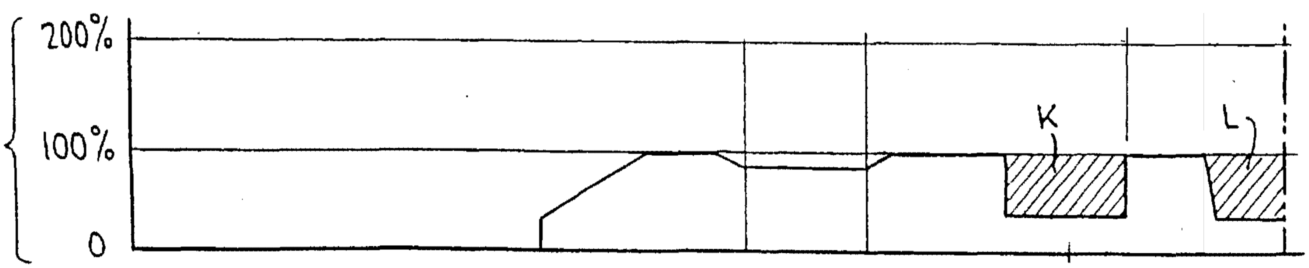


FIG. 13(c)

ENGINE + TURBO-CHARGER OPERATION



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10382577.030703

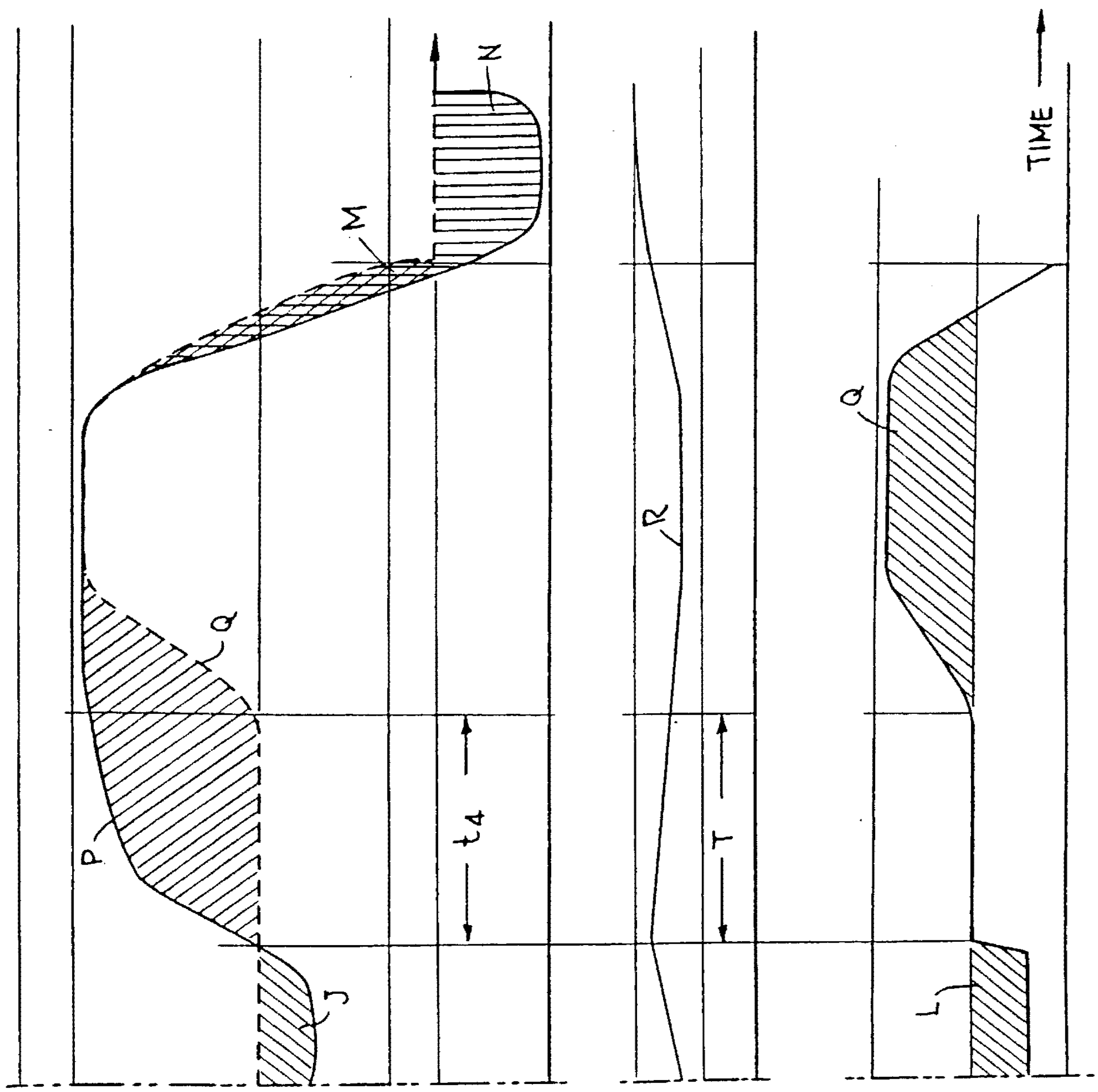
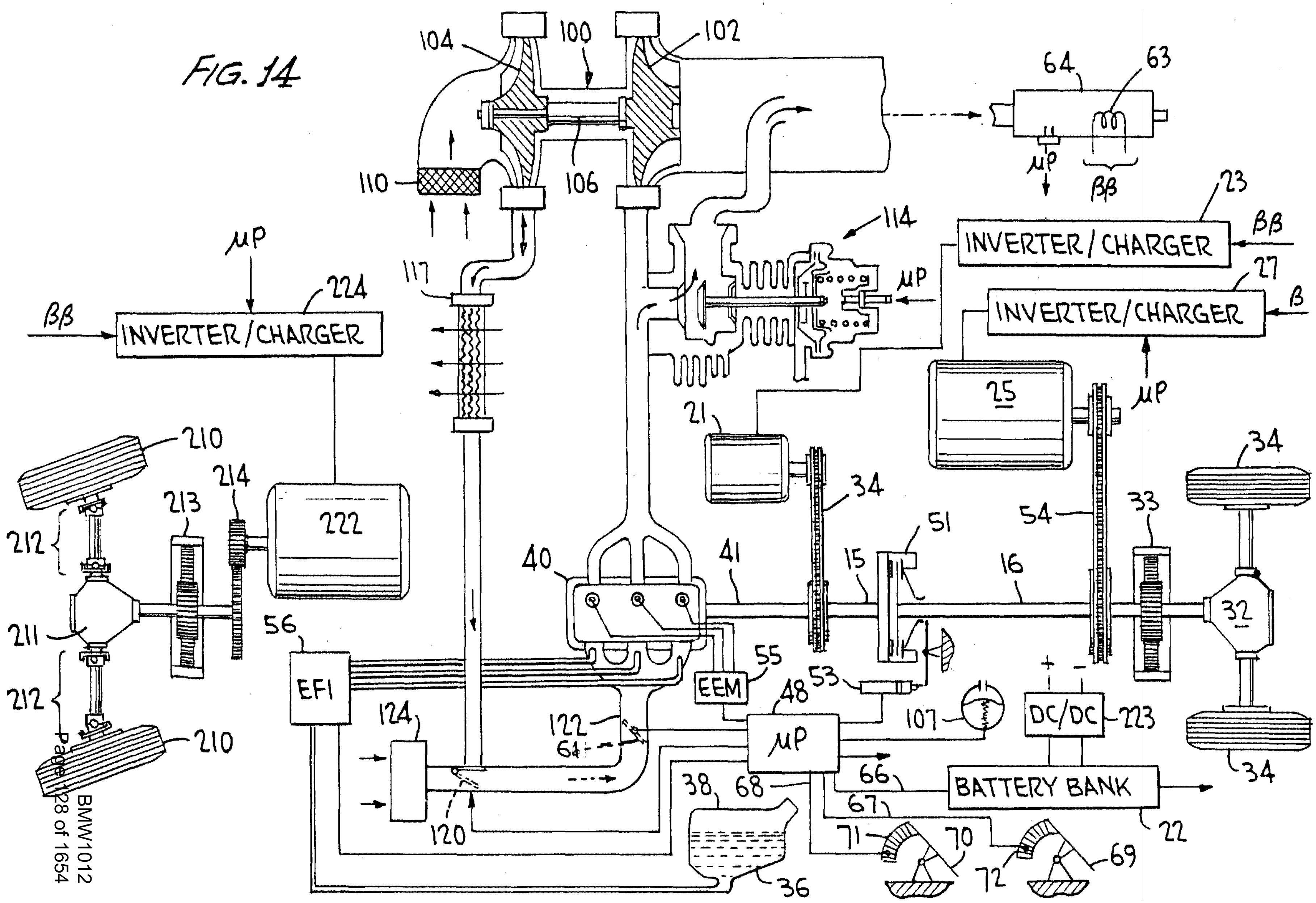


FIG. 13(a) (CONTINUED)

FIG. 13(b) (CONTINUED)

FIG. 13(c) (CONTINUED)

FIG. 14



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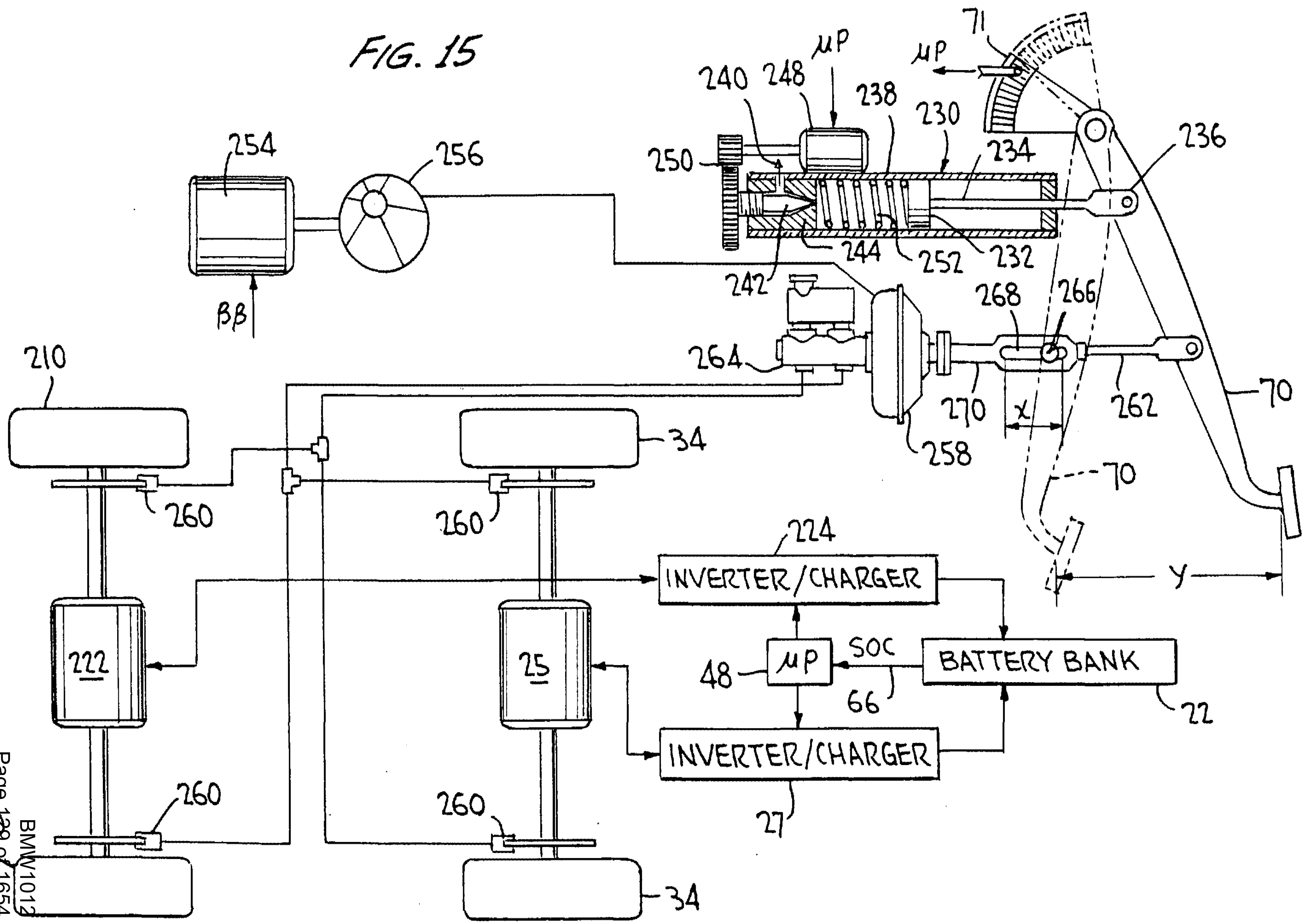
BMW1012

FIG. 15



10382577.030703

BMW1012
Page 129 of 1654

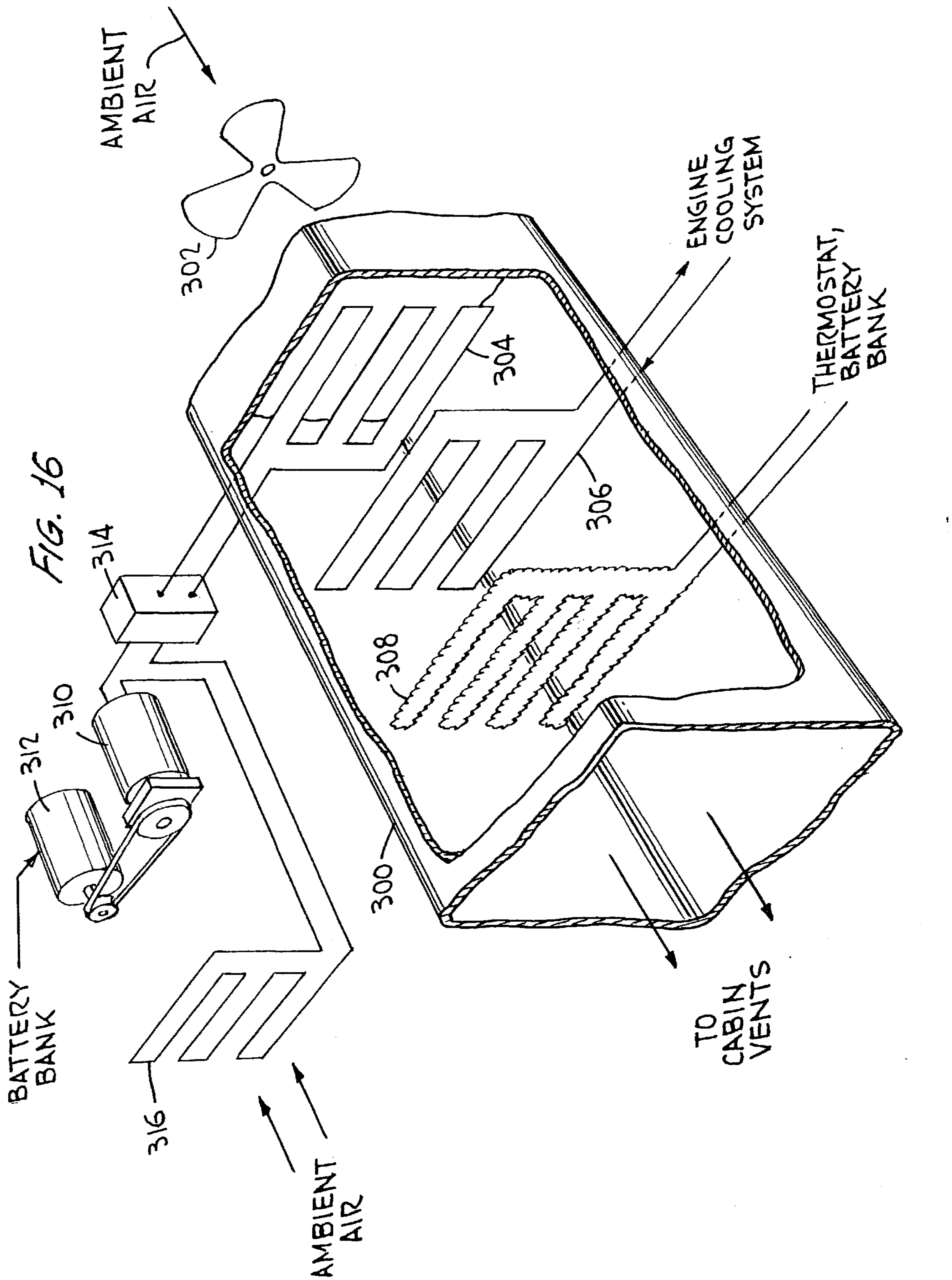

AMBIENT AIR
302
ENGINE COOLING SYSTEM
304
THERMOSTAT, BATTERY BANK
306
314
308
310
312
BATTERY BANK
300
TO CABIN VENTS
316
AMBIENT AIR

FIG. 16

PATENT APPLICATION SERIAL NO. 10/382577

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

03/12/2003 MAHMED1 00000009 10382577
01 FC:1001 750.00 OP

PTO-1556
(5/87)

*U.S. Government Printing Office: 2002 — 489-267/69033

0, 14, 16

PATENT APPLICATION FEE DETERMINATION RECORD
Effective January 1, 2003

Application or Docket Number

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)	SMALL ENTITY TYPE ☐ RATE	FEE	OR	OTHER THAN SMALL ENTITY RATE	FEE
TOTAL CLAIMS	7						
FOR	NUMBER FILED	NUMBER EXTRA	BASIC FEE	$375	OR	BASIC FEE	$750
TOTAL CHARGEABLE CLAIMS	7 minus 20=	* 0	X$ 9=		OR	X$18=	—
INDEPENDENT CLAIMS	3 minus 3 =	* 0	X42=		OR	X84=	—
MULTIPLE DEPENDENT CLAIM PRESENT ☐			+140=		OR	+280=	—
			TOTAL		OR	TOTAL	750

* If the difference in column 1 is less than zero, enter "0" in column 2

CLAIMS AS AMENDED - PART II

AMENDMENT A

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	* 7	Minus	** 20	=	X$ 9=		OR	X$18=	
Independent	* 3	Minus	*** 3	=	X42=		OR	X84=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM ☐					+140=		OR	+280=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	* 65	Minus	** 20	= 45	X$ 9=		OR	45 X$18=	810
Independent	* 8	Minus	*** 3	= 5	X42=		OR	5 X84=	420
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM ☐					+140=		OR	+280=	0
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	* 126	Minus	** 65	= 61	X$ 9=		OR	X$18=	1098.00
Independent	* 11	Minus	*** 8	= 3	X42=		OR	X84=	258.00
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM ☐					+140=		OR	+280=	/
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	1356.00

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

SERIAL NO.	FILING DATE
APPLICANT(S)	

CLAIMS ONLY

CLAIMS

	AS FILED		AFTER 1ST AMENDMENT		AFTER 2ND AMENDMENT	
	IND	DEP	IND	DEP	IND	DEP
1						
2						
3						
4						
5						
6						
7						
8						
9						
10	1		1			
11		|		|		
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13		|		|		
14	1		1			
15		1		1		
16	1		1			
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50						
TOTAL IND.	3		3			
TOTAL DEP.	4		4			
TOTAL CLAIMS	7		7			

	IND	DEP	IND	DEP	IND	DEP
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95						
96						
97						
98						
99						
100						
TOTAL IND.						
TOTAL DEP.						
TOTAL CLAIMS						

JC498 U.S. PTO
10/382577
03/07/03

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Patent Application of :	
Severinsky et al :	Examiner: N/A
Serial No.: 09/822,866 :	Group Art Unit: N/A
Filed: April 2, 2001 :	Att. Dkt.: PAICE201
For: Hybrid Vehicles	

Hon. Commissioner of Patents and Trademarks
Washington, DC 20231

INFORMATION DISCLOSURE STATEMENT

Dear Sir:

Listed on attached PTO-1449 forms are the issued patents and literature references considered to be most relevant to the patentability of the claims of this application. Copies of the patents listed on page 15 of the PTO-1449 are attached for the convenience of the Examiner, as is a copy of German patent 1,905,641, with uncertified translation. Copies of the other listed references were provided to the Examiner in connection with one or both of patent applications 09/264,817 and 09/392,743, so additional copies are not being submitted herewith.

Comments on the relevance of the new references which are material to the claims of this continuation-in-part *per se* are found in the application as filed, while the comments on these references found in the prosecution files of the two parent applications are also incorporated by reference herein.

Early and favorable action on the merits is earnestly solicited.

5/21/01
Dated

Respectfully submitted,

Michael de Angeli
Reg. No. 27,869
Suite 330
1901 Research Blvd.
Rockville, MD 20850
(301) 217-9585

#4 IDS

JC498 U.S. PTO 10/382577 03/07/03

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Patent Application of :	
Severinsky et al :	Examiner: N/A
Serial No.: N/A :	Group Art Unit: N/A
Filed: Herewith :	Att. Dkt.: PAICE201.DIV
For: HYBRID VEHICLES	

Hon. Commissioner of Patents and Trademarks
Washington, DC 20231

INFORMATION DISCLOSURE STATEMENT

Dear Sir:

This application is a divisional of Ser. No. 09/822,866. Incorporated herein by this reference are the original and three supplemental Information Disclosure Statements filed in the parent, copies of which are enclosed herewith. These, together with an Examiner's Notice of References Cited, a copy of which is also enclosed, collectively list all of the art deemed relevant to the claims of the application. Copies of the references were provided in the parent or in the applications from which it in turn claimed priority and thus are not being provided herewith. The Examiner is requested to indicate that all of the art thus listed has been considered.

Early and favorable action on the merits is earnestly solicited.

Respectfully submitted,

3/5/03
Dated

Michael de Angeli
Reg. No. 27,869
60 Intrepid Lane
Jamestown, RI 02835
401-423-3190

JC498 U.S. PTO 10/382577 03/07/03

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Patent Application of : Severinsky et al : Examiner: N/A
Serial No.: 09/822,866 : Group Art Unit: 3619
Filed: April 2, 2001 : Att. Dkt.: PAICE201
For: Hybrid Vehicles

Hon. Commissioner of Patents and Trademarks
Washington, DC 20231

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

Dear Sir:

Listed on attached PTO-1449 forms are a number of new patents discovered after filing of the above application. Copies of the listed patents are enclosed. The Examiner is respectfully requested to consider these patents with respect to the claims of this application.

The relevance of the newly-listed patents may be summarized as follows:

US patent 6,307,276 to Bader shows a hybrid drive system comprising an engine, a traction motor coupled to the countershaft of a multispeed transmission, and a controller which determines a running average value for the vehicle's "required driving torque". The engine output power is then varied as the average required power changes. The specification and claims give examples of 15 and 50 seconds as the time period over which the average is calculated, and it is made clear that the engine power is varied accordingly slowly. Where the engine power is insufficient to satisfy the instantaneous torque requirement, the battery is used to supply power to a traction motor; conversely, when the engine is producing more power than is needed, the excess is used to charge the batteries.

Insofar as Fig. 2 of Bader suggests that the "required driving torque" can be negative (for example, a negative torque can be considered to be applied to the motor/generator(s) by the kinetic energy of the vehicle, i.e., under deceleration or descents, for regenerative braking), this parameter might be misunderstood to be generally comparable to the "road load" parameter, which is analyzed by the present system to make its mode switching determinations, as illustrated by Figs. 6, 7, and 9. However, Bader's "drive power P_o can be calculated from the torque M_o and the rotational speed n_o". Col. 4, lines 21-22. Hence the "drive power" is not in fact suggestive of applicants' road load, since the engine output, i.e., "the torque M_o at the gear input" (col. 4, line 18), cannot be negative.

In any event, there is no suggestion in Bader of changing operational modes of a hybrid vehicle responsive to the value of the "drive power P_o", whether or not this is fairly equivalent to the road load. As made explicit by the relevant claims 1 - 9 of this application, according to an important aspect of the invention the vehicle is operated in different modes according to the road load (among other variables), and so that the engine is operated only under sufficient load to make its operation efficient. For example, when the road load is low, e.g., at low speeds, the engine is run only as necessary to charge the batteries. By comparison, in Bader it appears the engine is to be run constantly, and its speed varied slowly in accordance with the then average value of drive power. Bader thus fails to teach an important aspect of the invention.

Nii patent 6,131,680 is directed to a hybrid vehicle wherein an internal combustion engine and first and second motors are all connected to one of the sun gear, the planet carrier, or the ring gear of a planetary gearbox. Nii adjusts the relative gear ratios according to the torque required, which is apparently derived directly from the position of the accelerator pedal - see col. 22, lines 27 - 30. The Nii hybrid is operated in different modes depending on the state of charge of the battery, and the torque required. See Fig. 9. Under certain circumstances the planetary gearbox may be locked-up to avoid inefficiency. See, e.g., col. 9 line 1 - 7, and Fig. 10. However, the modes shown by Nii are not the same as those used by applicants, although there are some similarities. For example, as stated at col. 37, lines 1 - 6, and in Fig. 26, Nii sets his engine speed to idle when the vehicle is being operated in "motor driving" (i.e., electric car) mode; this is highly inefficient, since the engine produces no useful power at idle. By comparison, applicants shut the engine off completely except when it is being operated at high efficiency.

Mikami patent 5,839,533 is discussed in the application as filed, but was apparently not listed on the PTO-1449 forms filed previously; this patent is acordingly listed on the PTO-1449 filed herewith. A copy of this patent is also provided herewith.

Stemler patent 6,300,735 relates to control of planetary gearboxes as might be used in hybrid vehicles to control the torque supplied by the internal combustion engien and electric motors. Such a gearbox is not a feature *per se* of the invention described by the claims of the present application.

Yanase et al patent 6,318,487 shows a scheme for braking a hybrid vehicle when the battery is fully charged, so that regenerative braking would be inappropriate, and whereby friction braking is avoided; specifically, the engine is motored, so that energy is consumed by compressing air in the engine. This is not a feature of the invention defined by the claims of this application.

Deguchi et al patent 6,278,915 shows a control system for a hybrid comprising a continuously-variable transmission, wherein the transmission ratio is set responsive to target values for the driving torque, the generated electrical power, and the engine speed. Such a transmission is not found in the system defined by the claims of this application, and the control scheme described by this patent is irrelevant to the present claims.

Deguchi et al patent 6,190,282 relates to controlling the engine, motor, and clutch of a hybrid so as to avoid shock to the passengers upon clutch engagement. This is not relevant to the claims of the present application. A similar Deguchi et al patent, 5,993,351, was made of record previously.

Obayashi et al patent 6,232,733 appears to be a further development of the invention described in Egami patents 5,789,881 and 6,018,694, previously made of record. All three of these patents relate to operating the electric motors of a hybrid to reduce vibration when the engine is started. This is not a feature of the claims of this application.

Friedmann et al patent 5,788,004 shows a control system for hybrid vehicles wherein the overall system efficiency is continuously optimized by adjustment of the operational parameters of the various system components.

Kashiwase patent 6,146,302 shows a drive system for a hybrid wherein an engine and first motor are connected to the ring gear of a planetary gearbox, a second motor is connected to its planet carrier, a transmission is connected between the planet carrier and the road wheels of the vehicle, and clutches are provided to engage two of the sun gear, planet carrier and ring gear. No such planetary gearbox is required by the system of the invention.

Frank patent 6,116,363 is stated to be a continuation-in-part of patent 5,842,534, already made of record and disucssed in this application as filed. Both of these Frank patents disclose a braking system for a hybrid vehicle wherein the first 30% of pedal travel initiates regenerative braking, while the latter 70% of pedal travel initiates mechanical braking. See also Frank patent 6,054,844, already of record, which limits the braking torque to be provided by regenerative braking as a function of vehicle speed.

Maeda et al patent 6,074,321 shows a transaxle for a hybrid vehicle having a specific construction that is not particularly relevant to any of the claims of this application.

Moroto reissue patent Re. 36,678 is a reissue of patent 5,513,719, already of record.

Finally, Severinsky et al patent 6,338,391 has recently issued on application Serial No. 09/392,743, that is, is one of the parent applications.

An early and favorable action on the merits of the application is earnestly solicited.

Respectfully submitted,

2/8/02
Dated

Michael de Angeli
Reg. No. 27,869
60 Intrepid Lane
Jamestown, RI 02835
401-423-3190

INFORMATION DISCLOSURE CITATION IN AN APPLICATION	DOCKET NUMBER ANA201	APPLICATION NUMBER 09/822,866
	APPLICANT Severinsky et al	
	FILING DATE April 2, 2001	GROUP ART UNIT 3619

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	6307276	10/2001	Bader			
	6131680	10/2000	Nii et al			
	5839533	11/1998	Mikami et al			
	6300735	10/2001	Stemler			
	6318487	11/2001	Yanase et al			
	6278915	8/2001	Deguchi et al			
	6190282	2/2001	Deguchi et al			
	6232733	5/2001	Obayashi et al			
	5788004	8/1998	Friedmann et al			
	6146302	11/2000	Kashiwase			
	6116363	9/2000	Frank			
	6074321	6/2000	Maeda et al			

FOREIGN PATENT DOCUMENTS

	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

EXAMINER	DATE CONSIDERED

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP §609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.

INFORMATION DISCLOSURE CITATION IN AN APPLICATION	DOCKET NUMBER PAICE201	APPLICATION NUMBER 09/822,866
	APPLICANT Severinsky et al	
	FILING DATE 4/2/2001	GROUP ART UNIT 3619

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	Re36678	5/2000	Moroto et al			
	6338391	1/2002	Severinsky et al			

FOREIGN PATENT DOCUMENTS

	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

EXAMINER	DATE CONSIDERED

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP §609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Jc498 U.S. PTO
10/382577
03/07/03

In re the Patent Application of	:	
	:	
Severinsky et al	:	Examiner: David Dunn
	:	
Serial No.: 09/822,866	:	Group Art Unit: 3616
	:	
Filed: April 2, 2001	:	Att. Dkt.: PAICE201
	:	
For: Hybrid Vehicles		

Hon. Commissioner of Patents and Trademarks
Washington, DC 20231

SECOND SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

Dear Sir:

Listed on accompanying PTO-1449 form(s) are a number of additional patents that may be considered relevant by the Examiner to the claims of this application. These patents were identified in supplemental searching conducted after the filing of the application. Copies of the newly-cited documents are provided herewith. The examiner is respectfully requested to consider these documents in connection with the patentability of the claims of this application. Citation of these documents should not be construed to admit they are necessarily statutory prior art effective against this application.

The relevance of the documents thus cited is as follows:

Goehring et al patent 6,394,209 discloses a hybrid vehicle in which the internal combustion engine is stated to be operated only at or near full load. To thus operate the engine of the vehicle of the invention is an object of the invention, and a limitation to that effect is present in claim 1 of the application as amended. However, the Goehring reference refers only to a serial hybrid, and therefore does not teach a hybrid vehicle operated in different modes responsive to the road load, as also required by claim 1.

Tabata et al patent 6,081,042, to be candid, is extrememly difficult to comprehend. It does appear that Tabata shows a hybrid vehicle which can be driven by a motor/generator, an engine, or both, the operation mode to be chosen based on "the currently required output Pd" and the battery state of charge. See Fig. 6 and cols. 17 - 20. Insofar as understood, the value Pd is not the same thing as applicants' instantaneous torque requirement or road load RL. Pd is defined as "an output of the hybrid drive system 210 required to drive the vehicle against a running resistance. This currently required output Pd is calculated according to a predetermined data map or equation, on the basis of the operation amount θ_{AC} of the accelerator pedal, a rate of change of this value θ_{AC}, running speed of the vehicle (speed N_o of the output shaft 19) or the currently established operating position of the automatic transmission." Col. 18, lines 34 - 42.

Another Tabata patent, 5982,045, is directed to control of mode shifting in a hybrid such that transmission ratios or torque distribution ratio changes are prevented from occurring concurrently with mode shifting, the goal evidently being to smooth mode shifting. No disclosure of control of mode shifting responsive to a quantity comparable to applicants' road load is apparent.

Lawrie et al patent 5,993,350 discloses an "automated manual transmission clutch controller" which purports to combine the advantages of conventional automatic and manual transmissions. Mode shifting is evidently carried out responsive to any or several of various "information..includ[ing] vehicle speed, RPM or the like..[or] other vehicle condition signals". Col. 8, lines 37 - 49. The disclosures of three further Lawrie and Lawrie et al patents, 6,006,620, 6,019,698, and 5,797,257 appear to be essentially identical.

Nagano et al patent 6,059,064 shows a hybrid vehicle and appears to be directed to improvements in the braking system employed; these include using a prime mover (e.g., an electric motor) on one axle and another, e.g., an IC engine on another axle. Hill-holding is also addressed, as is anti-lock. The improvements in brake "feel" addressed in the present application do not appear to be discussed by Nagano.

The Examiner is respectfully urged to consider these patents in connection with examination of this application, and to indicate that he has done so in the file of the case.

Respectfully submitted,

9/1/02
Dated

Michael de Angeli
Reg. No. 27,869
60 Intrepid Lane
Jamestown, RI 02835
401-423-3190

Jc498 U.S. PTO 10/382577 03/07/03

INFORMATION DISCLOSURE CITATION IN AN APPLICATION

DOCKET NUMBER	PAICE201
APPLICATION NUMBER	09/822,866
APPLICANT	Severinsky et al
FILING DATE	4/2/2001
GROUP ART UNIT	3616

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLAS	FILING DATE
	6394209	5/2002	Goehring et al			
	6081042	6/2000	Tabata et al			
	5982045	11/1999	Tabata et al			
	5993350	11/1999	Lawrie et al			
	6019698	02/2000	Lawrie et al			
	5979257	11/1999	Lawrie			
	6006620	12/1999	Lawrie et al			
	6059064	05/2000	Nagano et al			

FOREIGN PATENT DOCUMENTS

	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

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10/382577 Jc498 U.S. PTO 03/07/03

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Patent Application of	
Severinsky et al	Examiner: David Dunn
Serial No.: 09/822,866	Group Art Unit: 3616
Filed: April 2, 2001	Att. Dkt.: PAICE201

For: Hybrid Vehicles

Hon. Commissioner of Patents and Trademarks
Washington, DC 20231

THIRD SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

Dear Sir:

Listed on accompanying PTO-1449 form(s) are five Japanese patent publications that may be considered relevant by the Examiner to the claims of this application. These publications were cited by the Japanese Patent Office in an office action dated September 2, 2002 in connection with prosecution of a Japanese patent application corresponding to the parent US applications, Ser. No. 09/264,817, now patent 6,209,672, and Ser. No. 09/392,743, now patent 6,338,391. A copy of a translation of this Japanese office action is attached, and copies of the newly-cited documents are provided herewith marked (1) - (5), in accordance with the Japanese Examiner's usage; copies of uncertified, partial translations of references 1 and 4 are also provided. The Examiner is respectfully requested to consider these documents in connection with the patentability of the claims of this application.

The relevance of the documents thus cited is as follows:

Japanese utility model registration 63-82283, published as "laid-open No. 2-7702", which was referred to in the Japanese office action as Reference 1 (a partial noncertified translation also being supplied), shows a hybrid vehicle comprising an internal combustion engine, an electric "traction" motor for providing additional torque to the wheels of the vehicle, and a second electric motor that can be operated to also supply additional torque to the wheels or operate as a generator to charge the battery during braking or hill descent. Typically, such hybrids are operated in different modes depending on whether the vehicle is sitting at a traffic light, accelerating, cruising on the highway, and so on. The same is true of the vehicle of the present invention.

In order that the hybrid vehicle can be made commercially acceptable, it is important that the "mode switching" decisions be made by a microprocessor or the like instead of the driver. Various references teach making this decision in different ways. Reference 1 does not address this question. Commonly, as in Japanese published application 06-080048, cited by the Japanese patent office as Reference 3 (which corresponds to US patent 5,697,466, already of record), the decision is made based on the degree to which the driver has depressed the accelerator pedal. By comparison, according to the present invention, as discussed extensively in the earlier prosecution of this and the parent applications, the mode switching decision is made based on the vehicle's instantaneous torque requirement or "road load" RL.

As previously, it is important to emphasize exactly what the terms "road load" RL means as used in the present claims, to distinguish over the art. "Road load" is a somewhat subtle concept, since during many phases of vehicle operation the road load quantitatively resembles, for example, the operator's foot pressure on the accelerator pedal, or simply the engine output power. However, the road load as used herein is neither of these. "Road load" as used herein is simply that amount of torque that must be supplied to the vehicle wheels in order to carry out the operator's current command.

Note that "road load" as thus defined can be positive, as during highway cruising, "highly" positive, as during acceleration or hill-climbing, negative, as during hill descent, and "heavily" negative, as during braking. Figs. 7 and 13 show this clearly, and it is explained in the specification of the application as well. The flowchart of Fig. 9 illustrates precisely how the mode switching decisions are made responsive to road load (with an additional variation possible based on the battery state of charge.)

The fact that according to the present invention the mode switching decisions are made responsive to road load, a quantity which can be positive or negative, distinguishes this invention from all prior art of which we are aware. It will be appreciated that making all of the mode switching decisions based essentially on monitoring this single variable (with subsidiary attention to the battery state of charge, as below) greatly simplifies the decision-making process, as compared, for example, to a system in which the operator's foot pressure on the throttle and brake pedals must be continually monitored.

The new references made of record hereby does not show this invention. Reference 1 does show a hybrid vehicle having components arranged comparably to those recited in claim 1, but there is no mention of the manner in which the mode-switching determinations are made. The Japanese Examiner made the comment that "the vehicle is operated in a plurality of operating modes in response to states of operation such as a load of the vehicle and the like", apparently based on the description in reference 1 of vehicle operation in different modes depending on the driving conditions. However, we find nothing in reference 1 that suggests mode switching based on road load as defined above.

None of the other references cited by the Japanese Examiner and made of record hereby (nor any of those previously made of record, of course) supply this deficiency of Reference 1. The Japanese Examiner cited published application 06-144020 (referred to as reference 2) against claim 1, for showing that the first motor also starts the engine, and cited reference 3 against claim 2, for showing that the state of charge of the battery can be considered in mode switching.

More specifically, in his remarks concerning claim 4, the Japanese Examiner asserted that reference 3 describes mode switching responsive to "road load (a press down amount of an accelerator pedal)(see [Fig. 3]) or the like". As above, "road load" as used in this application is something quite different than the degree to which the accelerator pedal is pressed down; for example, the latter cannot be negative, and road load as used herein can decidedly be negative. We have reviewed US patent 5,697,466 (which corresponds to Reference 3) in detail and it shows nothing comparable to mode switching based on road load as used in this application.

Claims 8 and 9 of this application are directed to the "turbocharger-on-demand" concept, which was an important aspect of the invention in parent application Ser. No. 09/392,743, now patent 6,338,391. Claims 15 - 20 of the Japanese application recite this concept, i.e., that of a turbocharger that is operated only when the road load exceeds a predetermined value for more than a minimum period of time. That is, the turbocharger is not operated continually, as in the usual prior art vehicles, but is only operated when needed, i.e., when road load exceeds the engine's normally aspirated torque capabilities (i.e., RL > MTO); moreover, the turbocharger is operated only when RL > MTO for more than some predetermined period of time T. This is an extremely powerful concept, and one which is only applicable to a hybrid vehicle. Providing the turbocharger on demand allows the engine to provide additional torque when needed, but to operate as a smaller, more efficient engine at other times.

More specifically, in a conventional turbocharged vehicle the turbocharger is spinning constantly, so that a turbine driven by the exhaust flow drives a compressor forcing air into the engine. The main problem with turbochargers as thus used is poor throttle response or "turbo lag", that is, a substantial time delay between the driver calling for more power by pressing on the accelerator pedal and the engine's response. While some progress has been made, mostly by use of smaller turbochargers, this problem is inevitable to some degree, since it takes some time for the turbocharger to "spool up" to its full speed.

The Japanese Examiner cited Japanese published application 55-069724 as reference 4; as noted, a partial noncertified translation of this reference is also provided. Reference 4 shows a turbocharger which is operated on demand, in response to a "load detecting means"; this is the first reference we have seen showing this concept. There is no suggestion of use of this turbocharger in a hybrid vehicle. A conventional (i.e., non-hybrid) vehicle fitted with a turbocharger of this type would have extremely poor throttle response if used to provide additional power for passing (i.e., overtaking) or hillclimbing; the "turbo lag" inherent in operation of a turbocharger starting from zero rpm would be on the order of tens of seconds, which would be totally unacceptable for a consumer vehicle. Possibly such a system would be useful in heavy truck operation or the like, where the load will vary significantly depending on whether the truck was loaded or not; in that case, the operator could be the "load detecting means", i.e., could throw a switch when he knew high power would be needed for an extended period of time.

By comparison, a turbocharger can be employed "on demand" in a hybrid vehicle according to the invention without poor throttle response caused by turbo lag, and without requiring any intervention by the operator. This is simply because the traction motor can be used to supply the vehicle's torque requirements in excess of MTO. Thus, when RL > MTO, the traction motor provides the additional torque required. If RL > MTO for longer than T, the turbocharger is activated and begins to spin. When it is up to operating speed, the traction motor can be deactivated. All this is shown clearly by Fig. 13, and would not be possible simply given the turbocharger-on-demand of Reference 4 in a conventional, non-hybrid vehicle. By comparison, in the present vehicle, at no point are the vehicle's torque requirements not met; therefore there is no "turbo lag".

It is apparent that this advantage can only be achieved by use of a turbocharger on demand in a hybrid vehicle. No combination of references can fairly be said to make this obvious. Specifically, the Japanese Examiner's comment as to claim 17, "it is a usual matter to control a turbocharger in response to a road load or the like" is not correct, for several reasons: no reference shows taking any kind of control action in response to road load as claimed; no reference suggests combining the turbocharger on demand of Reference 4 with a hybrid vehicle; and certainly no reference suggests the complete elimination of the turbo lag problem thus achieved, while at the same time the vehicle's useful load range is greatly broadened.

Finally, Japanese published application 04-274926 (Reference 5) was cited for a showing of preheating a catalyst before starting the associated engine, which is not a feature of the present claims.

The Examiner is respectfully urged to consider these patents in connection with examination of this application, and to indicate that he has done so in the file of the case.

Respectfully submitted,

Nov. 28, 2002
Dated

Michael de Angeli
Reg. No. 27,869
60 Intrepid Lane
Jamestown, RI 02835
401-423-3190

INFORMATION DISCLOSURE CITATION IN AN APPLICATION	DOCKET NUMBER PAICE201	APPLICATION NUMBER 09/822,866
	APPLICANT Severinsky et al	
	FILING DATE 4/2/01	GROUP ART UNIT 3616

J498 U.S. PTO 10/382577 03/07/03

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE

FOREIGN PATENT DOCUMENTS

	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO
	63 8 2 2 8 3	6/1988	Japan				
	06 1 4 4 0 2 0	11/1992	Japan				
	06 0 8 0 0 4 8	11/1992	Japan				
	55 0 6 9 7 2 4	11/1978	Japan				
	04 2 7 4 9 2 6	2/1991	Japan				

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

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JC498 U.S. PTO 10/382577 03/07/03

INFORMATION DISCLOSURE CITATION IN AN APPLICATION	DOCKET NUMBER PAICE201	APPLICATION NUMBER 09/822,866
	APPLICANT Severinsky et al	
	FILING DATE 04/02/01	GROUP ART UNIT N/A

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	5343970	9/94	Severinsky	180	65.2	
	5492192	2/96	Brooks et al			
	3566717	3/71	Berman et al			
	3732751	5/93	Berman et al			
	4165795	8/49	Lynch et al			
	5117931	6/92	Nishida			
	3923115	12/75	Helling			
	4588040	5/86	Albright, Jr., et al			
	5318142	6/94	Bates et al			
	5120282	6/92	Fjällström			
	4405029	9/83	Hunt			
	4470476	9/84	Hunt			
	4305254	12/81	Kawakatsu			

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	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO
	1905641	6/76	Germany			X	

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Simanaitis, "Electric Vehicles", *Road & Track*, May 1992, pp. 126-136

Reynolds, "AC Propulsion CRX", *Road & Track*, Oct. 1992, pp. 126-129

Kalberlah, "Electric Hybrid Drive Systems...", SAE Paper No. 910247, 1991

Bullock, "The Technological Constraints of Mass,Volume, Dynamic Power Range and Energy Capacity..." SAE Paper No. 891659 1989

Electric and Hybrid Vehicle Technology, vol. SP-915, SAE, Feb. 1992

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	APPLICANT: Severinsky et al	
	FILING DATE: 04/02/01	GROUP ART UNIT: N/A

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EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	4407132	10/83	Kawakatsu			
	4335429	6/82	Kawakatsu			
	4180138	12/19	Shea			
	4351405	9/82	Fields et al			
	4438342	3/84	Kenyon			
	4593779	6/86	Krohling			
	4923025	5/90	Ellers			
	3791473	2/74	Rosen			
	4269280	5/81	Rosen			
	4400997	8/83	Fiala			
	4697660	10/87	Wu et al			
	3970163	7/76	Kinoshita			
	4095664	6/78	Bray			

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	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

Wouk, "Hybrids: Then and Now", IEEE Spectrum, Vol. 32, 7, July 1995

Bates, "Getting a Ford HEV on...", IEEE Spectrum, Vol. 32, 7, July 1995

King et al, "Transit Bus takes...", IEEE Spectrum, Vol. 32, 7, July 1995

Yamaguchi, "Toyota readies gasoline/electric hybrid system", Automotive Engineering, July 1997, pp. 55-58

Wilson, "Not Electric, Not Gasoline..." Autoweek, June 2, 1997, pp. 17-18

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APPLICANT	Severinsky et al
FILING DATE	04/02/01
GROUP ART UNIT	N/A

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	4148192	4/79	Cummings			
	4306156	12/81	Monaco et al			
	4313080	11/82	Park			
	4354144	10/82	McCarthy			
	4533011	8/85	Heidemeyer			
	4951769	8/90	Kawamura			
	5053632	10/91	Suzuki et al			
	3525874	8/70	Toy			
	3650345	8/72	Yardney			
	3837419	9/74	Nakamura			
	3874472	4/75	Deane			
	4042056	8/77	Horwinski			
	4562894	1/86	Yang			

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	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

Bulgin, "The Future Works, Quietly", Autoweek, Feb. 23, 1998 pp. 12-13

"Toyota Electric and Hybrid Vehicles", a Toyota brochure

Nagasaka et al, "Development of the Hybrid/Battery ECU...", SAE paper 981122, 1998, pp. 19-27

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	APPLICANT: Severinsky et al	
	FILING DATE: 04/02/01	GROUP ART UNIT: N/A

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	4611466	9/86	Keedy			
	4815334	8/89	Lexen			
	3623568	11/71	Mori			
	3454122	8/69	Grady, Jr.			
	3211249	10/65	Papst			
	2666492	1/54	Nims et al			
	3502165	3/70	Matsukata			
	1824014	9/31	Froelich			
	3888325	10/75	Reinbeck			
	4578955	4/86	Medina			
	4765656	8/88	Weaver			
	4439989	4/84	Yamakawa			
	5301764	4/94	Gardner			

FOREIGN PATENT DOCUMENTS

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U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	5346031	9/94	Gardner			
	5667029	9/97	Urban et al			
	5704440	1/98	Urban et al			
	5495906	3/96	Furutani			
	5842534	12/98	Frank	180	65.2	
	5823280	10/98	Lateur	180	65.2	
	5826671	10/98	Nakae et al			
	5846155	12/98	Taniguchi et al			
	5845731	12/98	Buglione et al	180	65.2	
	5586613	12/96	Ehsani			
	5635805	6/97	Ibaraki et al			
	5249637	10/93	Heidl et al			
	5555858	9/96	Schmidt			

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U.S. PATENT DOCUMENTS

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	5558595	10/96	Schmidt et al			
	5980077	6/99	Moore			
	5722911	3/98	Ibaraki et al			
	5789882	8/98	Ibaraki et al			
	5550445	8/96	Nii			
	5650931	7/97	Nii			
	5865263	2/99	Yamaguchi et al			
	5788006	8/98	Yamaguchi et al			
	5791427	8/98	Yamaguchi et al			
	5799744	9/98	Yamaguchi et al			
	5806617	9/98	Yamaguchi et al			
	5899286	5/99	Yamaguchi et al			
	5433282	7/95	Moroto et al			

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	5778326	7/98	Moroto et al			
	5775449	7/98	Moroto et al			
	5697466	12/97	Moroto et al	180	65.2	
	5608308	3/97	Kiuchi et al			
	5614809	3/97	Kiuchi et al			
	5621304	4/97	Kiuchi et al			
	5893895	4/99	Ibaraki			
	5656921	8/97	Farrall			
	5773904	6/98	Schiebold et al			
	5515937	5/96	Adler et al			
	5650713	7/97	Takeuchi et al			
	5632352	5/97	Jenneret			
	5492189	2/96	Kreigler et al			

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	4354144	10/82	McCarthy			
	4697660	10/87	Wu et al			
	5831341	11/98	Selfors et al			
	5495907	3/96	Data			
	5672920	9/97	Donegan et al			
	5826671	10/98	Nakae et al			
	5757151	5/98	Donegan et al			
	6018694	1/00	Egami et al	701	102	
	5993351	11/99	Deguchi et al	477	5	
	5568023	10/96	Grayer et al			
	5890555	4/99	Miller			
	5172784	12/92	Varela, Jr.			
	4442285	4/84	Stewart et al			

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	APPLICANT: Severinsky et al	
	FILING DATE: 04/02/01	GROUP ART UNIT: N/A

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	4562894	1/86	Yang			
	4495451	1/85	Barnard			
	4583505	4/86	Frank et al			
	4597463	7/86	Barnard			
	5789881	8/98	Egami et al			
	5786640	7/98	Sakai et al			
	5176213	1/93	Kawai et al			
	5839530	11/98	Dietzel			
	5898282	4/99	Drozdz et al			
	5327987	7/94	Abdelmalek			
	5415245	5/95	Hammond			
	5705859	1/98	Karg et al			
	5713425	2/98	Buschhaus et al			

FOREIGN PATENT DOCUMENTS

	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

EXAMINER	DATE CONSIDERED

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP §609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.

INFORMATION DISCLOSURE CITATION IN AN APPLICATION	DOCKET NUMBER PAICE201	APPLICATION NUMBER 09/822,866
	APPLICANT Severinsky et al	
	FILING DATE 04/02/01	GROUP ART UNIT N/A

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	5820172	10/98	Brigham et al			
	5713426	2/98	Okamura			
	5713814	2/98	Hara et al			
	5823281	10/98	Yamaguchi et al			
	5427196	6/95	Yamaguchi et al			
	5839533	11/98	Mikami et al			
	5725064	3/98	Ibaraki et al			
	5755303	5/98	Yamamoto et al			
	5778997	7/98	Setaka et al			
	5785136	7/98	Falkenmayer et al			
	5785137	7/98	Reuyl			
	5785138	7/98	Yoshida			
	5566774	10/96	Yoshida			

FOREIGN PATENT DOCUMENTS

	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

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INFORMATION DISCLOSURE CITATION IN AN APPLICATION	DOCKET NUMBER PAICE201	APPLICATION NUMBER 09/822,866
	APPLICANT Severinsky et al	
	FILING DATE 04/02/01	GROUP ART UNIT N/A

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	5492190	2/96	Yoshida			
	5441122	8/95	Yoshida			
	5558175	9/96	Sherman			
	5558173	9/96	Sherman			
	5788597	8/98	Boll et al			
	5788003	8/98	Spiers			
	5791426	8/98	Yamada			
	5323868	6/94	Kawashima			
	5545928	8/96	Kotani			
	5291960	3/94	Brandenburg et al			
	5255733	10/93	King			
	5664635	9/97	Koga et al			
	5463294	10/95	Valdivia			

FOREIGN PATENT DOCUMENTS

	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

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INFORMATION DISCLOSURE CITATION IN AN APPLICATION	DOCKET NUMBER PAICE201	APPLICATION NUMBER 09/822,866
	APPLICANT Severinsky et al	
	FILING DATE 04/02/01	GROUP ART UNIT N/A

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	5562565	10/96	Moroto et al			
	5513719	6/96	Moroto et al			
	5513718	5/96	Suzuki et al			
	5833022	11/98	Welke			
	5841201	11/98	Tabata et al			
	5887670	3/99	Tabata et al			
	5862497	1/99	Yano et al			
	5637987	6/94	Fattic et al			
	5643119	4/94	Yamaguchi et al			
	5644200	4/94	Yang			
	5489001	2/96	Yang			
	5653302	8/94	Edye et al			
	5350031	4/94	Sugiyama et al			

FOREIGN PATENT DOCUMENTS

	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

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	APPLICANT Severinsky et al	
	FILING DATE 04/02/01	GROUP ART UNIT N/A

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	5345761	4/94	King			
	5337848	8/94	Bader			
	5327992	4/94	Boll			
	5589743	12/96	King			
	5345154	9/94	King			
	4862009	8/89	King			
	5372213	12/94	Hasebe et al			
	5495912	5/96	Gray, Jr., et al			
	5588498	12/96	Kitada			
	5492189	2/96	Kriegler			
	5193634	3/93	Masut			
	5125469	6/92	Scott			
	4511012	4/85	Rauneker			

FOREIGN PATENT DOCUMENTS

	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

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	APPLICANT Severinsky et al	
	FILING DATE 04/02/01	GROUP ART UNIT N/A

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	4631456	12/86	Drescher			
	4680986	7/87	Elsner			
	4953646	9/90	Kim			
	5927417	7/99	Brunner	180	65.6	
	6048289	4/00	Hattori	477	15	
	6026921	2/00	Aoyama	180	65.2	
	6053842	4/00	Kitada	477	5	
	5767637	6/98	Lansberry			
	5934395	8/99	Koide et al			
	5969624	10/99	Sakai et al			
	5986376	11/99	Werson			
	6018198	1/00	Tsuzuki et al			
	6054844	4/00	Frank			

FOREIGN PATENT DOCUMENTS

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	APPLICANT Severinsky et al	
	FILING DATE 04/02/01	GROUP ART UNIT N/A

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	6059059	9/94	Schmidt-Brucken			
	6098733	8/00	Ibaraki et al			
	6161384	12/00	Reinbold et al			
	5996347	12/99	Nagae et al			
	6109025	8/00	Murata et al			
	6131538	10/00	Kanai			
	4774811	10/88	Kawamura			
	5327992	7/94	Boll			
	5249637	10/93	Heidl et al			
	5495906	3/96	Furutani			
	6018694	1/00	Egami et al			
	6209672	4/01	Severinsky			

FOREIGN PATENT DOCUMENTS

	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

EXAMINER	DATE CONSIDERED

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP §609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.

Notice of References Cited	Application/Control No. 09/822,866	Applicant(s)/Patent Under Reexamination SEVERINSKY ET AL.	
	Examiner David Dunn	Art Unit 3616	Page 1 of 1

JC498 U.S. PTO 10/382577 03/07/03

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
	A	US-6,315,068	11-2001	Hoshiya et al.	180/65.2
	B	US-6,330,498	12-2001	Tamagawa et al.	701/22
	C	US-6,359,404	03-2002	Sugiyama et al.	318/432
	D	US-6470983	10-2002	Amano et al.	180/65.2
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
Washington, DC 20231
www.uspto.gov

APPLICATION NUMBER	FILING/RECEIPT DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NUMBER
10/382,577	03/07/2003	Alex J. Severinsky	PAICE201.DIV

CONFIRMATION NO. 9389

Michael de Angeli
60 Intrepid Lane
Jamestown, RI 02835

FORMALITIES LETTER

OC000000009913491

Date Mailed: 04/25/2003

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The oath or declaration is missing.
  A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
- To avoid abandonment, a late filing fee or oath or declaration surcharge as set forth in 37 CFR 1.16(e) of $130 for a non-small entity, must be submitted with the missing items identified in this letter.

SUMMARY OF FEES DUE:

Total additional fee(s) required for this application is **$130** for a Large Entity

- **$130** Late oath or declaration Surcharge.

A copy of this notice MUST be returned with the reply.

Y.G.

Customer Service Center
Initial Patent Examination Division (703) 308-1202
PART 3 - OFFICE COPY

OIPE JC139
JUN 17 2003
PATENT & TRADEMARK OFFICE

#3

MP

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Patent Application of	:	
Severinsky et al	:	Examiner: N/A
Serial No.: 10/382,577	:	Group Art Unit: 3616
Filed: March 7, 2003	:	Att. Dkt.: PAICE201.DIV

For: HYBRID VEHICLES

Hon. Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

RESPONSE TO NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

Dear Sir:

In response to the Notice to File Missing Parts of Nonprovisional Application mailed in this application on April 25, 2003 (copy enclosed), indicating that the oath or declaration is missing, and requesting a surcharge, please note that this application is a divisional of Ser. No. 09/822,866, now Patent 6,544,088. As such, under 37 CFR § 1.63 (d) no new oath or declaration referring to this application per se is required; a copy of the declaration filed in the parent is enclosed, as is a check for the $130 surcharge.

Examination of the application on the merits is respectfully requested.

Respectfully submitted,

6/12/03
Dated

Michael de Angeli
Reg. No. 27,869
60 Intrepid Lane
Jamestown, RI 02835
401-423-3190

UNITED STATES PATENT AND TRADEMARK OFFICE

OIPE JC139
JUN 17 2003
PATENT & TRADEMARK OFFICE

Commissioner for Patents
Washington, DC 20231
www.uspto.gov

APPLICATION NUMBER	FILING/RECEIPT DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NUMBER
10/382,577	03/07/2003	Alex J. Severinsky	PAICE201.DIV

CONFIRMATION NO. 9389

FORMALITIES LETTER

OC000000009913491

Michael de Angeli
60 Intrepid Lane
Jamestown, RI 02835

Date Mailed: 04/25/2003

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The oath or declaration is missing.
  A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
- To avoid abandonment, a late filing fee or oath or declaration surcharge as set forth in 37 CFR 1.16(e) of $130 for a non-small entity, must be submitted with the missing items identified in this letter.

SUMMARY OF FEES DUE:

Total additional fee(s) required for this application is **$130** for a Large Entity

- **$130** Late oath or declaration Surcharge.

A copy of this notice MUST be returned with the reply.

Y.G.

Customer Service Center
Initial Patent Examination Division (703) 308-1202

PART 2 - COPY TO BE RETURNED WITH RESPONSE

06/18/2003 EHABDELR1 00000050 10382577
01 FC:1051 130.00 OP

OIPE JC139
JUN 17 2003
PATENT & TRADEMARK OFFICE

#3

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:
Hybrid Vehicles,
the specification of which
___ is attached hereto
_X_ was filed on April 2, 2001 now assigned Application Serial No. 09/822,866 and was amended on ______________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified application, including the specification and claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119, of the international application for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed: NONE

Prior International Application(s) — Priority Claimed

(Number)	(Country)	(Day/Month/Yr.Filed)	Yes	No

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

09/264,817	3/9/99	Issued (6,209,672)
60/100,095	9/14/98	Converted
09/392,743	9/9/99	Pending
60/122,296	3/1/99	Converted
(Application SN)	(Filing Date)	Status (patented, pending, abandoned, converted)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

Michael de Angeli, Reg. No. 27,869

Send correspondence to: Michael de Angeli
1901 Research Blvd.
Suite 330
Rockville, MD 20850

Direct Telephone Calls to: (301) 217-9585

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under § 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first joint inventor: Alex J. Severinsky

Inventor's Signature Alex J. Severinsky Date 5/18/2001

Residence: Washington, DC Citizenship: US

Post Office Address: 4707 Foxhall Crescent, Washington, DC 20007

Full name of second joint inventor, if any: Theodore Louckes

Inventor's Signature Theodore Louckes Date 5/25/2001

Residence: Holly, MI Citizenship: US

Post Office Address: 10398 Appomatox, Holly, MI, 48442

OIPE JC141 AUG 1 8 2003 PATENT & TRADEMARK OFFICE

3616

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Patent Application of	
Severinsky et al	Examiner: N/A
Serial No.: 10/382,577	Group Art Unit: 3616
Filed: March 7, 2003	Att. Dkt.: PAICE201.DIV
For: Hybrid Vehicles	

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AUG 2 1 2003
GROUP 3600

Hon. Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Transmitted herewith is an amendment in the above - identified application.

X A check for the additional claim fee of $1230 as calculated below is enclosed for this amendment.

X The Commissioner is hereby authorized to charge any underpayment (or to credit overpayment) to our Deposit Account No. 04-0401. A duplicate copy of this sheet is attached.

LARGE ENTITY

	TOTAL CLAIMS	CLAIMS PREVIOUSLY PAID FOR		PRESENT EXTRA		ADDITIONAL RATE		
TOTAL	65	20	=	45	Extra	x	18	$ 810.00
INDEP.	8	3	=	5	Extra	x	84	$420.00
							TOTAL:	$1230.00

Aug. 11, 2003
Dated

Respectfully submitted,

Michael de Angeli
Reg. No. 27,869
60 Intrepid Lane
Jamestown, RI 02835
401-423-3190

OIPE JC141
AUG 18 2003
PATENT & TRADEMARK OFFICE

Drahm 8/29/03
6/B
Jue A

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Patent Application of	:	
	:	
Severinsky et al	:	Examiner: N/A
	:	
Serial No.: 10/382,577	:	Group Art Unit: 3616
	:	
Filed: March 7, 2003	:	Att. Dkt.: PAICE201.DIV
	:	
For: Hybrid Vehicles		

Hon. Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

RECEIVED
AUG 2 1 2003
GROUP 3600

PRELIMINARY AMENDMENT

Sir:

Prior to examination, kindly amend the above-identified application as follows:

08/19/2003 SZEWDIE1 00000112 10382577

01 FC:1201 420.00 OP
02 FC:1202 810.00 OP

IN THE CLAIMS:

Claims 1 - 9 (previously cancelled)

Claims 10 - 15 (cancelled)

16. (Amended) A method for determining the relative sizes of the internal combustion engine, starting/charging and traction motors, and battery bank of a hybrid vehicle comprising said components, said method comprising the steps of:

a. selecting an internal combustion engine having sufficient torque to drive the vehicle [without trailer] at medium to high speed along a moderate grade;

b. sizing the starting/charging motor to provide an engine load during battery charging equal to at least approximately 30% of the engine's maximum torque output;

c. sizing the traction motor to provide adequate torque at zero speed to overcome the maximum grade specified from rest, with the starter motor assisting as needed;

d. determining the maximum power drawn by the selected motor(s) under full power conditions;

e. calculating the battery voltage under load that will be required to provide the power to be drawn by the motor(s) under full power conditions, and so that the ratio of the battery voltage under load to the peak current drawn by the motor(s) is at least [2.5:1] <u>2.5 : 1</u>, and

f. selecting the battery bank to provide the calculated voltage under peak load conditions.

--17. (New) A method for controlling the operation of a hybrid vehicle having at least two pairs of road wheels, said vehicle being operable in a plurality of differing modes, said vehicle comprising an internal combustion engine for providing torque up to a maximum torque output (MTO), said internal combustion engine being controllably coupled to said road wheels of said vehicle by a clutch, a first electric motor being coupled to said internal combustion engine, a second electric motor coupled to said road wheels of said vehicle, said first and second electric motors being operable as generators, a battery bank for providing electrical energy to and accepting energy from said first and second electric motors, and a controller for controlling operation of said internal combustion engine, clutch, and first and second electric motors, and controlling flow of electrical energy between said first and second electric motors and said battery bank,

characterized in that according to said method, said controller controls said internal combustion engine, said first and second electric motors, and said clutch in order to control selection of the operational mode of said vehicle between at least a low-load mode I, a cruising mode IV, and an acceleration mode V, wherein torque to propel said vehicle is provided by one or both of said first and second electric motors, said internal combustion engine, and both said engine and one or both of said first and second electric motors, respectively, in response to monitoring the instantaneous torque requirements (RL) of the vehicle, which is the torque on the output drive shaft of said vehicle, and which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, whereby said vehicle is operated in a plurality of operating modes responsive to the value of RL, and so that said internal combustion engine is operated only when the output torque thereof is at least equal to a minimum value at which torque is efficiently produced.--

--18. (New) The method of claim 17, wherein said controller controls said vehicle to operate in said low load mode I while RL < SP, wherein SP is a setpoint expressed as a predetermined percentage of MTO, said highway cruising mode IV while SP < RL < 100% of MTO, and said acceleration mode V while RL > 100% of MTO.--

--19. (New) The method of claim 18, wherein said setpoint SP is at least approximately 30% of MTO.--

--20. (New) The method of claim 18, comprising the further step of disengaging said clutch during operation in mode I and engaging said clutch during operation in modes IV and V. --

--21. (New) The method of claim 18, wherein said controller further controls said vehicle to operate in a low-speed battery charging mode II, entered while RL < SP and the state of charge of the battery bank is below a predetermined level, during which said vehicle is propelled by torque provided by said second motor in response to energy supplied from said battery bank, and wherein said battery bank is simultaneously charged by supply of electrical energy from said first motor, being driven by torque by said internal combustion engine in response to supply of combustible fuel, said clutch being disengaged during operation in mode II.--

--22. (New) The method of claim 18, comprising the further step of employing said controller to monitor patterns of vehicle operation over time and vary said setpoint SP accordingly.--

--23. (New) The method of claim 18, comprising the further step of employing said controller to monitor RL over time, and to control transition between operation in modes I and IV accordingly, such that said transition occurs only when RL > SP for at least a predetermined time, or when RL > SP2, wherein SP2 is a larger percentage of MTO than SP.--

--24. (New) The method of claim 18, comprising the further step of employing said controller to monitor RL over time, and to control transition from operation in mode IV to operation in mode I accordingly, such that said transition occurs only when RL < SP for at least a predetermined time.--

--25. (New) The method of claim 18, comprising the further step of operating said controller to monitor RL over time, and to control the operating mode to change from operation in mode I directly to operation in mode V where a rapid increase in RL as desired by the operator is detected.--

--26. (New) The method of claim 18, comprising the further step of operating said controller to accept operator input of a desired cruising speed, said controller thereafter controlling the instantaneous engine torque output in accordance with variation in RL so as to maintain vehicle speed substantially constant, and to prevent transition to mode I operation until the operator provides a further signal indicative that the desired cruising speed is no longer desired.--

--27. (New) The method of claim 18, comprising the further step of performing regenerative charging of the battery bank under controller control when the engine's instantaneous torque output > RL, when RL is negative, or when braking is initiated by the operator.--

--28. (New) The method of claim 18, wherein said first and second electric motors are controlled together to provide maximum torque at least equal to the maximum torque of said internal combustion engine.--

--29. (New) The method of claim 18, wherein the maximum speed of at least said second motor is controlled to be at least 150% of the maximum speed of said internal combustion engine.--

--30. (New) The method of claim 18, wherein said hybrid vehicle further comprises a turbocharger being operatively and controllably coupled to said internal combustion engine for increasing the maximum torque output of said internal combustion engine to more than MTO when desired, and wherein according to said method, said controller controls selection of the operational mode of said vehicle between a low-load mode I, a cruising mode IV, an acceleration mode V, and a turbocharged mode VI, in response to monitoring the instantaneous torque requirements (RL) of the vehicle over time.--

--31. (New) The method of claim 30, wherein said controller controls said vehicle to operate in said modes as follows: in said low load mode I while RL < SP, wherein SP is a setpoint expressed as a predetermined percentage of MTO, in said highway cruising mode IV while SP < RL < 100% of MTO, in said acceleration mode V while RL > 100% of MTO for less than a predetermined time T, and in said sustained high-power mode VI while RL > 100% of MTO for more than a predetermined time T.--

--32. (New) The method of claim 30, wherein said time T is controlled responsive to the state of charge of the battery bank.--

--33. (New) A hybrid vehicle, comprising:

a controller capable of accepting inputs indicative of vehicle operating parameters and providing control signals in response to a control program;

a battery bank;

an internal combustion engine;

a first electric motor electrically coupled to said battery bank for (a) accepting electrical energy from said battery bank and (b) providing electrical energy to said battery bank, and said first electric motor being mechanically coupled to said internal combustion engine, the combination of said internal combustion engine and said first electric motor being mechanically coupled to a clutch controlled by said controller for controllable torque-transmitting connection between said combination and road wheels of said vehicle,

said first electric motor being responsive to commands from said controller, such that said first electric motor can be controlled to (1) accept torque from said internal combustion engine to charge said battery bank, (2) accept energy from said battery bank to apply torque to said internal combustion engine for starting said internal combustion engine, (3) accept energy from said battery bank to apply torque to said road wheels to propel said vehicle, and (4) accept torque from said road wheels to charge said battery bank; and

a second electric motor, electrically coupled to said battery bank, such that said second electric motor can be controlled for (a) accepting electrical energy from said battery bank and (b) providing electrical energy to said battery bank, said second electric motor being mechanically coupled to road wheels of said vehicle and being responsive to commands from said controller in order to control said second electric motor to (1) accept energy from said battery bank to apply torque to said road wheels to propel said vehicle, and (2) accept torque from said road wheels to charge said battery bank;

characterized in that said controller is provided with a value for the road load (RL), which is the instantaneous torque required by said vehicle, and which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, and a value for the torque required to charge the battery bank, and controls said internal combustion engine, said first and second electric motors, and said clutch so that said vehicle is operated in a plurality of operating modes responsive to said values, and so that said engine is operated in certain of said operating modes to produce an amount of torque which is equal to the road load and/or additional torque required to charge said battery bank through one or both of said electric motors, and wherein said engine is operated only when loaded so as to produce torque in a range between a minimum value at which torque is efficiently produced (SP) and the maximum torque output of the internal combustion engine (MTO).--

--34. (New) The hybrid vehicle of claim 33, wherein changes in the torque to be applied to the vehicle wheels are determined by said controller at least in part by monitoring commands provided by the vehicle operator.--

--35. (New) The hybrid vehicle of claim 33, wherein road load (RL) and a setpoint SP, set equal to a minimum value at which torque is efficiently produced by said engine, are both expressed as percentages of MTO, and said operating modes include:

a low-load mode I, wherein said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from said battery bank, while RL < SP,

a highway cruising mode IV, wherein said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel, while SP < RL < 100% of MTO, and

an acceleration mode V, wherein said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel and by torque provided by said second electric motor in response to energy supplied from said battery bank, while RL > 100% of MTO.--

--36. (New) The hybrid vehicle of claim 35, wherein said setpoint SP is at least approximately 30% of MTO.--

--37. (New) The hybrid vehicle of claim 35, wherein said clutch is disengaged during operation in mode I and engaged during operation in modes IV and V.--

--38. (New) The hybrid vehicle of claim 35, wherein said operating modes further include a low-speed battery charging mode II, entered while RL < SP and the state of charge of the battery bank is below a predetermined level, and wherein said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from said battery bank, and wherein said battery bank is simultaneously charged by supply of electrical energy from said first electric motor, being driven by torque in excess of SP by said internal combustion engine in response to supply of combustible fuel, said clutch being disengaged during operation in mode II.--

--39. (New) The hybrid vehicle of claim 35, wherein said setpoint SP may be varied by said controller in response to monitoring patterns of vehicle operation over time.--

--40. (New) The hybrid vehicle of claim 35, wherein said setpoint SP may be varied by said controller as a function of engine speed.--

--41. (New) The hybrid vehicle of claim 35, wherein the transition between operation in modes I and IV is controlled to occur only when RL > SP for at least a predetermined time, or when RL > SP2, wherein SP2 is a larger percentage of MTO than SP.--

--42. (New) The hybrid vehicle of claim 35, wherein the transition from operation in mode IV to operation in mode I is controlled to occur only when RL < SP for at least a predetermined time.--

--43. (New) The hybrid vehicle of claim 35, wherein the controller may control transition of the operating mode from operation in mode I directly to operation in mode V where a rapid increase in the torque to applied to the wheels of the vehicle as desired by the operator is detected. --

--44. (New) The hybrid vehicle of claim 35, wherein the controller may accept operator input of a desired cruising speed, and thereafter controls the instantaneous torque output by said internal combustion engine in accordance with variation in RL so as to maintain vehicle speed substantially constant, and does not permit transition to mode I operation until the operator provides a further signal indicating that the desired cruising speed is no longer desired.--

--45. (New) The hybrid vehicle of claim 35, wherein regenerative charging of the battery bank is performed when the instantaneous torque output by the internal combustion engine > RL, when RL is negative, or when braking is initiated by the operator.--

--46. (New) The hybrid vehicle of claim 35, wherein the total torque available at the road wheels from said internal combustion engine is no greater than the total torque available from said first and second electric motors combined.--

--47. (New) The hybrid vehicle of claim 33, wherein the engine and first electric motor are controllably coupled to a first set of road wheels of said vehicle and said second electric motor is coupled to a second set of road wheels of said vehicle.--

--48. (New) The hybrid vehicle of claim 33, further comprising a multispeed transmission disposed between said engine and said motors and the wheels of said vehicle, said transmission being operable to broaden the load-carrying range of said vehicle.

--49. (New) A hybrid vehicle, comprising:

a controller capable of accepting inputs indicative of vehicle operating parameters and providing control signals in response to a ~~control program;~~

a battery bank;

an internal combustion engine fitted with a turbocharger that is operable in response to control signals from said controller in order to increase the torque output by said internal combustion engine;

a first electric motor electrically coupled to said battery bank for (a) accepting electrical energy from said battery bank and (b) providing electrical energy to said battery bank, and said first electric motor being mechanically coupled to said internal combustion engine, the combination of said internal combustion engine and said first electric motor being mechanically coupled to a clutch controlled by said controller for controllable torque-transmitting connection between said combination and road wheels of said vehicle,

said first electric motor being responsive to commands from said controller, such that said first electric motor can be controlled to (1) accept torque from said internal combustion engine to charge said battery bank, (2) accept energy from said battery bank to apply torque to said internal combustion engine for starting said internal combustion engine, (3) accept energy from said battery bank to apply torque to said road wheels to propel said vehicle, and (4) accept torque from said road wheels to charge said battery bank; and

a second electric motor, electrically coupled to said battery bank, such that said second electric motor can be controlled for (a) accepting electrical energy from said battery bank and (b) providing electrical energy to said battery bank, said second electric motor being mechanically coupled to road wheels of said vehicle and being responsive to commands from said controller in order to control said second electric motor to (1) accept energy from said battery bank to apply torque to said road wheels to propel said vehicle, and (2) accept torque from said road wheels to charge said battery bank;

characterized in that said controller is provided with a value for the road load, which is the torque on the output drive shaft of said vehicle, and which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, and controls said internal combustion engine, said turbocharger, said first and second electric motors, and said clutch so that said vehicle is operated in a plurality of operating modes responsive to said values, and so that said engine is operated in certain of said operating modes to produce an amount of torque which is equal to the road load and/or additional torque required to charge said battery bank through one or both of said electric motors, and wherein said controller causes said turbocharger to operate, increasing the maximum output torque of said internal combustion engine, only when the instantaneous road load exceeds the internal combustion engine's normally-aspirated maximum torque output for more than a predetermined period of time, and wherein said internal combustion engine is operated only when loaded in a range between a minimum value at which torque is efficiently produced and its maximum torque output value.--

--50. (New) The hybrid vehicle of claim 49, wherein the road load (RL) is expressed as a percentage of the maximum torque output of the internal combustion engine while normally-aspirated (MTO), and said operating modes include:

a low-load mode I, wherein said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from said battery bank, while RL < SP, wherein SP is a setpoint expressed as a predetermined percentage of MTO,

a highway cruising mode IV, wherein said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel, while SP < RL < 100%

of MTO,

an acceleration mode V, wherein said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel and by torque provided by said second electric motor in response to energy supplied from said battery bank, while RL > 100% of MTO for less than a predetermined time T, and

a high-power mode VI, wherein said turbocharger is operated such that said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel while RL > 100% of MTO for more than a predetermined time T.

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--51. (New) The hybrid vehicle of claim 50, wherein said setpoint SP is at least approximately 30% of MTO.--

--52. (New) The hybrid vehicle of claim 50, wherein said clutch is disengaged during operation in mode I and engaged during operation in modes IV, V, and VI.--

--53. (New) The hybrid vehicle of claim 50, wherein said time T is controlled responsive to the state of charge of the battery bank.--

--54. (New) The hybrid vehicle of claim 49, wherein the engine and first electric motor are controllably coupled to a first set of road wheels of said vehicle and said second electric motor is coupled to a second set of road wheels of said vehicle.--

--55. (New) The hybrid vehicle of claim 49, further comprising a multispeed transmission disposed between said engine and said motors and the wheels of said vehicle, said transmission being operable to broaden the load-carrying range of said vehicle.--

--56. (New) A method for controlling the operation of a hybrid vehicle operable in a plurality of differing modes, said vehicle comprising an internal combustion engine for providing torque up to a maximum torque output (MTO), said internal combustion engine being controllably coupled to road wheels of said vehicle, a first electric motor being coupled to said internal combustion engine, said first electric motor being operable as a generator, a second motor coupled to the wheels of said vehicle and also operable as a generator, a battery bank for providing electrical energy to and accepting energy from said electric motors, and a controller for controlling operation of said internal combustion engine and the coupling of said engine to said road wheels, of said electric motors, and controlling flow of electrical energy between said electric motors and said battery bank,

characterized in that according to said method, said controller controls said internal combustion engine, said electric motors, and the coupling of said engine to said wheels so that said vehicle is operated in a plurality of operating modes responsive to the instantaneous torque requirement (RL) of the vehicle, which is the torque on the output drive shaft of said vehicle, and which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, and so that said internal combustion engine is operated only when loaded such that the output torque thereof is at least equal to a minimum value at which torque is efficiently produced, said operating modes including:

a low load mode I entered into while RL < SP, wherein SP is a setpoint expressed as a predetermined percentage of MTO, and in which torque propelling said vehicle is provided by said motors,

a highway cruising mode IV entered into while SP < RL < 100% of MTO and in which torque propelling said vehicle is provided by said engine, and

an acceleration mode V entered into while RL > 100% of MTO and in which torque propelling said vehicle is provided by said motors and said engine.--

--57. (New) The method of claim 56, wherein SP is equal to at least approximately 30% of MTO.--

--58. (New) The method of claim 56, comprising the further step of decoupling said engine from said wheels during operation in mode I and coupling said engine to said wheels during operation in modes IV and V. --

--59. The method of claim 56, wherein said controller further controls said vehicle to operate in a low-load battery charging mode II, entered while RL < SP and the state of charge of the battery bank is below a predetermined level, during which said vehicle is propelled by torque provided by said second motor in response to energy supplied from said battery bank, and wherein said battery bank is simultaneously charged by supply of electrical energy from said first motor, being driven by torque by said internal combustion engine in response to supply of combustible fuel, said engine being decoupled from said wheels during operation in mode II.--

--60. (New) The method of claim 56, comprising the further step of employing said controller to monitor patterns of vehicle operation over time and vary said setpoint SP accordingly.--

--61. (New) The method of claim 56, comprising the further step of employing said controller to monitor RL over time, and to control transition between operation in modes I and IV accordingly, such that said transition occurs only when RL > SP for at least a predetermined time, or when RL > SP2, wherein SP2 is a larger percentage of MTO than SP.--

--62. (New) The method of claim 56, comprising the further step of employing said controller to monitor RL over time, and to control transition from operation in mode IV to operation in mode I accordingly, such that said transition occurs only when RL < SP for at least a predetermined time.--

--63. (New) The method of claim 56, comprising the further step of operating said controller to monitor RL over time, and to control the operating mode to change from operation in mode I directly to operation in mode V where a rapid increase in the torque to be applied to the wheels as desired by the operator is detected.--

--64. (New) The method of claim 56, comprising the further step of operating said controller to accept operator input of a desired cruising speed, said controller thereafter controlling the instantaneous engine torque output in accordance with variation in RL so as to maintain vehicle speed substantially constant, and to prevent transition to mode I operation until the operator provides a further signal indicative that the desired cruising speed is no longer desired.--

--65. (New) The method of claim 56, comprising the further step of performing regenerative charging of the battery bank under controller control when the engine's instantaneous torque output > RL, when RL is negative, or when braking is initiated by the operator.--

--66. (New) The method of claim 56, wherein said hybrid vehicle further comprises a multispeed transmission disposed between said engine and said motors and the wheels of said vehicle, said transmission being operable responsive to a control signal from said controller to broaden the load-carrying range of said vehicle.--

--67. (New) The method of claim 56, wherein said hybrid vehicle further comprises a turbocharger being operatively and controllably coupled to said internal combustion engine for being operated and thereby increasing the maximum torque output of said internal combustion engine to more than MTO when desired, and wherein according to said method, said controller controls selection of the operational mode of said vehicle between a low-load mode I, a cruising mode IV, an acceleration mode V, and a turbocharged mode VI, in response to monitoring the instantaneous torque requirements (RL) of the vehicle over time.--

--68. (New) The method of claim 67, wherein said controller controls said vehicle to operate in said modes as follows: in said low load mode I while RL < SP, wherein SP is a setpoint expressed as a predetermined percentage of MTO, in said highway cruising mode IV while SP < RL < 100% of MTO, in said acceleration mode V while RL > 100% of MTO for less than a predetermined time T, and in said sustained high-power mode VI while RL > 100% of MTO for more than a predetermined time T.--

--69. (New) The method of claim 67, wherein said time T is controlled responsive to the state of charge of the battery bank.--

--70. (New) The method of claim 67, comprising the further step of decoupling said engine from said wheels during operation in mode I and coupling said engine to said wheels during operation in modes IV, V, and VI.

--71. (New) A hybrid vehicle operable in a plurality of differing modes, said vehicle comprising an internal combustion engine for providing torque up to a maximum normally-aspirated torque output (MTO), said internal combustion engine being fitted with a turbocharger operable in response to a control signal for increasing the maximum torque output of said internal combustion engine beyond MTO, said internal combustion engine being controllably connected to road wheels of said vehicle through means controllable by a controller, a first electric motor coupled to said engine, and a second electric motor coupled to road wheels of said vehicle, both said electric motors being operable as generators, a battery bank for providing electrical energy to and accepting energy from said electric motors, at least one controllable inverter/charger connected between said electric motors and said battery bank, and a controller for controlling operation of said internal combustion engine and connection thereof to said wheels, said electric motors, and said turbocharger, and for controlling flow of electrical energy between said electric motors and said battery bank,

characterized in that said controller is provided with a signal indicative of the instantaneous road load (RL) of said vehicle, which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, and controls operation of said internal combustion engine, conection of said engine to said wheels, said at least one electric motor, and said turbocharger, so that said vehicle is operated in said plurality of differing modes responsive to said signal, and said controller further controls operation of said vehicle so that said internal combustion engine is operated only when the output torque thereof is at least equal to a minimum value at which torque is efficiently produced; and wherein:

the road load (RL) is expressed as a percentage of the maximum torque output of the engine while normally-aspirated (MTO), and said operating modes include:

a low-load mode I, wherein said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from said battery bank, while RL < SP, wherein SP is a setpoint expressed as a predetermined percentage of MTO,

a highway cruising mode IV, wherein said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel, while SP < RL < 100% of MTO, said turbocharger not being operated in said mode IV,

an acceleration mode V, wherein said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel and by torque provided by said second electric motor in response to energy supplied from said battery bank, while RL > 100% of MTO for less than a predetermined time T, said turbocharger not being operated in said mode V, and

a high-power mode VI, wherein said turbocharger is operated such that said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel while RL > 100% of MTO for more than said predetermined time T.--

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Ent.

Correct numbering

--71. (New) The hybrid vehicle of claim 70, wherein said setpoint SP is at least approximately 30% of MTO.--

--~~72~~ 73. (New) The hybrid vehicle of claim 70, wherein said engine is disconnected from said wheels during operation in mode I and connected to said wheels during operation in modes IV, V, and VI. --

--~~73~~ 74. (New) The hybrid vehicle of claim 70, wherein said time T is controlled responsive to the state of charge of the battery bank.--

--~~74~~ 75. (New) The hybrid vehicle of claim 70, wherein torque from said internal combustion engine is transmitted to a first set of road wheels and torque from said second electric motor is transmitted to a second set of road wheels.--

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--~~75~~ 76. (New) The hybrid vehicle of claim 70, wherein said first electric motor is coupled to said internal combustion engine for starting said internal combustion engine in response to a control signal from said controller.--

--~~76~~ 77. (New) The hybrid vehicle of claim 70, further comprising a multispeed transmission disposed between said engine and said motors and the wheels of said vehicle, said transmission being operable to broaden the load-carrying range of said vehicle.--

--~~77~~ 78. (New) A method for controlling the operation of a hybrid vehicle operable in a plurality of differing modes, said vehicle comprising an internal combustion engine for providing torque up to a maximum torque output (MTO), said internal combustion engine being controllably coupled to road wheels of said vehicle by a clutch, a first electric motor being coupled to said internal combustion engine, a second electric motor coupled to road wheels of said vehicle, said first and second electric motors being operable as generators, a battery bank for providing electrical energy to and accepting energy from said first and second electric motors, and a controller for controlling operation of said internal combustion engine, clutch, and first and second electric motors, and controlling flow of electrical energy between said first and second electric motors and said battery bank,

characterized in that according to said method, said controller controls selection of the operational mode of said vehicle between at least a low-load mode I and a cruising mode IV, wherein torque to propel said vehicle is provided by said at least said second electric motor or said internal combustion engine, respectively, in response to monitoring the instantaneous torque requirements (RL) of the vehicle, which is the torque on the output drive shaft of said vehicle, and which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, and said controller further controls operation of said vehicle so that said internal combustion engine is operated only when the output torque thereof is at least equal to a minimum value at which torque is efficiently produced, and

wherein said vehicle further comprises a catalytic converter comprising a catalyst for reducing undesirable emissions of CO, NOx, and unburned hydrocarbons from said internal combustion engine to harmless products, said catalytic converter being provided with means controlled by said controller for heating said catalyst to an effective working temperature, and wherein when said controller determines that it is desirable to start said engine, e.g., in order to change the operating mode of said vehicle from mode I to mode IV, or to charge said battery, said controller heats said catalyst to a minimum effective working temperature if necessary before controlling said first electric motor to spin said internal combustion engine for starting.--

--~~78~~ 79. (New) A method for determining the relative sizes of the internal combustion engine, first and second electric motors, and battery bank of a hybrid vehicle comprising said components, and a method for operating the vehicle thus designed, the determining steps of said method comprising the steps of:

a. selecting the internal combustion engine having sufficient torque to drive the vehicle at medium to high speed along a moderate grade;

b. sizing the first electric motor to provide an internal combustion engine load during battery charging adequate to ensure that torque is produced efficiently by said engine;

c. sizing the second electric motor to provide adequate torque at zero speed to overcome the maximum grade specified from rest, with the first electric motor assisting as needed;

d. selecting the torque vs. speed profile of the second electric motor to allow convenient city driving, without use of torque from the internal combustion engine; and

e. selecting the battery capacity to be sufficient to avoid excessively frequent discharging and charging cycles; and

the operating steps of said method comprising the steps of:

a. monitoring the instantaneous torque requirement (RL) of the vehicle, which is the torque on the output drive shaft of said vehicle, and which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, and

b. employing a controller to control selection of the operational mode of said vehicle between at least a low-load mode I and a cruising mode IV, wherein torque to propel said vehicle is provided by said at least said second electric motor or said internal combustion engine, respectively, in response to RL, and wherein said controller further controls operation of said vehicle so that said internal combustion engine is operated only when the output torque thereof is at least equal to a minimum value at which torque is efficiently produced.--

--79. The method of claim 78, wherein said engine is provided with a turbocharger controlled by said controller to increase the engine's maximum torque output during extended operation under circumstances where RL exceeds the maximum torque output of the internal combustion engine in normally-aspirated mode for an extended period of time, wherein the turbocharger increases the engine's maximum torque output by at least about 25%.--

--80. The method of claim 78, wherein said first electric motor is sized so as to load the internal combustion engine to approximately 70% of its maximum torque output at an engine speed at which torque is efficiently produced during battery charging.--

REMARKS

After entry of the above amendment, claims 16 - 80 remain in the application. Claims 10 - 15 were directed to different inventions and have been cancelled hereby, while claims 1 - 9 were issued in the parent patent. Claim 16 is an original claim to the method of sizing the components of a hybrid vehicle, while claim 78 and its dependent claims 79 and 80 are new claims directed similarly. All of the other new claims 17 - 77 added hereby are directed to the hybrid vehicle of the invention, defined in terms of its components and the method of control employed to ensure that they work together properly to achieve the objects of the invention, or to the method of the invention, which claims include a catalog of the parts of the vehicle as a means of establishing support for the method of the invention.

More specifically, claims 17 - 77 recite that the vehicle is operated in various operational modes, that is, in which the torque required to propel the vehicle is provided from different sources, and that the operational mode at any given time is chosen by a controller responsive to the road load of the vehicle, that is, its instantaneous torque requirement. This was also recited in original claim 1. Claims 16 and 78 - 80 refer as noted to the sizing of the various components that is needed to ensure that they can carry out these functions, i.e., in order to operate in the various operating modes, although these are not recited *per se* in claims 16 and 78 - 80. Since new claims 17 - 77 have the same inventive concept as claim 1, which distinguishes over all art known to the inventors, and since claims 16 and 78 - 80 are directed to sizing the components for so doing, it is respectfully submitted that claims 16 - 80 can properly be examined in a single application.

Hence it is respectfully submitted that all claims are properly examinable in a single application, and furthermore that they are allowable.

For the Examiner's information, an updated search for patents related to the inventive subject matter was recently completed, and it is the intention of the undersigned to file a further Information Disclosure Statement within the next few weeks.

Respectfully submitted,

Aug. 11, 2003
Dated

Michael de Angeli
Reg. No. 27,869
60 Intrepid Lane
Jamestown, RI 02835
401-423-3190

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Patent Application of	:	
	:	
Severinsky et al	:	Examiner: N/A
	:	
Serial No.: 10/382,577	:	Group Art Unit: 3616
	:	
Filed: March 7, 2003	:	Att. Dkt.: PAICE201.DIV
	:	

For: HYBRID VEHICLES

Hon. Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

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AMENDMENT

Hon. Commissioner for Patents
P. O. Box 1450
Alexandria VA 22313-1450

Transmitted herewith is an amendment in the above - identified application.

_X_ A check for the additional claim fee of $ 1356 as calculated below is enclosed for this amendment.

___ The Commissioner is hereby authorized to charge any underpayment (or to credit overpayment) to our Deposit Account No. 04-0401. A duplicate copy of this sheet is attached.

LARGE ENTITY

	TOTAL CLAIMS	CLAIMS PREVIOUSLY PAID FOR		PRESENT EXTRA		ADDITIONAL RATE	
TOTAL	126	65	=	61	Extra	x 18	$ 1098.00
INDEP.	11	8	=	3	Extra	x 86	$ 258.00
						TOTAL:	$ 1356.00

Respectfully submitted,

5/19/04
Dated

Michael de Angeli
Reg. No. 27,869
60 Intrepid Lane
Jamestown, RI 02835
401-423-3190

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Fee OK

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In re the Patent Application of	:
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Severinsky et al	: Examiner: N/A
	:
Serial No.: 10/382,577	: Group Art Unit: 3616
	:
Filed: March 7, 2003	: Att. Dkt.: PAICE201.DIV
	:

For: Hybrid Vehicles

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GROUP 3600

Hon. Commissioner for Patents
P.O. Box 1450
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SUPPLEMENTAL PRELIMINARY AMENDMENT

Sir:

Prior to examination, kindly amend the above-identified Application as follows:

05/21/2004 YPOLITE1 00000043 10382577

01 FC:1201 258.00 OP
02 FC:1202 1098.00 OP

IN THE CLAIMS:

Claims 1 - 15 (previously cancelled)

16. (Amended) A method for determining the relative sizes of the internal combustion engine, starting/charging and traction motors, and battery bank of a hybrid vehicle of predetermined weight comprising said components, said method comprising the steps of:

a. selecting an internal combustion engine having sufficient torque to drive the vehicle at ~~medium to high~~ a specified speed along a ~~moderate~~ specified maximum grade;

b. sizing the starting/charging motor to provide an engine load during battery charging equal to at least approximately 30% of the engine's maximum torque output in normally-aspirated operation;

c. sizing the traction motor to provide adequate torque at zero speed to overcome the maximum grade specified from rest, with the engine and/or starting/charging ~~starter~~ motor assisting as needed;

d. determining the maximum power drawn by the selected motor(s) under full power conditions;

e. calculating the battery voltage under load that will be required to provide the power to be drawn by the motor(s) under full power conditions, and so that the ratio of the battery voltage under load to the peak current drawn by the motor(s) is at least 2.5 : 1, and

f. selecting the battery bank to provide the calculated voltage under peak load conditions.

--17. (Amended) A method for controlling the operation of a hybrid vehicle having at least two pairs of road wheels, said vehicle being operable in a plurality of differing modes, said vehicle comprising an internal combustion engine for providing torque up to a maximum torque output (MTO) <u>when normally aspirated</u>, said internal combustion engine being controllably coupled to said road wheels of said vehicle ~~by a clutch~~, a first electric motor being coupled to said internal combustion engine, a second electric motor coupled to said road wheels of said vehicle, said first and/or second electric motors being operable as generators, a battery bank for providing electrical energy to and/or accepting energy from said first and/or second electric motors, and a controller for controlling operation of said internal combustion engine, ~~clutch,~~ and first and second electric motors, ~~and~~ controlling flow of electrical energy between said first and second electric motors and said battery bank, <u>and controlling flow of mechanical energy between said engine, said first and second electric motors, and said wheels,</u>

characterized in that according to said method, said controller controls said internal combustion engine, said first and second electric motors, ~~and said clutch~~ <u>and flow of electrical and mechanical energy therebetween</u> in order to control selection of the operational mode of said vehicle between at least a low-load mode I, a cruising mode IV, and an acceleration mode V, wherein torque to propel said vehicle is provided by one or both of said first and second electric motors, said internal combustion engine, and both said engine and one or both of said first and second electric motors, respectively, in response to monitoring the instantaneous torque requirements (RL) of the vehicle, which is the torque ~~on the output drive shaft~~ <u>required for propulsion</u> of said vehicle, and which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, whereby said vehicle is operated in ~~a~~ said plurality of operating modes responsive to the value of RL, and so that said internal combustion engine is operated when the engine torque required to propel the vehicle, or to propel said vehicle and/or drive either or both electric motor(s) to charge said battery ~~only when the output torque thereof~~ is at least equal to a minimum value at which torque is efficiently produced.--

--18. (Amended) The method of claim 17, wherein said controller controls said vehicle to operate in said low load mode I while RL < SP, wherein SP is a setpoint expressed as a predetermined percentage of MTO, said highway cruising mode IV while SP < RL < ~~100% of~~ MTO, and said acceleration mode V while RL > ~~100% of~~ MTO.--

--19. (previously presented) The method of claim 18, wherein said setpoint SP is at least approximately 30% of MTO.--

--20. (Amended) The method of claim 18, wherein said engine is controllably connected to said wheels by a clutch, and comprising the further step of disengaging said clutch during operation in mode I and engaging said clutch during operation in modes IV and V. --

--21. (Amended) The method of claim 18, wherein said controller further controls said vehicle to operate in a low-speed battery charging mode II, entered while RL < SP and the state of charge of the battery bank is below a predetermined level, during which said vehicle is propelled by torque provided by said second motor in response to energy supplied from said battery bank, and wherein said battery bank is simultaneously charged by supply of electrical energy from said first motor, being driven by torque by said internal combustion engine in response to supply of combustible fuel, said ~~clutch~~ engine being disengaged from said wheels during operation in mode II, and wherein said engine is loaded by said first motor such that it produces torque at least equal to SP while being operated in said mode II.--

--22. (previously presented) The method of claim 18, comprising the further step of employing said controller to monitor patterns of vehicle operation over time and vary said setpoint SP accordingly.--

--23. (previously presented) The method of claim 18, comprising the further step of employing said controller to monitor RL over time, and to control transition between operation in modes I and IV accordingly, such that said transition occurs only when RL > SP for at least a predetermined time, or when RL > SP2, wherein SP2 is a larger percentage of MTO than SP.--

--24. (previously presented) The method of claim 18, comprising the further step of employing said controller to monitor RL over time, and to control transition from operation in mode IV to operation in mode I accordingly, such that said transition occurs only when RL < SP for at least a predetermined time.--

--25. (previously presented) The method of claim 18, comprising the further step of operating said controller to monitor RL over time, and to control the operating mode to change from operation in mode I directly to operation in mode V where a rapid increase in RL as desired by the operator is detected.--

--26. (Amended) The method of claim 18, comprising the further step of operating said controller to accept operator input of a desired cruising speed, said controller thereafter controlling the instantaneous engine torque output and operation of said motor(s) to supply additional torque as needed in accordance with variation in RL so as to maintain vehicle speed substantially constant~~, and to prevent transition to mode I operation until the operator provides a further signal indicative that the desired cruising speed is no longer desired~~.--

--27. (previously presented) The method of claim 18, comprising the further step of performing regenerative charging of the battery bank under controller control when the engine's instantaneous torque output > RL, when RL is negative, or when braking is initiated by the operator.--

--28. (previously presented) The method of claim 18, wherein said first and second electric motors are controlled together to provide maximum torque at least equal to the maximum torque of said internal combustion engine.--

--29. (previously presented) The method of claim 18, wherein the maximum speed of at least said second motor is controlled to be at least 150% of the maximum speed of said internal combustion engine.--

--30. (previously presented) The method of claim 18, wherein said hybrid vehicle further comprises a turbocharger being operatively and controllably coupled to said internal combustion engine for increasing the maximum torque output of said internal combustion engine to more than MTO when desired, and wherein according to said method, said controller controls selection of the operational mode of said vehicle between a low-load mode I, a cruising mode IV, an acceleration mode V, and a turbocharged mode VI, in response to monitoring the instantaneous torque requirements (RL) of the vehicle over time.--

--31. (Amended) The method of claim 30, wherein said controller controls said vehicle to operate in said modes as follows:
in said low load mode I while RL < SP, wherein SP is a setpoint expressed as a predetermined percentage of MTO, in said highway cruising mode IV while SP < RL < ~~100% of~~ MTO, in said acceleration mode V while RL > ~~100% of~~ MTO for less than a predetermined time T, and in said sustained high-power mode VI while RL > ~~100% of~~ MTO for more than a predetermined time T.--

--32. (previously presented) The method of claim 30, wherein said time T is controlled responsive to the state of charge of the battery bank.--

--33. (Amended) A hybrid vehicle, comprising:

a controller capable of accepting inputs indicative of vehicle operating parameters and providing control signals in response to a control program;

a battery bank;

an internal combustion engine;

a first electric motor electrically coupled to said battery bank for (a) accepting electrical energy from said battery bank and (b) providing electrical energy to said battery bank, and said first electric motor being mechanically coupled to said internal combustion engine, the combination of said internal combustion engine and said first electric motor being mechanically coupled to a~~ clutch controlled by said controller for ~~controllable torque-transmitting connection between said combination and road wheels of said vehicle,

said first electric motor being responsive to commands from said controller, such that said first electric motor can be controlled to (1) accept torque from said internal combustion engine to charge said battery bank, or(2) accept energy from said battery bank to apply torque to said internal combustion engine for starting said internal combustion engine~~, (3) accept energy from said battery bank to apply torque to said road wheels to propel said vehicle, and (4) accept torque from said road wheels to charge said battery bank~~; and

a second electric motor, electrically coupled to said battery bank, ~~such that said second electric motor can be controlled for (a) accepting electrical energy from said battery bank and (b) providing electrical energy to said battery bank, said second electric motor being~~ mechanically coupled to road wheels of said vehicle, and ~~being~~ responsive to commands from said controller in order to ~~control said second electric motor to~~ (1) accept energy from said battery bank to apply torque to said road wheels to propel said vehicle, or (2) accept torque from said road wheels to charge said battery bank;

characterized in that said controller is provided with a value for the road load (RL), which is the instantaneous torque required by said vehicle for propulsion, and which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, and a value for the torque required to charge the battery bank, and controls said internal combustion engine~~,~~ and said first and second electric motors, ~~and said clutch~~ so that said vehicle is operated ~~in a plurality of operating modes~~ responsive to said ~~values~~ value RL, and so that said engine is operated ~~in certain of said operating modes~~ when the engine torque required to propel said vehicle and/or charge said battery bank by producing ~~to produce~~ an amount of torque which is equal to the road load and/or additional torque required to charge said battery bank through one or both of said electric motors, ~~and wherein said engine is operated only when loaded so as to produce torque~~ is in a range between a minimum value at which torque is efficiently produced ~~(SP)~~ and the maximum torque output of the internal combustion engine when normally aspirated (MTO).--

--34. (Amended) The hybrid vehicle of claim 33, wherein changes in the torque to be applied to or accepted from the vehicle wheels are determined by said controller at least in part by monitoring commands provided by the vehicle operator.--

--35. (Amended) The hybrid vehicle of claim 33, wherein said vehicle is operated in a plurality of operating modes responsive to the value of RL ~~road load (RL)~~ and a setpoint SP, set equal to a minimum value at which torque is efficiently produced by said engine, ~~are~~ both expressed as percentages of MTO, and said operating modes include:

a low-load mode I, wherein said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from said battery bank, while RL < SP,

a highway cruising mode IV, wherein said vehicle is propelled by torque provided by said internal combustion engine ~~in response to supply of combustible fuel~~, while SP < RL < ~~100%~~

~~of~~ MTO, and

an acceleration mode V, wherein said vehicle is propelled by torque provided by said internal combustion engine ~~in response to supply of combustible fuel~~ and by torque provided by said second electric motor in response to energy supplied from said battery bank, while RL > ~~100% of~~ MTO.--

--36. (previously presented) The hybrid vehicle of claim 35, wherein said setpoint SP is at least approximately 30% of MTO.--

--37. (Amended) The hybrid vehicle of claim 35, wherein the combination of said ~~clutch~~ engine and said first motor is disengaged from said wheels during operation in mode I and engaged during operation in modes IV and V.--

--38. (Amended) The hybrid vehicle of claim 35, wherein said operating modes further include a low-speed battery charging mode II, entered while RL < SP and the state of charge of the battery bank is below a predetermined level, ~~and wherein said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from said battery bank~~, and wherein said battery bank is simultaneously charged by supply of electrical energy from said first electric motor, being driven by torque in excess of SP by said internal combustion engine in response to supply of combustible fuel, the combination of said engine and said first motor ~~said clutch~~ being disengaged from said wheels during operation in mode II.--

--39. (previously presented) The hybrid vehicle of claim 35, wherein said setpoint SP may be varied by said controller in response to monitoring patterns of vehicle operation over time.--

--40. (previously presented) The hybrid vehicle of claim 35, wherein said setpoint SP may be varied by said controller as a function of engine speed.--

--41. (previously presented) The hybrid vehicle of claim 35, wherein the transition between operation in modes I and IV is controlled to occur only when RL > SP for at least a predetermined time, or when RL > SP2, wherein SP2 is a larger percentage of MTO than SP.--

--42. (previously presented) The hybrid vehicle of claim 35, wherein the transition from operation in mode IV to operation in mode I is controlled to occur only when RL < SP for at least a predetermined time.--

--43. (Amended) The hybrid vehicle of claim 35, wherein the controller may control transition of the operating mode from operation in mode I directly to operation in mode V where a rapid increase in the torque to <u>be</u> applied to the wheels of the vehicle as desired by the operator is detected. --

--44. (Amended) The hybrid vehicle of claim 35, wherein the controller may accept operator input of a desired cruising speed, and thereafter controls the instantaneous torque output by said internal combustion engine <u>and by either or both motor(s)</u> in accordance with variation in RL so as to maintain vehicle speed substantially constant~~, and does not permit transition to mode I operation until the operator provides a further signal indicating that the desired cruising speed is no longer desired~~.--

--45. (Amended) The hybrid vehicle of claim 35, wherein regenerative charging of the battery bank is performed when the instantaneous torque output by the internal combustion engine > RL, when RL is negative, or when braking is initiated by the operator.--

--46. (previously presented) The hybrid vehicle of claim 35, wherein the total torque available at the road wheels from said internal combustion engine is no greater than the total torque available from said first and second electric motors combined.--

--47. (previously presented) The hybrid vehicle of claim 33, wherein the engine and first electric motor are controllably coupled to a first set of road wheels of said vehicle and said second electric motor is coupled to a second set of road wheels of said vehicle.--

--48. (previously presented) The hybrid vehicle of claim 33, further comprising a multispeed transmission disposed between said engine and said motors and the wheels of said vehicle, said transmission being operable to broaden the load-carrying range of said vehicle.

--49. (Amended) A hybrid vehicle, comprising:

a controller capable of accepting inputs indicative of vehicle operating parameters and providing control signals in response to a control program;

a battery bank;

an internal combustion engine fitted with a turbocharger that is operable in response to control signals from said controller in order to increase the torque output by said internal combustion engine;

a first electric motor electrically coupled to said battery bank for (a) accepting electrical energy from said battery bank and (b) providing electrical energy to said battery bank, and said first electric motor being mechanically coupled to said internal combustion engine, the combination of said internal combustion engine and said first electric motor being mechanically coupled to road wheels of said vehicle to a clutch by a controlled by said controller for controllable torque-transmitting connection between said combination and road wheels of said vehicle, said connection being controlled by said controller,

said first electric motor being responsive to commands from said controller, such that said first electric motor can be controlled to (1) accept torque from said internal combustion engine to charge said battery bank, and/or (2) accept energy from said battery bank to apply torque to said internal combustion engine for starting said internal combustion engine, (3) accept energy from said battery bank to apply torque to said road wheels to propel said vehicle, and (4) accept torque from said road wheels to charge said battery bank; and

a second electric motor, electrically coupled to said battery bank, such that said second electric motor can be controlled for (a) accepting electrical energy from said battery bank and (b) providing electrical energy to said battery bank, said second electric motor being mechanically coupled to road wheels of said vehicle, and being responsive to commands from said controller in order to control said second electric motor to (1) accept energy from said battery bank to apply torque to said road wheels to propel said vehicle, and (2) accept torque from said road wheels to charge said battery bank;

characterized in that said controller is provided with a value for the road load, which is the torque ~~on the output drive shaft~~ required for propulsion of said vehicle, and which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, and controls said internal combustion engine, said turbocharger, and said first and second electric motors~~, and said clutch so that said vehicle is operated in a plurality of operating modes responsive to said values, and~~ and wherein said controller causes said turbocharger to operate, increasing the maximum output torque of said internal combustion engine, ~~only when the instantaneous~~ when the road load exceeds a predetermined value for more than a predetermined period of time, and wherein said internal combustion engine is operated to propel said vehicle and/or drive either or both motors to charge said battery bank ~~only~~ when ~~loaded~~ the engine torque required to do so is in a range between a minimum value at which torque is efficiently produced and its maximum torque output value.--

--50. (previously presented) The hybrid vehicle of claim 49, wherein said vehicle is operated in a plurality of operating modes responsive to the road load (RL), which is expressed as a percentage of the maximum torque output of the internal combustion engine while normally-aspirated (MTO), and wherein said operating modes include:

a low-load mode I, wherein said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from said battery bank, while RL < SP, wherein SP is a setpoint expressed as a predetermined percentage of MTO,

a highway cruising mode IV, wherein said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel, while SP < RL < ~~100% of~~ MTO,

an acceleration mode V, wherein said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel and by torque provided by said second electric motor in response to energy supplied from said battery bank, while RL > ~~100% of~~ MTO for less than a predetermined time T, and

a high-power mode VI, wherein said turbocharger is operated such that said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel while RL > ~~100% of~~ MTO for more than a predetermined time T.--

--51. (previously presented) The hybrid vehicle of claim 50, wherein said setpoint SP is at least approximately 30% of MTO.--

--52. (Amended) The hybrid vehicle of claim 50, wherein said ~~clutch~~ controllable torque-transmitting connection between said combination and road wheels of said vehicle is disengaged during operation in mode I and engaged during operation in modes IV, V, and VI.--

--53. (previously presented) The hybrid vehicle of claim

50, wherein said time T is controlled responsive to the state of charge of the battery bank.--

--54. (previously presented) The hybrid vehicle of claim 49, wherein the engine and first electric motor are controllably coupled to a first set of road wheels of said vehicle and said second electric motor is coupled to a second set of road wheels of said vehicle.--

--55. (previously presented) The hybrid vehicle of claim 49, further comprising a multispeed transmission disposed between said engine and said motors and the wheels of said vehicle, said transmission being operable to broaden the load-carrying range of said vehicle.--

--56. (Amended) A method for controlling the operation of a hybrid vehicle operable in a plurality of differing modes, said vehicle comprising an internal combustion engine for providing torque up to a maximum torque output (MTO), said internal combustion engine being controllably coupled to road wheels of said vehicle, a first electric motor ~~being coupled to said internal combustion engine, said first electric motor~~ being operable as a ~~generator~~ starter, a second motor coupled to the wheels of said vehicle and ~~also~~ operable as a generator, a battery bank for providing electrical energy to and accepting energy from said electric motors, and a controller for controlling operation of said internal combustion engine and the coupling of said engine to said road wheels, of said electric motors, and controlling flow of electrical energy between said electric motors and said battery bank,

characterized in that ~~according to said method~~ said controller controls said internal combustion engine, said electric motors, and the coupling of said engine to said wheels so that said vehicle is operated in a plurality of operating modes, said controller producing control signals in response to vehicle operating conditions to arbitrate between said plurality of operating modes, said controller producing a control signal to operate said internal combustion engine when the ~~responsive to~~ instantaneous torque requirement (RL) of the vehicle, which is the torque ~~on the output drive shaft of~~ required to propel said vehicle, and which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, exceeds a predetermined minimum level so that said internal combustion engine is operated such that the output torque thereof is at least equal to a minimum value at which torque is efficiently produced, said operating modes including:

a low load mode I entered into while RL < SP, wherein SP is a setpoint expressed as a predetermined percentage of MTO, and in which torque propelling said vehicle is provided by said motors,

a highway cruising mode IV entered into while SP < RL < ~~100% of~~ MTO and in which torque propelling said vehicle is provided by said engine, and

an acceleration mode V entered into while RL > ~~100% of~~ MTO and in which torque propelling said vehicle is provided by one or both of said motors and said engine.--

--57. (previously presented) The method of claim 56, wherein SP is equal to at least approximately 30% of MTO.--

--58. (previously presented) The method of claim 56, comprising the further step of decoupling said engine from said wheels during operation in mode I and coupling said engine to said wheels during operation in modes IV and V. --

--59. (Amended) The method of claim 56, wherein said controller further controls said vehicle to operate in a low-load battery charging mode II, entered while RL < SP and the state of charge of the battery bank is below a predetermined level, during which said vehicle is propelled by torque provided by said second motor in response to energy supplied from said battery bank, and wherein said battery bank is simultaneously charged by supply of electrical energy from said first motor being operated as a generator and ~~,~~ being driven by torque at least equal to SP provided by said internal combustion engine, said engine being decoupled from said wheels during operation in mode II.--

--60. (previously presented) The method of claim 56, comprising the further step of employing said controller to monitor patterns of vehicle operation over time and vary said setpoint SP accordingly.--

--61. (previously presented) The method of claim 56, comprising the further step of employing said controller to monitor RL over time, and to control transition between operation in modes I and IV accordingly, such that said transition occurs only when RL > SP for at least a predetermined time, or when RL > SP2, wherein SP2 is a larger percentage of MTO than SP.--

--62. (previously presented) The method of claim 56, comprising the further step of employing said controller to monitor RL over time, and to control transition from operation in mode IV to operation in mode I accordingly, such that said transition occurs only when RL < SP for at least a predetermined time.--

--63. (previously presented) The method of claim 56, comprising the further step of operating said controller to monitor RL over time, and to control the operating mode to change from operation in mode I directly to operation in mode V where a rapid increase in the torque to be applied to the wheels as desired by the operator is detected.--

--64. (Amended) The method of claim 56, comprising the further step of operating said controller to accept operator input of a desired cruising speed, said controller thereafter controlling the instantaneous engine torque output in accordance with variation in RL so as to maintain vehicle speed substantially constant~~, and to prevent transition to mode I operation until the operator provides a further signal indicative that the desired cruising speed is no longer desired~~.--

--65. (Amended) The method of claim 56, comprising the further step of performing regenerative charging of the battery bank ~~under controller control~~ when the engine's instantaneous torque output > RL, when RL is negative, or when braking is initiated by the operator.--

--66. (previously presented) The method of claim 56, wherein said hybrid vehicle further comprises a multispeed transmission disposed between said engine and said motors and the wheels of said vehicle, said transmission being operable responsive to a control signal from said controller to broaden the load-carrying range of said vehicle.--

--67. (Amended) The method of claim 56, wherein said hybrid vehicle further comprises a turbocharger being operatively and controllably coupled to said internal combustion engine for being operated and thereby increasing the maximum torque output of said internal combustion engine to more than MTO when desired, and wherein according to said method, said controller controls selection of the operational mode of said vehicle between a low-load mode I, a cruising mode IV, an acceleration mode V, and a turbocharged mode VI, in response to monitoring the instantaneous torque requirements (RL) of the vehicle over time.--

--68. (Amended) The method of claim 67, wherein said controller controls said vehicle to operate in said modes as follows:

in said low load mode I while RL < SP, wherein SP is a setpoint expressed as a predetermined percentage of MTO, in said highway cruising mode IV while SP < RL < MTO, in said acceleration mode V while RL > MTO for less than a predetermined time T, and in said sustained high-power mode VI while RL > MTO for more than a predetermined time T.--

--69. (Amended) The method of claim ~~67~~ <u>68</u>, wherein said time T is controlled responsive to the state of charge of the battery bank.--

--70. (previously presented) The method of claim 67, comprising the further step of decoupling said engine from said wheels during operation in mode I and coupling said engine to said wheels during operation in modes IV, V, and VI.--

--71. (Amended) A hybrid vehicle operable in a plurality of differing modes, said vehicle comprising an internal combustion engine for providing torque up to a maximum normally-aspirated torque output (MTO), said internal combustion engine being fitted with a turbocharger operable in response to a control signal for increasing the maximum torque output of said internal combustion engine beyond MTO, said internal combustion engine being controllably connected to road wheels of said vehicle through ~~means~~ a torque-transmitting connection controllable by a controller, a first electric motor coupled to said engine, and a second electric motor coupled to road wheels of said vehicle, both said electric motors being operable as generators, a battery bank for providing electrical energy to and accepting energy from said electric motors, at least one controllable inverter/charger connected between said electric motors and said battery bank, and a controller for controlling operation of said internal combustion engine and connection thereof to said wheels, said electric motors, and said turbocharger, and for controlling flow of electrical energy between said electric motors and said battery bank,

characterized in that said controller is provided with a signal indicative of the instantaneous road load (RL) of said vehicle, which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, and controls operation of said internal combustion engine, ~~conection~~ connection of said engine to said wheels, said at least one electric motor, and said turbocharger, so that said vehicle is operated in said plurality of differing modes responsive to said signal, and said controller further controls operation of said vehicle so that said internal combustion engine is operated ~~only~~ when the output torque required to be produced by the engine to prople the vehicle or to propel the vehicle while charging the battery bank ~~thereof~~ is at least equal to a minimum value at which torque is efficiently produced~~;~~ , and wherein:

the road load (RL) is expressed as a percentage of the maximum torque output of the engine while normally-aspirated (MTO), and said operating modes include:

a low-load mode I, wherein said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from said battery bank, while RL < SP, wherein SP is a setpoint expressed as a predetermined percentage of MTO,

a highway cruising mode IV, wherein said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel, while SP < RL < ~~100% of~~ MTO, said turbocharger not being operated in said mode IV,

an acceleration mode V, wherein said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel and by torque provided by said second electric motor in response to energy supplied from said battery bank, while RL > ~~100% of~~ MTO for less than a predetermined time T, said turbocharger not being operated in said mode V, and

a high-power mode VI, wherein said turbocharger is operated such that said vehicle is propelled by torque provided by said internal combustion engine in response to supply of combustible fuel while RL > ~~100% of~~ MTO for more than said predetermined time T.--

--71. (previously presented) The hybrid vehicle of claim 70, wherein said setpoint SP is at least approximately 30% of MTO.--

--72. (previously presented) The hybrid vehicle of claim 70, wherein said engine is disconnected from said wheels during operation in mode I and connected to said wheels during operation in modes IV, V, and VI. --

--73. (previously presented) The hybrid vehicle of claim 70, wherein said time T is controlled responsive to the state of charge of the battery bank.--

--74. (previously presented) The hybrid vehicle of claim 70, wherein torque from said internal combustion engine is transmitted to a first set of road wheels and torque from said second electric motor is transmitted to a second set of road wheels.--

--75. (previously presented) The hybrid vehicle of claim 70, wherein said first electric motor is coupled to said internal combustion engine for starting said internal combustion engine in response to a control signal from said controller.--

--76. (previously presented) The hybrid vehicle of claim 70, further comprising a multispeed transmission disposed between said engine and said motors and the wheels of said vehicle, said transmission being operable to broaden the load-carrying range of said vehicle.--

--77. (Amended) A method for controlling the operation of a hybrid vehicle operable in a plurality of differing modes, said vehicle comprising an internal combustion engine for providing torque up to a maximum torque output (MTO), said internal combustion engine being controllably coupled to road wheels of said vehicle ~~by a clutch~~, a first electric motor being coupled to said internal combustion engine, a second electric motor coupled to road wheels of said vehicle, at least one of said first and second electric motors being operable as ~~generators~~ a generator, a battery bank for providing electrical energy to and accepting energy from said first and second electric motors, and a controller for controlling operation of said internal combustion engine, ~~clutch,~~ and first and second electric motors, and controlling flow of electrical energy between said first and second electric motors and said battery bank,

characterized in that according to said method, said controller controls selection of the operational mode of said vehicle between at least a low-load mode I and a cruising mode IV, wherein torque to propel said vehicle is provided by said at least said second electric motor or said internal combustion engine, respectively, in response to monitoring the instantaneous torque requirements (RL) of the vehicle, which is the torque ~~on the output drive shaft of~~ required to propel said vehicle, and which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, and said controller further controls operation of said vehicle so that said internal combustion engine is operated ~~only~~ in response to a signal indicative of the instantaneous torque demands (RL) of the vehicle, and when loaded such that ~~when~~ the output torque thereof is at least equal to a minimum value at which torque is efficiently produced, and

wherein said vehicle further comprises a catalytic converter comprising a catalyst for reducing undesirable emissions of CO, NOx, and unburned hydrocarbons from said internal combustion engine to harmless products, said catalytic converter being provided with means controlled by said controller for heating said catalyst to an effective working temperature, and wherein when said controller determines that it is desirable to start said engine~~, e.g., in order to change the operating mode of said vehicle from mode I to mode IV, or to charge said battery~~, said controller heats said catalyst to a minimum effective working temperature if necessary before controlling said first electric motor to spin said internal combustion engine for starting.--

--78. (Amended) A method for determining the relative sizes of the internal combustion engine, first and second electric motors, and battery bank of a hybrid vehicle of predetermined weight comprising said components, and a method for operating the vehicle thus designed, the determining steps of said method comprising the steps of:

a. selecting the internal combustion engine having sufficient torque to drive the vehicle at ~~medium to high~~ specified speed along a ~~moderate~~ specified maximum grade;

b. sizing the first electric motor to provide an internal combustion engine load during battery charging adequate to ensure that torque is produced efficiently by said engine;

c. sizing the second electric motor to provide adequate torque at zero speed to overcome the maximum grade specified from rest, with the first electric motor assisting as needed;

d. selecting the torque vs. speed profile of the second electric motor to allow convenient city driving, without use of torque from the internal combustion engine; and

e. selecting the battery capacity to be sufficient to avoid excessively frequent discharging and charging cycles; and

the operating steps of said method comprising the steps of:

a. monitoring the instantaneous torque requirement (RL) of the vehicle, which is the torque ~~on the output drive shaft~~ required for propulsion of said vehicle, and which can be positive, as during steady-state cruising or acceleration, zero, or negative, as during regenerative braking, and

b. employing a controller to control selection of the operational mode of said vehicle between at least a low-load mode I and a cruising mode IV, wherein torque to propel said vehicle is provided by said at least said second electric motor or said internal combustion engine, respectively, in response to RL, and wherein said controller further controls operation of said vehicle so that said internal combustion engine is operated ~~only~~ when loaded such that the output torque thereof is at least equal to a minimum value at which torque is efficiently produced.--

--79. (Previously presented)The method of claim 78, wherein said engine is provided with a turbocharger controlled by said controller to increase the engine's maximum torque output during extended operation under circumstances where RL exceeds the maximum torque output of the internal combustion engine in normally-aspirated mode for an extended period of time, wherein the turbocharger increases the engine's maximum torque output by at least about 25%.--

--80. (Previously presented) The method of claim 78, wherein said first electric motor is sized so as to load the internal combustion engine to approximately 70% of its maximum torque output at an engine speed at which torque is efficiently produced during battery charging.--

Add the following new claims:

--81. (New) A hybrid vehicle, comprising:

an internal combustion engine controllably coupled to road wheels of said vehicle;

a first electric motor connected to said engine and operable to start the engine responsive to a control signal;

a second electric motor connected to road wheels of said vehicle, and operable as a motor, to apply torque to said wheels to propel said vehicle, and as a generator, for accepting torque from at least said wheels for generating current;

a battery, for providing current to said motors and accepting charging current from at least said second motor; and

a controller for controlling the flow of electrical and mechanical power between said engine, first and second motors, and wheels,

wherein said controller starts and operates said engine when torque produced by said engine to propel the vehicle or to propel the vehicle and/or to drive either one or both said electric motor(s) to charge said battery is at least equal to a setpoint (SP) above which said engine torque is efficiently produced.--

--82. (New) The vehicle of claim 81, wherein said controller monitors patterns of vehicle operation over time and varies said setpoint SP accordingly.--

--83. (New) The vehicle of claim 81, wherein said controller monitors RL over time, and controls transition between propulsion of said vehicle by said motor(s) to propulsion by said engine responsive to RL reaching SP, such that said transition occurs only when RL > SP for at least a predetermined time, or when RL > SP2, wherein SP2 > SP.--

--84. (New) The vehicle of claim 83, wherein said controller further controls transition from propulsion of said vehicle by said engine to propulsion by said motor(s) such that said transition occurs only when $RL < SP$ for at least a predetermined time.--

--85. (New) The vehicle of claim 81, wherein said setpoint SP may be varied by said controller as a function of engine speed.--

--86. (New) The vehicle of claim 81, wherein said setpoint SP is at least approximately 30% of the maximum torque output of the engine when normally-aspirated (MTO).--

--87. (New) The vehicle of claim 81, wherein said vehicle is operated in a plurality of operating modes responsive to the value for the road load (RL) and said setpoint SP, both expressed as percentages of the maximum torque output of the engine when normally-aspirated (MTO), and said operating modes include:

a low-load mode I, wherein said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from said battery bank, while $RL < SP$,

a highway cruising mode IV, wherein said vehicle is propelled by torque provided by said internal combustion engine, while $SP < RL < MTO$, and

an acceleration mode V, wherein said vehicle is propelled by torque provided by said internal combustion engine and by torque provided by either or both electric motor(s) in response to energy supplied from said battery bank, while $RL > MTO$.--

--88. (New) The vehicle of claim 87, wherein the combination of said engine and said first motor is disengaged from said wheels during operation in mode I and engaged during operation in modes IV and V.--

--89. (New) The vehicle of claim 87, wherein said operating modes further include a low-speed battery charging mode II, entered while RL < SP and the state of charge of the battery bank is below a predetermined level, and during which said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from said battery bank, and wherein said battery bank is simultaneously charged by supply of electrical energy from said first electric motor, being driven by torque in excess of SP by said internal combustion engine, the combination of said engine and said first motor being disengaged from said wheels during operation in mode II.--

--90. (New) The vehicle of claim 87, wherein the controller may control transition of the operating mode from operation in mode I directly to operation in mode V where a rapid increase in the torque to be applied to the wheels of the vehicle as desired by the operator is detected. --

--91. (New) The vehicle of claim 87, further comprising a turbocharger operatively and controllably coupled to said internal combustion engine for being operated and thereby increasing the maximum torque output of said internal combustion engine to more than MTO when desired, and wherein said controller controls selection of the operational mode of said vehicle between a low-load mode I, a cruising mode IV, an acceleration mode V, and a turbocharged mode VI, in response to monitoring the instantaneous torque requirements (RL) of the vehicle over time.--

--92. (New) The vehicle of claim 91, wherein said controller controls said vehicle to operate in said modes as follows:

in said low load mode I while RL < SP, in said highway cruising mode IV while SP < RL < MTO, in said acceleration mode V while RL > MTO for less than a predetermined time T, and in said sustained high-power mode VI while RL > MTO for more than a predetermined time T.--

--93. (New) The vehicle of claim 92, wherein said time T is controlled responsive to the state of charge of the battery bank.--

--94. (New) The vehicle of claim 81, wherein the controller may accept operator input of a desired cruising speed, and thereafter controls the instantaneous torque output by said internal combustion engine and by either or both motor(s) in accordance with variation in RL so as to maintain vehicle speed substantially constant.--

--95. (New) The vehicle of claim 81, wherein regenerative charging of the battery bank is performed when the instantaneous torque output by the internal combustion engine > RL, when RL is negative, or when braking is initiated by the operator.--

--96. (New) The vehicle of claim 81, wherein the total torque available at the road wheels from said internal combustion engine is no greater than the total torque available from said first and second electric motors combined.--

--97. (New) The vehicle of claim 81, wherein the engine and first electric motor are controllably coupled to a first set of road wheels of said vehicle and said second electric motor is coupled to a second set of road wheels of said vehicle.--

--98. (New) The vehicle of claim 81, further comprising a variable-ratio transmission disposed between said engine and said motors and the wheels of said vehicle.--

--99. (New) The hybrid vehicle of claim 81, wherein said engine is rotated before starting such that its cylinders are heated by compression of air therein.--

--100. (New) The hybrid vehicle of claim 81, wherein the rate of change of torque produced by said engine is limited, such that combustion of fuel within said engine can be controlled to occur substantially at the stoichiometric ratio, and wherein if said engine is incapable of supplying the instantaneous torque required, the additional torque required is supplied by either or both of said motor(s).--

--101. (New) The hybrid vehicle of claim 81, wherein said engine is controllably coupled to road wheels of said vehicle by a clutch.--

--102. (New) The vehicle of claim 81, wherein said engine can be operated at torque output levels less than SP under abnormal and transient conditions, e.g., in order to allow starting and stopping of the engine or to provide torque to satisfy drivability or safety considerations.--

--103. (New) A method of control of a hybrid vehicle, said vehicle comprising an internal combustion engine capable of efficiently producing torque at loads between a lower level SP and a maximum torque output MTO, a battery bank, and one or more electric motors being capable of providing output torque responsive to supplied current, and of generating electrical current responsive to applied torque, said engine being controllably connected to wheels of said vehicle for applying propulsive torque thereto and to said at least one motor for applying torque thereto, said method comprising the steps of:

determining the instantaneous torque RL required to propel said vehicle responsive to an operator command;

monitoring the state of charge of said battery bank;

employing said at least one electric motor to propel said vehicle when the torque RL required to do so is less than said lower level SP;

employing said engine to propel said vehicle when the torque RL required to do so is between said lower level SP and MTO;

employing both said at least one electric motor and said engine to propel said vehicle when the torque RL required to do so is more than MTO; and

employing said engine to propel said vehicle when the torque RL required to do so is less than said lower level SP and using the torque between RL and SP to drive said at least one electric motor to charge said battery when the state of charge of said battery bank indicates the desirability of doing so.--

--104. (New) The method of claim 103, comprising the further step of employing said controller to monitor patterns of vehicle operation over time and vary said setpoint SP accordingly.--

--105. (New) The method of claim 103, comprising the further step of employing said controller to monitor RL over time, and to control transition between propulsion of said vehicle by said motor(s) to propulsion by said engine such that said transition occurs only when RL > SP for at least a predetermined time, or when RL > SP2, wherein SP2 is a larger percentage of MTO than SP.--

--106. (New) The method of claim 103, comprising the further step of employing said controller to monitor RL over time, and to control transition between propulsion of said vehicle by said engine to propulsion by said motor(s) such that said transition occurs only when RL < SP for at least a predetermined time.--

--107. (New) The method of claim 103, comprising the further step of operating said controller to accept operator input of a desired cruising speed, said controller thereafter controlling the instantaneous engine torque output and operation of said motor(s) to supply additional torque as needed in accordance with variation in RL to maintain the speed of said vehicle substantially constant.--

--108. (New) The method of claim 103, wherein said vehicle is operated in a plurality of operating modes responsive to the values for the road load RL and said setpoint SP, said operating modes including:

a low-load mode I, wherein said vehicle is propelled by torque provided by said second electric motor in response to energy supplied from said battery bank, while RL < SP, a highway cruising mode IV, wherein said vehicle is propelled by torque provided by said internal combustion engine, while SP < RL < MTO, and

an acceleration mode V, wherein said vehicle is propelled by torque provided by said internal combustion engine and by torque provided by either or both electric motor(s) in response to energy supplied from said battery bank, while RL > MTO.--

--109. (New) The method of claim 108, wherein said setpoint SP is at least approximately 30% of MTO.--

--110. (New) The method of claim 108, comprising the further step of decoupling said engine from said wheels during operation in mode I and coupling said engine to said wheels during operation in modes IV and V. --

--111. (New) The method of claim 108, wherein said controller further controls said vehicle to operate in a low-load battery charging mode II, entered while RL < SP and the state of charge of the battery bank is below a predetermined level, during which said vehicle is propelled by torque provided by said second motor in response to energy supplied from said battery bank, and wherein said battery bank is simultaneously charged by supply of electrical energy from said first motor being operated as a generator and being driven by torque at least equal to SP provided by said internal combustion engine, said engine being decoupled from said wheels during operation in mode II.--

--112. (New) The method of claim 108, comprising the further step of operating said controller to monitor RL over time, and to control the operating mode to change from operation in mode I directly to operation in mode V where a rapid increase in the torque to be applied to the wheels as desired by the operator is detected.--

--113. (New) The method of claim 108, wherein said hybrid vehicle further comprises a turbocharger being operatively and controllably coupled to said internal combustion engine for being operated and thereby increasing the maximum torque output of said internal combustion engine to more than MTO when desired, and wherein according to said method, said controller controls selection of the operational mode of said vehicle between a low-load mode I, a cruising mode IV, an acceleration mode V, and a turbocharged mode VI, in response to monitoring the instantaneous torque requirements (RL) of the vehicle over time.--

--114. (New) The method of claim 113, wherein said controller controls said vehicle to operate in said modes as follows:

in said low load mode I while RL < SP, wherein SP is a setpoint expressed as a predetermined percentage of MTO, in said highway cruising mode IV while SP < RL < MTO, in said acceleration mode V while RL > MTO for less than a predetermined time T, and in said sustained high-power mode VI while RL > MTO for more than a predetermined time T.--

--115. (New) The method of claim 114, wherein said time T is controlled responsive to the state of charge of the battery bank.--

--116. (New) The method of claim 103, comprising the further step of performing regenerative charging of the battery bank when the engine's instantaneous torque output > RL, when RL is negative, or when braking is initiated by the operator.--

--117. (New) The method of claim 103, wherein said hybrid vehicle further comprises a variable-ratio transmission disposed between said engine and said motors and the wheels of said vehicle, said transmission being operable responsive to a control signal from said controller.--

--118. (New) The method of claim 103, wherein a clutch connects a first output shaft of or driven by said engine and/or first motor with a second output shaft of or driven by said second motor connected to said wheels, and wherein the speeds of said engine and/or first motor and of said second motor are controlled such that when said clutch is engaged the speeds of the first and second output shafts are substantially equal, whereby said shafts may be connected by a non-slipping clutch.-

--119. (New) The method of claim 103, wherein the rate of change of torque output by said engine is limited, such that combustion of fuel within said engine can be controlled to occur substantially at the stoichiometric ratio, and wherein if said engine is incapable of supplying the instantaneous torque required, the additional torque required is supplied by either or both of said motor(s).--

--120. (New) The method of claim 103, wherein said engine is rotated before starting such that its cylinders are heated by compression of air therein.--

--121. (New) The method of claim 103, wherein said engine can be operated at torque output levels less than SP under abnormal and transient conditions, e.g., in order to allow starting and stopping of the engine or to provide torque to satisfy drivability or safety considerations.--

--122. (New) A hybrid vehicle of predetermined weight comprising an internal combustion engine, starting/charging and traction motors, and battery bank, said components being specified as follows:

a. the internal combustion engine having sufficient torque to drive the vehicle at specified speed along a specified maximum grade;

b. the starting/charging motor being connected to the engine and providing an engine load during battery charging equal to at least a setpoint SP which is a minimum level at which the engine efficiently produces torque;

c. the traction motor providing adequate torque at zero speed to overcome the maximum grade specified from rest, with the starter motor assisting as needed; and

d. the battery bank being sized so that is is capable of being charged by said starting/charging motor while loading said engine to said setpoint SP, and so that the ratio of the battery voltage to the peak current drawn by the motor(s) when producing maximum torque is at least 2.5 : 1.--

--123. (New) The method of claim 20, wherein said clutch connects a first output shaft of or driven by said engine and/or first motor with a second output shaft of or driven by said second motor connected to said wheels, and wherein the speeds of said engine and/or first motor and of said second motor are controlled such that when said clutch is engaged during the transition from mode I to mode IV, the speeds of the first and second output shafts are substantially equal, whereby said shafts may be connected by a non-slipping clutch.-

--124. (New) The method of claim 17, wherein the rate of change of torque output by said engine is limited, such that combustion of fuel within said engine can be controlled to occur substantially at the stoichiometric ratio, and wherein if said engine is incapable of supplying the instantaneous torque required, the additional torque required is supplied by either or both of said motor(s).--

--125. (New) The hybrid vehicle of claim 17, wherein said engine is rotated before starting such that its cylinders are heated by compression of air therein.--

--126. (New) The hybrid vehicle of claim 35, wherein the rate of change of torque output by said engine is limited, such that combustion of fuel within said engine can be controlled to occur substantially at the stoichiometric ratio, and wherein if said engine is incapable of supplying the instantaneous torque required, the additional torque required is supplied by either or both of said motor(s).--

--127. (New) The hybrid vehicle of claim 33, wherein said engine is rotated before starting such that its cylinders are heated by compression of air therein.--

--128. (New) The hybrid vehicle of claim 33, further comprising a transmission for varying the ratio between the speeds of input and output shafts thereof, disposed between said engine and said motors and the wheels of said vehicle.--

--129. (New) The method of claim 56, wherein the rate of change of torque output by said engine is limited, such that combustion of fuel within said engine can be controlled to occur substantially at the stoichiometric ratio, and wherein if said engine is incapable of supplying the instantaneous torque required, the additional torque required is supplied by either or both of said motor(s).--

--130. (New) The method of claim 56, comprising the further step of rotating said engine before starting such that its cylinders are heated by compression of air therein.--

--131. (New) The hybrid vehicle of claim 71, further comprising a transmission for varying the ratio between the speeds of input and output shafts thereof, disposed between said engine and said motors and the wheels of said vehicle.--

--132. (New) The hybrid vehicle of claim 77, wherein said engine is rotated before starting such that its cylinders are heated by compression of air therein.--

--133. (New) The method of claim 16, wherein step (c) precedes either or both of steps (a) and (b). --

--134. (New) The vehicle of claim 33, wherein said controllable torque-transmitting connection between the combination of the engine and first electric motor and the wheels of said vehicle is made by a clutch.--

--135. (New) The method of claim 56, wherein said engine is controllably coupled to the wheels of said vehicle by a clutch.--

--136. (previously presented as claim 71, second occurrence) The hybrid vehicle of claim ~~70~~ 71, wherein said setpoint SP is at least approximately 30% of MTO.--

--137. (New) The hybrid vehicle of claim 71, wherein said engine is controllably connected to the wheels of said vehicle by a clutch.--

--138. (New) The vehicle of claim 33, wherein said engine can be operated at torque output levels less than SP under abnormal and transient conditions, e.g., in order to allow starting and stopping of the engine or to provide torque to satisfy drivability or safety considerations.--

--139. (New) The method of claim 17, wherein said engine can be operated at torque output levels less than SP under abnormal and transient conditions, e.g., in order to allow starting and stopping of the engine or to provide torque to satisfy drivability or safety considerations.--

--140. (New) The vehicle of claim 49, wherein said engine can be operated at torque output levels less than SP under abnormal and transient conditions, e.g., in order to allow starting and stopping of the engine or to provide torque to satisfy drivability or safety considerations.--

--141. (New) The method of claim 56, wherein said engine can be operated at torque output levels less than SP under abnormal and transient conditions, e.g., in order to allow starting and stopping of the engine or to provide torque to satisfy drivability or safety considerations.--

REMARKS

After entry of the above amendment, claims 16 - 141 remain in the application. Amendments have been made to some of claims 16 - 80 presented previously to clarify the scope of the invention, while claims 81 - 141 are new. All claims are directed to the hybrid vehicle, its method of control, or the relative capabilities of its components, which are all closely related aspects of the invention. It is respectfully submitted that claims 16 - 141 can properly be examined in a single application.

No new matter is added by this amendment. The subject matter of the independent claims has clearly been addressed in the parent application. As to the new dependent claims, support for claim 118 (non-slipping clutch) is provided at page 46, lines 11 - 34, page 47, lines 20 - 33, for claims 99, 120, 125, 127, 130 and 132 (rotating the engine before starting to preheat the cylinders) at page 69, lines 17 - 21; for claims 117, 128, and 131 (transmission) at page 57, lines 11 - 15; and for claims 119, 124, 126 and 129 (control of rate of change of engine speed with the motors supplying the torque deficiency, if any) at page 70, line 17 - page 71, line 1 and page 69, lines 22 - 26.

Support for claims 102, 121, and 131 - 141 (operation of engine at torque output levels less than SP under abonormal or emergency conditions) is provided by discussion of use of "fuzzy logic" to vary SP responsive to variation in operating conditions, usage over time, and the like. See page 63, lines 2 - 12. Further, it will be realized that such conditions as starting and stopping the engine are essential, but during which the engine cannot produce torque at least equal to SP; thus it would be realized by one of skill in the art that the engine would necessarily operated other than at outputs less than SP during these transient or abnormal circumstances. Production of torque less than SP during starting is also shown in Fig. 7(a), at point D.

Entry of the Amendment and favorable action on the merits is earnestly solicited.

For the Examiner's information, a Supplemental Information Disclosure Statement reflecting the results of several new searches, action before foreign Patent Offices, and other sources of information is intended to be filed shortly.

Respectfully submitted,

5/19/04
Dated

Michael de Angeli
Reg. No. 27,869
60 Intrepid Lane
Jamestown, RI 02835
401-423-3190

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JUN 02 2004
GROUP 3600

In re the Patent Application of Severinsky et al

Serial No.: 10/382,577

Filed: March 7, 2003

For: Hybrid Vehicles

Examiner: N/A

Group Art Unit: 3616

Att. Dkt.: PAICE201.DIV

#8
6-2-04

Hon. Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

Sir:

As discussed in the Preliminary Amendment dated August 11, 2003 in this application, applicants have performed additional searching for new patents possibly relevant to the subject matter of this application as amended, and other new patents and other documents have also come recently to applicants' attention. A number of patents and other documents thus located are listed on attached PTO-1449 forms, and are discussed below. Citation of a document herein should not be considered an admission that the disclosure thereof is indeed relevant to the invention defined by the claims, nor that the document thus made of record is indeed effective as prior art under 35 USC '102.

A correction is also desirable with respect to a statement made in an earlier Information Disclosure Statement (IDS). In the IDS filed on November 18, 1999 in grandparent application Ser. No. 09/264,817, which has been incorporated by reference to form part of the IDS for the present application, Taniguchi patent 5,846,155 was described as showing "a parallel hybrid of generally conventional topology, that is, comprising an ICE [internal combustion engine] and an electric motor connected to the road wheels of the vehicle through a continuously-variable transmission, but discloses a relatively sophisticated operational scheme, wherein the source of propulsive torque varies in accordance with the road load and the state of charge of the battery bank ('SOC')".

This could be misunderstood to suggest that Taniguchi suggests control of the hybrid vehicle's operating mode responsive to the road load and SOC. In fact, Taniguchi does not teach selection of the source of vehicle propulsive torque, much less the operating mode, in accordance with the road load and SOC, but in response to vehicle speed and accelerator pedal position. See col. 8, lines 13 - 40:

> Moreover, the individual engagement means, as shown in FIGS. 4 and 5, are operated as shown in the operation diagram of FIG. 6. *In the power split mode, the split drive unit 9 functions at the start and at a low/medium speed.* The output of the engine 2 is transmitted to the ring gear R through the input clutch Ci. On the other hand, the rotor 5a of the motor-generator 5 is connected to the sun gear S to charge the engine output partially or to output it as the motor so that the composed force is output from the carrier CR to the CVT input shaft 7a.
>
> On the other hand, *the parallel hybrid mode functions in a medium/high speed range.* In this state, the rotary elements of the planetary gear 6 are rotated together, and the output of the engine 2 is fed as it is to the CVT input shaft 7a. At the same time, the motor-generator 5 is connected to the input shaft 7a to assist the engine output or to charge the output partially.
>
> *The motor mode is in the state in which the accelerator opening is small and in which the revolution number is small, e.g., in which the engine 2 need not be used, such as in a traffic jam. Then, the motor-generator 5 is used as the motor to drive the vehicle.* In this state, the input clutch Ci is released to disconnect the engine 2 and the CVT input shaft 7a, and the direct-coupled clutch Cd is applied to output the revolution of the motor-generator rotor 5a directly to the input shaft 7a.
>
> *On the other hand, the engine mode functions during high speed cruising, and the vehicle is driven exclusively by the engine output without any participation of the motor-generator 5.* [Emphasis added].

The Examiner is respectfully requested to review the Taniguchi reference and confirm that in fact the road load is not used to determine the operating mode; in fact, Taniguchi controls the operation of the CVT, and the source of propulsive torque, in response to the vehicle speed and accelerator pedal position.

Turning now to new documents made of record hereby:

Abe 6,281,660 shows a battery charger for an electric vehicle.

Adler et al patent 5,515,937 claims a series hybrid where the power required by traction motors is drawn from either the batteries or directly from the engine/generator unit directly, depending on evaluation of their respective efficiencies and the batteries' state of charge, with respect to each new demand for power.

Barske patent 5,336,932 ties the operation of a generator used to charge a battery to specific fuel-consumption curves stored in ROM.

Bullock patent 6,170,587 shows a hybrid drive, all claims of which require at least three different types of energy storage, e.g., combustible fuel, battery, flywheel, or hydraulic accumulator.

Fattic et al patent 5,637,987 shows a hybrid vehicle in which an internal combustion engine and motor are coupled by controllable friction or electrical loading devices to control ratios.

Gray, Jr. patent 5,887,674 relates to a vehicle driven by a "fluidic motor", that is, having a hydraulic motor driving the wheels, in turn driven by a pump driven by an internal combustion engine.

Patent 4,762,191 to Hagin discloses a hybrid power train for a bus wherein multiple axles are driven via a driveshaft. Some of the dependent claims of the present application, recite connection of the combination of engine and first electric motor to a first set of wheels and connection of the second electric motor to a second set of wheels, which is quite different.

Hoshiya patent 6,315,068 shows a hybrid in which control of the torque provided by the motor is responsive to the torque provided by the engine, so that the engine can be operated at a target speed.

Ibaraki patent 5,856,709, discloses and claims a hybrid topology wherein an engine and a motor/generator are connected to different elements of a "synthesizing/distributing mechanism". A large number (nine or more) of operating modes are provided. The determination of the amount of torque required to propel the vehicle is apparently made in response to the position of the acclerator pedal; see col. 15, lines 59 - 61.

Patent 6,225,784 of Kinoshita claims a battery charge controller for a vehicle, wherein the level of charge above which further charging is permitted is varied based on the battery temperature. Patent 6,232,748 to the same inventor and assignee allows only discharge when the battery is above a specified temperature, and patent 6,204,636, again to the same inventor and assignee, controls the charging and discharge rate of the battery responsive to sensing of the "memory effect" of the battery. None of these expedients are claimed in the present application.

Four Lawrie and Lawrie et al patents, 5,993,350, 6,019,698, 5,979,257, and 6,006,620, and Reed et al 5,943,918 (et al here including Lawrie) are directed to transmissions for hybrids that combine the efficiency of manual transmissions with the convenience of automatic transmissions. Motors are used to operate the conventional "H"-pattern shifter, and a clutch, while the motor/generator present in a hybrid is employed to match the speeds of input and output shafts, to ensure smooth shifting. Finally, Reed, Jr. et al 6,332,257 claims a method of converting a manual transmission to automated operation.

Lovatt et al patent 6,291,953 shows an "electrical drive system", in some cases applied to a hybrid vehicle, requiring a lock-up torque converter.

Minowa et al patent 6,142,907 (Hitachi) claims a hybrid wherein either an engine or a motor is used to propel the vehicle. A generator is selectively connected to the wheels through a two-speed transmission. Patent 6,328,670 is a continuation.

Morisawa et al 5,984,034 discloses a hybrid wherein regenerative braking is used to oppose engine torque when idling to keep the vehicle stopped. Morisawa et al 6,119,799 issued on a continuation and discloses a hybrid offering control of braking responsive to "obstruction [e.g., a car ahead] detection". Another patent based on the same underlying document, no. 6,334,498, claims supplying power from a motor during upshifts of an automatic transmission being driven by an engine. None of these is a feature of the claimed invention.

Another Morisawa patent, no. 5,895,333, is limited to packaging details for a planetary gearbox for a hybrid vehicle. Still another Morisawa patent, no. 6,306,057, claims a complex planetary gearbox arranged so that the internal combustion engine is used to power the vehicle when reversing.

Nagano et al 6,344,008 discloses a hybrid wherein a transmission is coupled between an engine and a torque synthesizing device, which also accepts torque from a single motor.

Nakajima et al 6,090,007 shows a control scheme for a hybrid vehicle including a continuously variable transmission. Patent

6,328,671 to Nakajima et al is a continuation-in-part of the '007 patent and shows setting the "target drive power" based on the accelerator pedal position and vehicle speed.

Nekola patent 5,660,077 shows a variable-speed transmission stated to be useful in a hybrid vehicle, including a cone-shaped gear; the meshing gear slides along the conical gear to vary their relative speeds.

Nitta patent 6,321,150 shows an Aabnormality monitoring system@ that is responsive to faults in a very specific type of communication scheme that can be used for a hybrid vehicle. Another Nitta patent, no. 6,203,468, requires first and second motors on either side of a lock-up clutch, to smooth transitions between series and parallel operation.

Nogi et al patent application US 2001/0037905 is directed to lean-burn operation of a hybrid.

Omote patent 5,944,630 claims controlling torque applied by a motor during shifting operations, to smooth shift transitions.

Oyama patent 6,070,680 relates to prevention of stalling of the engine of a hybrid vehicle due to rapid deceleration; the traction motor provides torque to the engine in such cases.

Patent 6,123,642 to Saito claims a "speed change control apparatus" wherein a motor is connected to the wheels of a vehicle through a multispeed transmission; power to the transmission is cut during shifting.

Tabata et al patent 6,158,541 shows a hybrid vehicle wherein the battery is divided into several portions so that one or more can be completely discharged while the others remain partially charged.

A further Tabata et al patent, no. 5,847,469, is directed to a hybrid wherein the electric motor is employed for reversing if the battery is sufficiently charged, and the engine otherwise.

Another Tabata et al patent, no. 6,317,665, shows a hybrid in which a torque converter with lock-up clutch is disposed between the engine and motor and the wheels; the claims require the lock-up clutch to be released during mode switching to prevent rough running.

Another Tabata patent, no. 6,183,389, is directed to hybrids having "torque transmission systems" (i.e., torque converters; see col. 1, line 52) fitted with lock-up clutches; the invention has to do with the control system for the clutch.

Yet another Tabata et al patent, no. 5,873,426, claims a hybrid having an automatic transmission with differing shift patterns selected depending on the load; apparently, the engine is used as the only torque source in one mode and the engine and motor together in another.

Another Tabata et al patent, no. 5,923,093, recites in claim 1 that the automatic transmission is inhibited from shifting during regenerative braking, in claim 5 "braking shift control means" used when regenerative braking is not available, to downshift the transmission to increase engine braking, in claim 13 braking shift control means operated similarly prior to operation of regenerative braking, in claim 17 a clutch between transmission and engine that is engaged during regenerative braking, and in claim 23 means for preventing changing between engine and regenerative braking during a braking operation.

Still a further Tabata et al patent, no. 6,340,339, is limited to specific constructional details of a motor and transmission assembly for a hybrid.

In another Tabata et al patent, no. 5,935,040, claims 1, 5, 7, and 9 all require a manually-operated member for selecting drive modes, while claim 3 requires an automatic transmission operated so that the drive force remains constant in various drive modes as long as the required output remains constant.

Takaoka et al patent application US 2003/0085577 has claims drawn to control of gear selection in an automatic transmission for a hybrid based on engine efficiency; apparently, if the torque required cannot be supplied efficiently by the engine and motor working together, the transmission is downshifted.

Tuzuki et al patent 5,415,603 shows details of a hydraulic system for a hybrid vehicle in which the oil is used for cooling of a traction motor and lubrication of the transmission.

Wakuta et al patent 6,258,001 is directed to very narrow mechanical aspects of a motor and transmission assembly for a hybrid.

Woon et al patent 5,890,470 claims a method of controlling engine output power, evidently intended to improve on conventional governors as used on diesel engines to smooth throttle response and shifting. Claim 1 is typical and requires operating the engine at a constant horsepower value responsive to throttle position regardless of engine speed.

Yamada et al patent 6,328,122 discloses a series hybrid wherein the ICE can be used for vehicle propulsion only in the event of a failure in the charging system.

Nada patent 6,653,230 is also directed to operation of a hybrid after a particular failure.

Yamaguchi patent 5,915,489 shows a hybrid powertrain. It appears that the output torque is determined based on vehicle speed and accelerator pedal position; see col. 6, lines 17 - 21.

Yamaguchi et al patent 6,278,195 shows applying torque from the electric motor of a hybrid to quickly stop the engine.

Yamaguchi et al patent 6,247,437 claims control of the operation of a starter motor, e.g., for a hybrid, responsive to an engine parameter relevant to its startability. For example, if the engine is cold, fuel is supplied at a lower cranking RPM to limit the drain on the battery. A divisional application (not being supplied), Yamaguchi et al published patent application 2001/0022166, similarly claims a starting control for an engine, in which the rotating speed is limited when the engine is cold to avoid excessive use of battery power.

Yamaguchi patent 5,967,940 is directed to control of the power provided by the engine of a hybrid to prevent noise due to gear backlash.

Yamaguchi 6,135,914 discloses a method of control of a hybrid including an ICE and two motor/generators. The invention has to do with limiting the engine speed so that the first motor/generator is not rotated beyond its capability in the event of a failure The Yamaguchi system operates in engine-only, motor-only, and engine+motor modes (see col. 4, lines 46 - 54), but the method by which the choice between these is made is not explicit.

Field patent 5,081,365 discloses a hybrid vehicle wherein an engine is connected to road wheels through an electric motor, which is operated variously as traction motor or generator, depending on the batteries' state of charge and the vehicle operating mode; the operating mode is selected by the operator from an urban mode, a highway mode, an engine mode, and a cruise control mode. The selection is apparently to be made responsive to motor speed. Field acknowledges at col. 7, line 48 the desirability of operating the engine near its rated power to thus realize high efficiency; as discussed in detail below, Field suggest using an engine that is sized so that it operates at nearly maximum output during flat-highway, constant speed cruising. Such an engine would necessarily be too small to propel the vehicle up hills, so its performance would suffer under such circumstances.

Two additional patents to Field and Field et al, nos. 6,044,922 and 6,481,516, relate to developments of the system disclosed in the '365 Field patent above; the '516 patent is stated to be a continuation of the '922 patent, but their disclosures are not in fact identical. The vehicle described in these patents comprises two separate battery packs, a high-voltage battery pack for supplying power to the traction motor and a lower-powered accessory battery for operating usual vehicle ancillary components such as lights, radio, and the like.

Kubo patent 5,722,502 shows a hybrid vehicle comprising an ICE, a generator and a traction motor also operable as a generator. The vehicle can be operated in a variety of modes, include PEV ("pure electric vehicle", in which the ICE is not run at all; see col. 10, lines 18 - 28), SHV ("serial electric vehicle", wherein the ICE is run to drive the generator, which in turn supplies current to the traction motor to power the vehicle; see col. 5, lines 33 - 51), and "continuous-type PSHV" ("parallel-serial hybrid vehicle", where torque from the ICE is used to propel the vehicle and to drive the generator to power the traction motor to propel the vehicle if torque from the ICE is inadequate; see col. 5, lines 52 - 66). A distinction is drawn between this continuous-type PSHV and a "changeover-type PSHV", as exemplified by Japanese Laid-Open Publication 2-7702; see col. 3, lines 2 - 9 and col. 5, line 66 - col. 6, line 10.

The selection between the PEV mode and one or the other of the SHV and PSHV modes is made by the operator (see col. 10, line 47), while the selection between SHV and PHSV modes is made according to the battery's state of charge (SOC); see col. 6, lines 12 - 13. When the driver selects a mode other than the PEV mode, the engine is operated continuously (col. 11, lines 26 - 32), and may idle when not significantly loaded (col. 12, lines 31 - 32; col. 13, lines 51 - 52); if the battery is fully charged but braking is required, such that regenerative braking would be inappropriate, the engine can be operated as a mechanical brake (col. 11, lines 6 - 20).

In PSHV mode, an engine control unit (ECU) then determines whether torque is to be supplied from the traction motor, ICE, or both, depending on the accelerator pedal angle: "Further, if the change in accelerator pedal angle is too large for the torque to be supplied...by the ICE alone or...by the ICE alone because fuel consumption and emission are degraded, the ECU 20 controls the [inverter] to compensate by using the motor 10 for at least that part of the torque required at the driving wheels." (Col. 13, lines 32 - 39). At low speeds in PSHV mode, it appears that the ICE provides power to the traction motor through the first motor, being operated as a generator.

Tsukamoto et al 5,771,478 shows a hybrid vehicle in which the function of a clutch or torque converter, allowing slipping of an ICE with respect to the wheels of a vehicle, e.g., when accelerating from a stop, is provided by a gearbox connected between the ICE, wheels, and a motor-generator. Excess torque provided by the ICE at starting is absorbed by the motor-generator and stored in a battery; it can then be used to run accessories or propel the vehicle.

Tabata et al 5,833,570 relates to smoothing the shifting of an automatic transmission of a hybrid by application of torque from the traction motor. Tabata 5,951,614 is generally similar, but shows smoothing of shifting by reducing the torque supplied by either the motor/generator or ICE.

Hata et al 5,875,691 discloses and claims a specific arrangement of the components of a hybrid (ICE, motor, transmission) for packaging convenience.

Haka 5,931,271 shows a hybrid powertrain wherein one-way clutches are provided so that the same motor/generator can start an ICE and be disconnected therefrom for efficient regenerative braking.

Shibata et al patent 3,719,881 shows a battery charger arrangement especially for a serial hybrid vehicle, wherein an internal combustion engine is operated to drive a generator only above a minimum load, so as to reduce emissions, which increase at low loads.

Etienne patent 4,187,436 also shows a battery charging arrangement for a serial hybrid vehicle, which includes a first battery for powering the traction motor and a second battery for starting the ICE.

Lynch et al patent 4,165,795 shows a hybrid drive arrangement in which an ICE and a motor/generator are mechanically coupled to one another, and to the wheels of the vehicle, through a transmission. The engine is sized to provide the average power necessary for ordinary driving, and is operated near its optimal efficiency point at all times; the motor/generator is operated for load-leveling, that is, when the vehicle's torque requirements exceed the power provided by the engine the motor/generator adds torque, and when the engine's torque output exceeds the vehicle's torque requirement, the motor/generator operates as a battery charger. The difficulty with this approach is simply that the vehicle's torque requirements may vary by a factor of up to 1000%, or more, between city driving and highway driving, particularly when there are grades (using battery power to climb a grade of any length will quickly discharge any reasonably-sized battery bank) so this solution is not useful in "real-world" driving.

Hadley et al 5,283,470 shows an electric car, that is, without ICE, with regenerative braking. Hadley et al 5,406,126 is similar.

Schmidt 5,669,842 shows a hybrid drive in which either the ICE or one of several separate motors drive the accessories, depending on whether the engine is running. The engine and motors are arranged so that the engine and the mating member of the geartrain are driven at the same speed, allowing the clutch to be synchronously engaged.

Ibaraki et al 6,003,626 discloses a hybrid in which the engine normally propels the vehicle and charges the battery through a generator; if the generator fails, the engine propels the vehicle.

Takahara et al 6,009,365 discloses a hybrid with ICE and motor connected to the wheels through a continuously variable transmission (CVT). During coasting the actual torque being exerted is compared to a calculated desired torque and the actual torque adjusted accordingly.

Bower patent 6,231,135 relates to improvements in brake systems for hybrid vehicles. Although the present application is a division of an application which was a continuation-in-part of earlier applications, and which added disclosure of a new braking system to the disclosure of the parent application, no claims to that braking system are now being pursued in this application.

Soejima 5,951,118 discloses a vehicle braking system, not limited to hybrids, which includes a seating velocity reducing device for slowing the closing of a valve; this can be employed together with regenerative braking in a hybrid. Otomo et al 5,984,432 is similar. As above, no claims of the present application are directed to improvements in braking systems, although the parent was a C-I-P which added material relating thereto to the disclosure of the grandparent application.

Numazawa et al patent 5,497,941, Umebayahi et al patent 6,265,692, and Matsuda et al patent 6,357,541 all relate to improvements in HVAC systems. As in the case of the braking systems discussed above, no claims are currently being pursued to certain new material relating to HVAC systems that was added by the parent C-I-P application to the disclosure of the parent applications.

Takahara et al patent 6,064,161 shows operating a motor/generator of a hybrid to brake a slipping wheel. This is not a feature of the claimed invention. Takahara also shows that the vehicle operating mode can be controlled responsive to accelerator pedal position and vehicle velocity, in common with many other references. See Fig. 5.

Kaiser et al 5,979,158 suggests that emissions of an ICE on starting can be reduced by spinning the ICE to a speed approximating its idle speed, activating the ignition system for about a second, and only then activating the fuel supply. This is suggested to be useful in a hybrid. No claims of the present application are directed to high-rpm starting, although the advantages of doing so are discussed in the application. Kaiser also mentions preheating of the catalyst; this step is recited in claim 77, but is not solely relied upon for patentability. Claim 77 recites, *inter alia,* that the vehicle's operating mode is selected responsive to road load, which is not shown by Kaiser.

Salecker 5,983,740 discloses a system for controlling the engine speed during shifting of an automatic transmission to smooth transition between gears; there is a brief mention that this could be useful in a hybrid.

Salecker 6,006,149 has a closely related disclosure and claims continuing to monitor operating parameters, especially temperatures of various components, for a time (the example being one second) after the engine has been shut off.

Yang patent 5,562,566 is extremely difficult to understand, but appears to disclose a power unit combining an ICE and a motor, which is stated to be useful in vehicles, ships, aircraft, and in industrial and process equipment. The invention seems to be directed to a unit for combining the torque, but again the patent is extremely difficult to understand. Patents 5,547,433 and 5,549,524, also to Yang, appear to be directed to related inventions.

Origuchi patent 5,212,431 is directed to a serial electric hybrid vehicle wherein a generator, preferably to be driven by a gas turbine, is operated in response to monitoring of the battery's state of charge.

Antony et al 5,714,851 shows a serial hybrid with a bypass current path around the rectifiers and battery, to connect a generator driven by an ICE directly to a traction motor.

Horwinski patent 3,904,883 discloses a hybrid, wherein a single electric motor/generator is provided with separably rotatable armature and rotator, so that the unit can be operated as both motor and generator. An ICE is provided to drive the unit, and also to propel the vehicle under various conditions. Mode switching is apparently to be accomplished responsive to the battery's state of charge; see col. 5, lines 20 - 21 and col. 6, lines 64 - 66. The vehicle is intended to operate primarily as an electric car, with overnight charging from the power grid (see col. 6, lines 45 - 51) with the engine primarily provided as a range-extender, though, as noted, the engine can supply torque to the wheels; see col. 5, line 64 - col. 6 line 30.

Reichmann et al 5,851,698 and Venkatesan et al 5,856,047 are directed to nickel-metal hybride (NiMH) batteries optimized for hybrid vehicle applications.

Park 4,331,911 shows a method for equalizing the voltage across individual cells of storage batteries.

Miller et al 4,126,200 shows a vehicle having a flywheel for energy storage. Hagin et al 4,216,684 is similar. Matthews 4,591,016 shows recovering energy during regenerative braking by accelerating a flywheel. Michel 4,592,454 shows doing so employing a hydropneumatic accumulator.

Stuhr 4,674,280 shows an accumulator for the storage of energy in a hydraulic system.

Fiala 4,416,360 shows a vehicle powertrain in which a flywheel connected to the engine by a clutch is rotated by a starter motor, and then used to start the engine using rotational inertia stored in the flywheel; the "starter" motor can then be operated as a generator to recharge the battery.

Moore 4,090,577 shows a hybrid with a conventional engine/transmission assembly driving one pair of wheels, with a solar-charged battery and motor combination driving a second pair.

Walker 5,323,688 discloses hydraulic wheel motors stated to be capable of regenerative braking.

Coe 5,384,521 discloses flywheel energy storage for a vehicle, with electromagnetic couplers.

Boll et al 5,623,194 shows a charge information system for an electric or hybrid vehicle for monitoring battery status and advising the operator.

Weiss 5,947,855 shows a hybrid drive for a tractor or the like wherein torque from an ICE is combined with torque from an electric motor, driven by a generator powered by the ICE is combined individually at the drive wheels by a "Ravigneaux" summing gear set. This is stated to provide flexibility in control.

Smith 5,971,088 shows a battery charging apparatus for regenerative charging wherein the generator is built into the vehicle driveshaft and moves with it as the vehicle encounters bumps and the like.

Walker 5,971,092 shows a hybrid comprising two ICEs, sized to accomodate differing typical loads, plus a hydraulic accumulator. The engines are preferably two-strokes with "inertia pistons" sliding in bores in the main pistons.

Schulze et al 5,675,203 shows a motor/generator; the direction of rotation of the output shaft can be reversed by axial movement of a short-circuit winding.

Fliege 5,675,222 shows switchable winding motors for electric road vehicles.

Fliege 5,915,488 shows reducing the power supplied to switching components in a hybrid drive in response to detection of acceleration over a limiting value, e.g., to prevent sparking and erosion of switch contacts as they are jarred apart over bumps.

Lutz 5,679,087 and 5,685,798 disclose details of planetary gearboxes for vehicles.

Lutz 5,691,588 shows a clutch assembly for connecting motor and ICE of a hybrid, having separately-actuated friction plates on opposite sides of a hub forming part of the rotor.

Lutz et al patent 5,755,302 discloses a specific arrangement of a clutch connecting an engine, motor, and transmission of a hybrid - the rotor is attached to the transmission shaft and the stator to either the engine or the transmission housing, while the clutch also fits at least partially within the stator.

Fliege 5,678,646 discloses modular motors that can be stacked with interconnected coolant circuits to provide different power capacities, stated to be useful in hybrids.

Ruthlein et al 5,698,905 relates to emergency starting of a hybrid with a dead battery, by rearranging connections to allow starting by towing.

Lutz 5,713,427 shows a coupling structure for a hybrid comprising a deformable, resilient disc member.

Lutz 5,829,542 shows vehicles with separate motors on each wheel of at least one pair of wheels.

Welke patent 5,833,022 shows a specific constructional arrangement for a clutch and single traction motor of a hybrid vehicle. No operating scheme is discussed.

Adler et al 5,816,358 shows automatic disconnection of the current supply in the event of accident or the like in vehicles having relatively high current and voltage electric power supplies, e.g., hybrid vehicles.

Gardner 4,753,078 shows a hopelessly complicated hybrid vehicle design involving, among other impracticalities, "recovery of electricity from electromagnetic wind generators, gyrogenerators, and gravitational generators, and for the recovery of compressed air from air pumps...replacing the standard shock absorbers."

Wicks 5,000,003 shows a "combined cycle" engine wherein heat normally lost in the exhaust gases and rejected by heat exchange with cooling water from an ICE is recovered and used to drive a turbine or the like, and suggests that this might be especially suitable for use in a hybrid vehicle.

Lay 5,141,173 shows a vehicle capable of flight as well as travel along the ground. An ICE can propel the vehicle or drive a generator and thence electric motors, depending on the range and speed of intended travel.

Kutter 5,242,335 shows a drivetrain for a hybrid vehicle, shown in automobile and bicycle embodiments, wherein muscle power is combined with power from an auxiliary motor.

Kuang 5,264,764 shows use of an ICE as a power source to serve as a range extender for an electric car, that is, the ICE does not directly propel the vehicle.

Addie 3,699,351 shows a bi-modal vehicle, such as a rail car, which can be propelled by an external power source, such as a third rail, or by a prime mover, such as a gas turbine. A split torque device allows some of the turbine torque to be delivered to the output shaft and the remainder to a motor/generator combination.

Shibata et al 3,719,881 shows a series hybrid, that is, an electric car comprising an ICE arranged to charge a battery connected to a traction motor, wherein the battery's state of charge is monitored and used to control operation of the ICE; the load on the ICE is monitored and the ICE is shut off when the load drops below a predetermined value.

Berman patent 3,753,059 shows a control circuit for a motor operated in both propulsive and regenerative modes, as might be employed in the hybrid vehicle drive system of Berman patent 3,566,717, already of record. Berman 3,790,816 shows an "energy storage and transfer power processor" apparently intended for use with the same system.

Williams 4,099,589 shows a series hybrid wherein the preferred power path is from an ICE to an AC generator to an AC motor, to the wheels; a rectifier, battery and DC motor are also provided as an auxiliary or additional power source.

Rowlett 4,233,858 shows a vehicle propulsion system wherein two electric motors are provided. Torque from the two motors is combined; excess torque is stored in a flywheel, to provide load-leveling.

Dailey 4,287,792 shows a variable gear ratio transmission.

Fiala 4,411,171 shows a hybrid vehicle power train in which a single electric motor/generator and an ICE are coupled to the wheels of the vehicle. Various operating modes are described.

Tankersley et al patent 5,403,244 shows an electric vehicle with a planetary gearbox for reducing the shaft speed of an electric motor to a speed suitable for driving the wheels of the vehicle, and also providing a direct drive.

Hadley et al 5,406,126 shows another serial hybrid. The invention appears to have to do with the method of regenerative charging offered.

Westphal patent 5,570,615 shows a three-mass flywheel construction, with two of the masses connected by springs and the thrid by planetary gears for balancing of various moments and vibrations.

Nedungadi patent 6,110,066 shows a hybrid vehicle operating in four modes, as follows (col. 4, lines 25 - 38): "There are four modes of operation for the vehicle, namely: (a) electric; (b) charge; (c) assist; and, (d) regenerative. In the electric mode, only the motor is providing propulsion power to the vehicle. In the charge mode, part of the engine power drives the vehicle and the rest is absorbed by the motor (operating as a generator) to charge the batteries. In the assist mode, both the engine and the motor are providing power to propel the vehicle. In the regenerative mode, power from the decelerating wheels is diverted to the motor so that it can be used to charge the batteries. .... The controller selects the most appropriate mode depending upon the position of the accelerator pedal, the vehicle speed and the state of charge of the battery." Nedungadi makes it clear that the idea is to keep the engine "as loaded as possible" (col. 8, line 46). In assist mode, this is done by keeping the engine at maximum power; in the charge mode, the engine is maintained at its point of maximum fuel efficiency. See col. 5, lines 46 - 53.

Fini patent 6,387,007 shows several embodiments of hybrids. Mode control appears to be accomplished responsive to accelerator pedal position.

Tsai et al 6,592,484 shows a hybrid comprising an ICE and a single motor as prime movers. The invention is directed to a transmission including four clutches and two planetary gearsets. Some 13 operating modes are stated to be provided.

Horwinski patent 3,904,883 is essentially a predecessor of the Horwinski patent already of record.

Yamada patent 6,041,877 was recently cited in an Office Action issued against a Japanese application based on a PCT application with disclosure corresponding to the disclosures of the two parent applications. According to a non-certified translation of the Office Action, Yamada was cited because it shows "a hybrid vehicle in which a battery is configured as two separate battery sub-banks"; this was cited against a claim not corresponding to any now in this application, including a similar recitation. (Claim 29 of issued patent 6,209,672 includes a comparable limitation.) The disclosure of Yamada otherwise seems merely cumulative to numerous references of record. Japanese Utility Model Application No. 50-099456 (provided with a translated summary sheet only) was also cited in the same Office Action, the Japanese Examiner stating that "there is described a technology in which two battery groups in an electrically driven vehicle (B1 and B2, B4 and B3) are connected in series and the middle of the two battery groups is earthed to a vehicle chassis." Again, this is not relevant to any claim now being asserted herein.

Tabata patent 5,887,670 shows a single-motor hybrid. Mode determination is accomplished (see Fig. 7) responsive to a "currently required output Pd" which is determined responsive to pedal position, rate of change thereof, vehicle speed and trasnmission lever position (see col. 23, lines 20 - 26).

Otsu et al patent 6,123,163 shows a single-motor hybrid configured as a sort of city scooter. The vehicle operates in different modes depending on the "aimed" torque, which is determined responsive to accelerator opening and vehicle speed.

See Fig. 13, col. 10, lines 56 - 67 and col. 17, lines 11 - 33. Otsu 6,260,644 seems to have the same disclosure, and Suzuki 6,253,865 to relate to the same design.

Arai patent 6,435,296 shows a hybrid with an engine driving one set of wheels and a motor driving the other. In order that a DC motor can be used, avoiding the expense of an inverter, the motor is to be used as little as possible.

Sherman 5,789,823 shows both a torque converter and a friction clutch in a single motor hybrid. This is essentially an engine-assist arrangement; the engine can only be started when the vehicle transmission is in neutral (see col. 3, lines 30 - 38), so that it must be run at all times, and the motor/generator is stated to only assist the engine during times of peak power requirement (col. 4, lines 36 - 38). Another Sherman patent 5,258,651 is not directed to hybrid vehicles, but to a system for starting an ICE.

Onimaru 6,007,443 (Nippon Soken) shows a hybrid wherein an ICE is connected through a CVT and a clutch to a motor/generator, the output shaft of which drives the wheels. Above a minimum velocity, the engine is operated at a maximum speed. See col. 7, line 17. At lower vehicle speeds, the engine is permitted to idle; see col. 6, lines 9 - 23.

Ehsani et al, in "Propulsion System Design of Electric and Hybrid Vehicles", discuss determination of the sizes and capacities of an ICE and traction motor for a hybrid vehicle. This is generally relevant to the subject matter of claims 16 and 112. However, note that Ehsani fails entirely to address the relationship claimed between the voltage and current of the battery bank, as claimed. Ehsani et al, in "Parametric Design of the Drive Train of an Electrically Peaking Hybrid (ELPH) Vehicle", go into further detail, and indicate that the vehicle of concern is a single-motor hybrid wherein torque from the ICE and motor can be combined by a "matchgear", as in applicant's prior patent 5,343,970. Ehsani patent 5,586,613, apparently directed to the same work, is discussed in the application as filed.

Yamaguchi et al, "Development of a New Hybrid System - Dual System", SAE paper 960231 (1996) appears to be merely cumulative to numerous patents to the same inventors already of record. "Dual System - Newly Developed Hybrid System" (publication details not known), by some of the same authors, of which only a partial copy is available, is generally cumulative but does provide a diagram showing operation of the various components as a function of time

Takaoka et al, in "A High-Expansion-Ratio Gasoline Engine for the Toyota Hybrid System", discuss the details of an ICE designed for use in a hybrid vehicle. This paper states that "By using the supplementary drive power of the electric motor, the system eliminates the light-load range, where concentrations of hydrocarbons in the emissions are high and the exhaust temperature is low." (p. 57; a similar statement is made on p. 59) and "By allocating a portion of the load to the electric motor, the system is able to reduce engine load fluctuation under conditions such as rapid accleeration. This makes it possible to reduce quick transients in engine load so that the air-fuel ratio can be stabilized easily." (p. 58). The former statement simply emphasizes the fact that engines are operated more efficiently at higher loads, and the latter that stoichiometric combustion can be more nearly obtained if the engine's speed and/or load is varied as slowly as possible.

Sasaki et al, "Toyota's Newly Developed Electric-Gasoline Hybrid Powertrain System" (publication data not available) provides a mathematical analysis of the planetary gearbox.

PCT application PCT/SE81/00280, published as WO 82/01170, shows a hybrid vehicle wherein an ICE is used for propulsion under some circumstances and an electric motor under others, e.g., to provide a forklift truck that operates electrically when indoors and is driven by the ICE when outdoors. The change from one torque source to the other is made as a function of vehicle speed. See p. 3, lines 19 - 28.

Japanese utility model publication 53-55105 (of which only a partial translation is available) appears to show a hybrid vehicle having both an ICE and a motor as sources of propulsive torque, but the description provided is inadequate to understand how the two sources are to be operated. The disclosure of Japanese patent application publication 48-64626 (of which only a partial translation is available) seems to be similar.

Japanese unexamined patent application publication 4-67703 (of which only a partial translation is available) appears to relate to an electric vehicle.

Japanese patent application publication 4-297330 (of which only a partial translation is available) seems to relate to supplementing the regenerative braking available using a traction motor as the source of braking torque with regenerative braking from a generator attached to an ICE, and with friction from motoring the engine under braking.

Japanese patent application publication 55-110328 (of which only a partial translation is available) relate to a vehicle wherein a first pair of wheels is driven by a "main driving unit", a second pair being driven by an "auxiliary power unit", wherein the auxiliary power unit is controlled responsive to a difference in speed between the first and second pairs of wheels.

Japanese utility model publication 51-103220 (of which only a partial translation is available) describes a control system for a hybrid wherein the output shaft of an ICE is connected to that of an electric motor through a clutch, the clutch being controlled to operate when speed sensors on the shafts indicate that their rotational speeds are equal.

Japanese patent 49-29642 (of which only a partial translation is available) also shows a hybrid wherein the shaft of an ICE is connected by a clutch to that of an electric motor; in this case a one-way clutch is also provided.

Japanese patent publication 6-245317 (of which only a partial translation is available) relates to a device for preventing overcharging of the battery of an electric vehicle.

European patent application publication no. 510 582 shows a vehicle powerplant featuring both an ICE and an electric motor as sources of propulsion, and thus a hybrid of sorts, though the term is not mentioned. No suggestion is made that the control of operating mode is made other than by an operator; the determining factor seems to be whether emission must be completely prohibited, as in indoor operation.

European patent application publication no. 510 582 also shows a hybrid vehicle featuring both an ICE and an electric motor as sources of propulsion. Again there is no teaching of the specifics of switching operating mode; the invention has to do with loading the ICE by means of the generator so as to match the speed of the engine to the speed of a drive shaft driven by the traction motor before engaging a clutch connecting the two.

German OS 25 17 110, provided with an English-language abstract, is stated by the abstract to show a hybrid vehicle with a turbine engine. It appears that the vehicle is operated as an electric car until the current drawn exceeds a preset value, when the turbine is actuated; thereafter, the turbine is run at an "optimum setting", with the load split between battery charging and vehicle propulsion.

Mayrhofer et al, "A Hybrid Drive Based on a Structure Variable Arrangement" (1994), shows a hybrid vehicle design involving an ICE, two motor/generators, a planetary gearbox to enable combinations of sources of torque, and no less than four clutches, obviously much more complicated than would be desirable. Of interest with respect to the present invention is that in one operating strategy (see page 196) Mayrhofer et al suggest that the ICE should be activated only when the mean value of the power demanded exceeds a limit for more than a minimum time, 20 seconds being the example given. It is apparent that the ICE is thus to be used only for load-leveling and that mode changes are not being made based on the road load *per se*. In other strategies the engine operation appears to be even further afield from applicants' simple and direct strategy.

A December 1990 *Popular Science* article, "Diesel-Electric VW", describes a hybrid wherein an electric motor, also serving a generator and engine starter, is disposed between clutches connecting the motor to an ICE on one side and the vehicle wheels on the other. It is not clear what modes are provided, although some transitions are apparently made responsive to accelerator pedal position and vehicle velocity.

A May 1991 *Popular Science* article, "Electric Vehicles Only", addresses the then-current state of the art in electric vehicles and mentions hybrids only peripherally.

An April 1991 article appearing in *NASA Tech Briefs* discusses lead/acid batteries having woven electrodes.

As indicated, none of the newly-cited patents made of record hereby disclose or suggest the invention claimed herein. Early and favorable action on the merits of the application is earnestly solicited.

Respectfully submitted,

May 19, 2004
Dated

Michael de Angeli
Reg. No. 27,869
60 Intrepid Lane
Jamestown, RI 02835
401-423-3190

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MAY 2 8 2004
PATENT & TRADEMARK OFFICE

INFORMATION DISCLOSURE CITATION IN AN APPLICATION	DOCKET NUMBER PAICE201.DIV	APPLICATION NUMBER 10/382,577
	APPLICANT Severinsky et al	
	FILING DATE 3/7/2003	GROUP ART UNIT 3616

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	6281660	08/2001	Abe			
	5515937	5/1996	Adler et al			
	5336932	4/1994	Barske			
	6170587	1/2001	Bullock			
	5887674	3/1999	Gray			
	4762191	8/88	Hagin			
	6315068	11/2001	Hoshiya et al			
	5856709	1/1999	Ibaraki et al			
	6204636	3/2001	Kinoshita et al			
	6225784	5/2001	Kinoshita et al			
	6232748	5/2001	Kinoshita et al			
	6019698	2/2000	Lawrie			

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FOREIGN PATENT DOCUMENTS

	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

EXAMINER	DATE CONSIDERED

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP § 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.

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U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	5993350	11/1999	Lawrie et al			
	5979257	11/1999	Lawrie			
	6006620	12/1999	Lawrie et al			
	6291953	9/2001	Lovatt et al			
	6332257	12/2001	Reed Jr. et al			
	5943918	8/1999	Reed Jr. et al			
	5755302	5/1998	Lutz et al			
	6142907	11/2000	Minowa			
	6328670	12/2001	Minowa			
	6119799	9/2000	Morisawa			
	5984034	11/1999	Morisawa			
	6334498	1/2002	Morisawa			

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FOREIGN PATENT DOCUMENTS

	DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	TRANSLATION YES	TRANSLATION NO

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

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OIPE JC177
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	APPLICANT Severinsky et al	
	FILING DATE 3/7/2003	GROUP ART UNIT 3616

RECEIVED
JUN 0 2 2004
GROUP 3600

U.S. PATENT DOCUMENTS

EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
	5895333	4/1999	Morisawa			
	6306057	10/2001	Morisawa			
	6344008	2/2002	Nagano			
	6090007	7/2000	Nakajima			
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OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

		Published application US 2001/0037905 of Nogi et al

EXAMINER	DATE CONSIDERED

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP § 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.

OIPE JC177
MAY 2 8 2004
PATENT & TRADEMARK OFFICE

INFORMATION DISCLOSURE CITATION IN AN APPLICATION	DOCKET NUMBER PAICE201.DIV	APPLICATION NUMBER 10/382,577
	APPLICANT Severinsky et al	
	FILING DATE 3/7/2003	GROUP ART UNIT 3616

U.S. PATENT DOCUMENTS

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GROUP 3600

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Published patent application US 2003/0085577 of Takaoka et al, May 8, 2003

EXAMINER	DATE CONSIDERED

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	APPLICANT Severinsky et al	
	FILING DATE 3/7/2003	GROUP ART UNIT 3616

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GROUP 3600

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	APPLICANT Severinsky et al	
	FILING DATE 3/7/2003	GROUP ART UNIT 3616

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OIPE JC177 MAY 2 8 2004 PATENT & TRADEMARK OFFICE

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	APPLICANT Severinsky et al	
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EXAMINER INITIAL	DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE
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	APPLICANT Severinsky et al	
	FILING DATE 3/7/03	GROUP ART UNIT 3616

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OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc)

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	APPLICANT Severinsky et al	
	FILING DATE 3/7/03	GROUP ART UNIT 3616

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GROUP 3600

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	FILING DATE 3/7/03	GROUP ART UNIT 3616

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OIPE JC177
MAY 2 8 2004
PATENT & TRADEMARK OFFICE

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	APPLICANT Severinsky et al	
	FILING DATE 3/7/03	GROUP ART UNIT 3616

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GROUP 3600

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Partial Translation of JPP'626

Title of the Invention: Driving System for a Vehicle

Inventor: Shohtaroh Naitoh

Applicant: Kabushiki Kaisha Hitachi Seisakusho

Filing date: December 10, 1971

Filing Number: 46-99430

Publication Date: September 6, 1973

Publication No.: 48-64626

• Scope of claim for Patent

1. A driving system for a vehicle characterized by providing an engine for driving one of front wheels or rear wheels, and a motor for driving another of front wheels or rear wheels.

• Brief description of the drawings

Figure 1 is a constitutional drawing of an embodiment of a driving system for a vehicle according to the present invention.

• Reference Numerals

1 ... Frame of Vehicle
2 ... Engine
4a, 4b ... Front wheel
5 ... Motor
7a, 7b ... Rear Wheel
8 ... Generator
9 ... High Voltage Battery
10 ... Charging Diode
11 ... Control System
12 ... Low Voltage Battery for starting up a vehicle
13 ... Pole Changing Switch

Partial Translation of JPP'642

Title of the Invention: Driving Mechanism Control System for a Vehicle with an Electric Motor and an Internal Combustion Engine

Inventor: Kohhei Iritani

Applicant: Kabushiki Kaisha Toyota Jidohshokki Seisakusho

Filing date: September 9, 1970

Filing Number: 45-85443

Patent Grant Date: August 6, 1974

Patent No.: 49-29642

• Scope of claim for Patent

1. Driving mechanism control system for a vehicle comprising:

an electric motor,

an internal combustion engine which drives a generator for supplying electric power to said electric motor,

a connecting clutch for connecting said electric motor to said internal combustion engine only when the rotating speed of said electric motor is greater than a predetermined speed,

an one-way clutch which can transmit driving force from said internal combustion engine to said electric motor, and is connected with said connecting clutch in series, and

a connecting mechanism for connecting a control pedal for controlling electric power supplied to said electric motor with a lever of a control system for controlling fuel amount supplied to said internal combustion engine when said internal combustion engine is in operation and said connecting clutch is in a connecting state.

• Brief description of drawings

Figure shows an embodiment of a driving mechanism control system for a vehicle according to the present invention.

• Reference Numeral

1 ... Internal combustion engine
2 ... Transmission gear
3 ... Connecting clutch
4 ... One-way clutch
5 ... Electric motor
6 ... Differential gear
7 ... Driving wheel
8 ... Chain
9 ... Generator
10 ... Relay
11 ... Battery
12 ... Vehicle speed sensor
13 ... Acceleration pedal
14 ... Control unit
15 ... Sliding contact
16 ... Driving rod
17 ... Control system
18 ... Lever
19 ... Contact
20 ... Sliding cylinder
21 ... Solenoid
22 ... Rod
23 ... Switch
24 ... Electric power source
25 ... Ignition switch

26 ... Spring
27 ... Back spring
28 ... Switch
29 ... Manual grounding switch
30 ... Driving system
31 ... Clutch

⑲ Japanese Patent Office (JP)

⑫ Unexamined Utility Model Publication

⑪ Unexamined Utility Model Publication

53-55105

㊸ Publication Date: May 11, 1978

㊿ IPC

H 02 P 9/14
B 60 L 11/12
H 02 J 7/16

㊴ Name of Invention: Generator Control System for a Hybrid Vehicle

㉑ Utility Model Application No: 51-138199

㉒ Filing Date: October 13, 1976

㉑ Applicant: Toyo Kohgyo Kabushiki Kaisha

㊼ Scope of Claims for Utility Model

Generator control system for a hybrid vehicle, which provides different kinds of power sources, an engine and a motor powered by a battery, and is driven by at least one of said power sources, wherein

said battery is charged by a generator driven by said engine,

a detecting means is provided for detecting a depressing amount of an accelerator which controls output of said engine, and

at least one of a field circuit and an armature circuit of said generator is controlled by said detecting circuit.

Brief Description of the Drawings

Figure 1 is an explanatory drawing of a hybrid vehicle

Figure 2 is a circuit diagram of a generator controlled by a generator control system of the present invention.

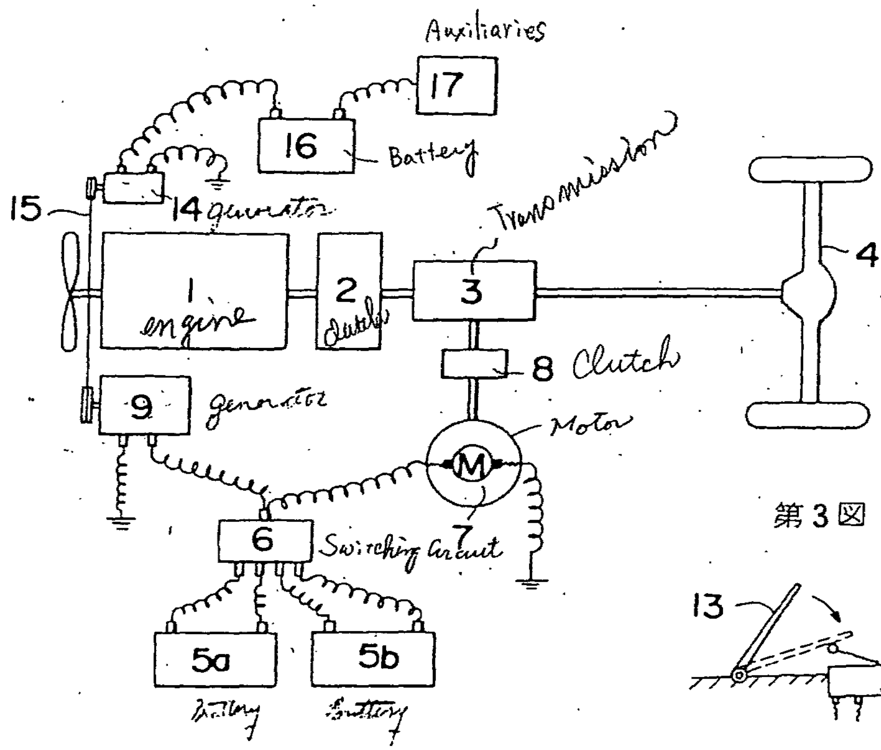
Figure 3 is an explanatory drawing of a relationship between an accelerator and an accelerator switch.

Figure 4 is a modified embodiment of an accelerator switch.

Figure 5 is a graph showing torques at various gear positions when a generator is charged and when a generator is not charged.

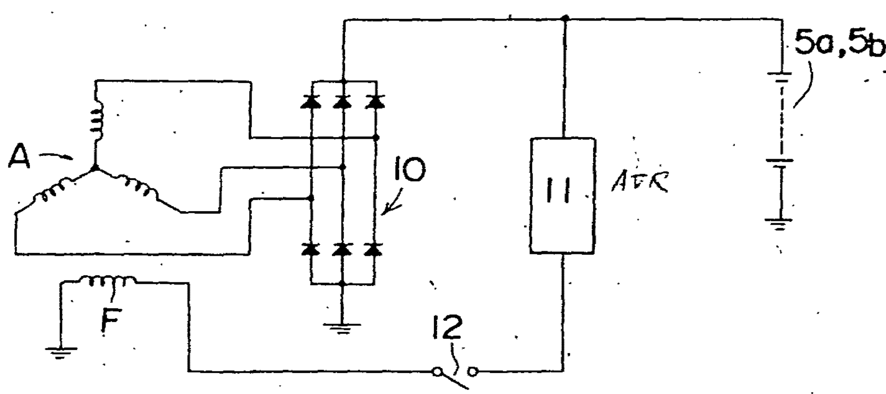
1 ... engine
5a, 5b ... battery for running
7 ... motor
9 ... generator
12 ... accelerator switch
13 ... accelerator
A ... armature circuit
F ... field circuit

第1図



第3図

第2図



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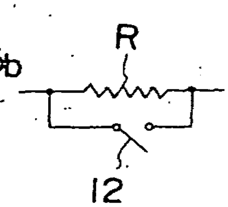

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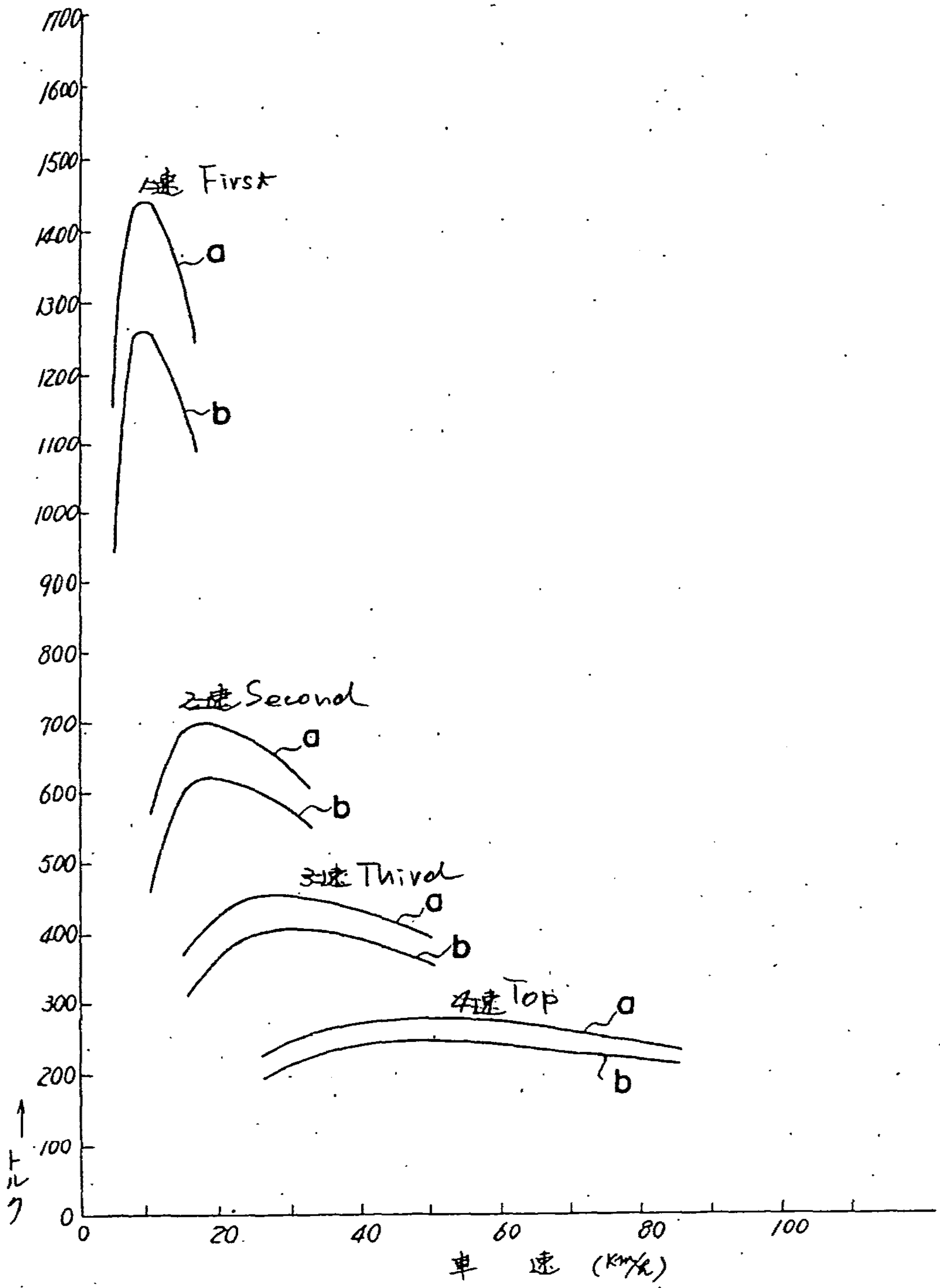

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Page 292 of 1654

(19) Japanese Patent Office (JP)

(12) Unexamined Patent Publication

(11) Unexamined Patent Publication

4-67703

(43) Publication Date: March 3, 1992

(51) IPC

B 60 L 11/02
1/00
11/18
H 02 J 7/16

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(54) Name of Invention: Electric Vehicle

(21) Patent Application No.: 2-176218

(22) Filing Date: July 5, 1990

(71) Applicant: Nissan Corporation

(57) Scope of Claims for Patent

Electric vehicle comprising;

an electric motor for driving a vehicle;

auxiliary equipments arranged on said vehicle;

rechargeable battery for powering to said electric motor and said auxiliary equipments;

generating means for generating power to charge said rechargeable battery;

detecting means for detecting operating conditions of said vehicle; and

controlling means for directly supplying electric power from said generating means to said electric motor, and gradually decreasing electric power to said auxiliary equipments.

Brief Description of the Drawings

Figure 1 is a structural diagram of the present invention.

Figure 2 is a block diagram of one embodiment of the present invention.

Figure 3 is a flowchart for the block diagram of Figure 2.

Figure 4 is a flowchart for another embodiment of the present invention.

1 ... electric motor
3 ... air conditioner (auxiliary equipment)
5 ... defroster (auxiliary equipment)
7 ... lump (auxiliary equipment)
9 ... 100 Volt battery (rechargeable battery)
CL1 ... generating means
CL2 ... controlling means
CL3 ... operating condition detecting means
11 ... 12 Volt Battery
13 ... in vehicle generator
15 ... solar battery
17 ... regenerating brake
19 ... controller
21 ... controller
23 ... charge/discharge controller

25 ... D/D converter
27 ... controller
29 ... controller
33 ... central controller
35 ... speed sensor
37 ... accelerator opening sensor

BMW1012
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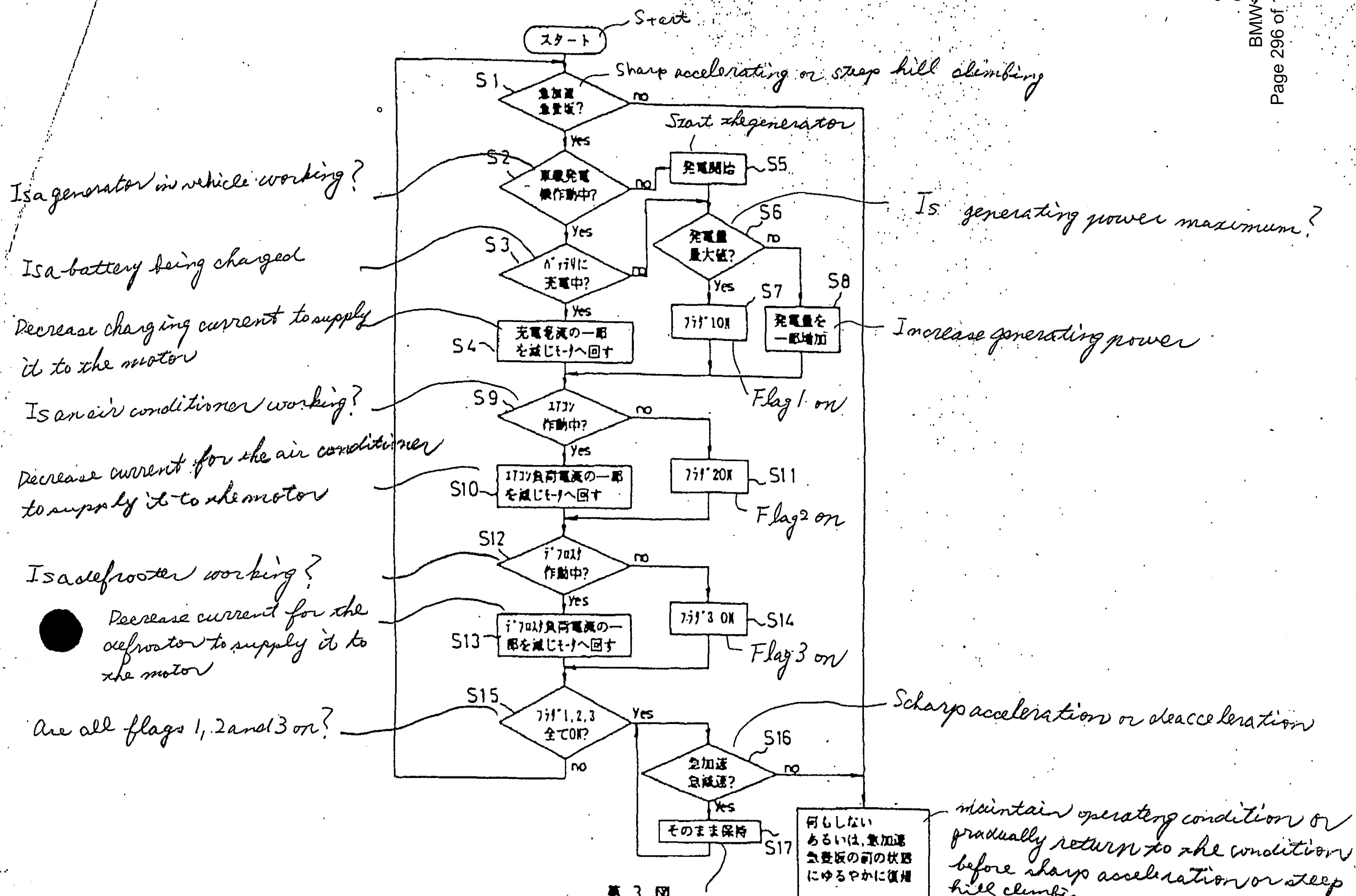

第 3 図

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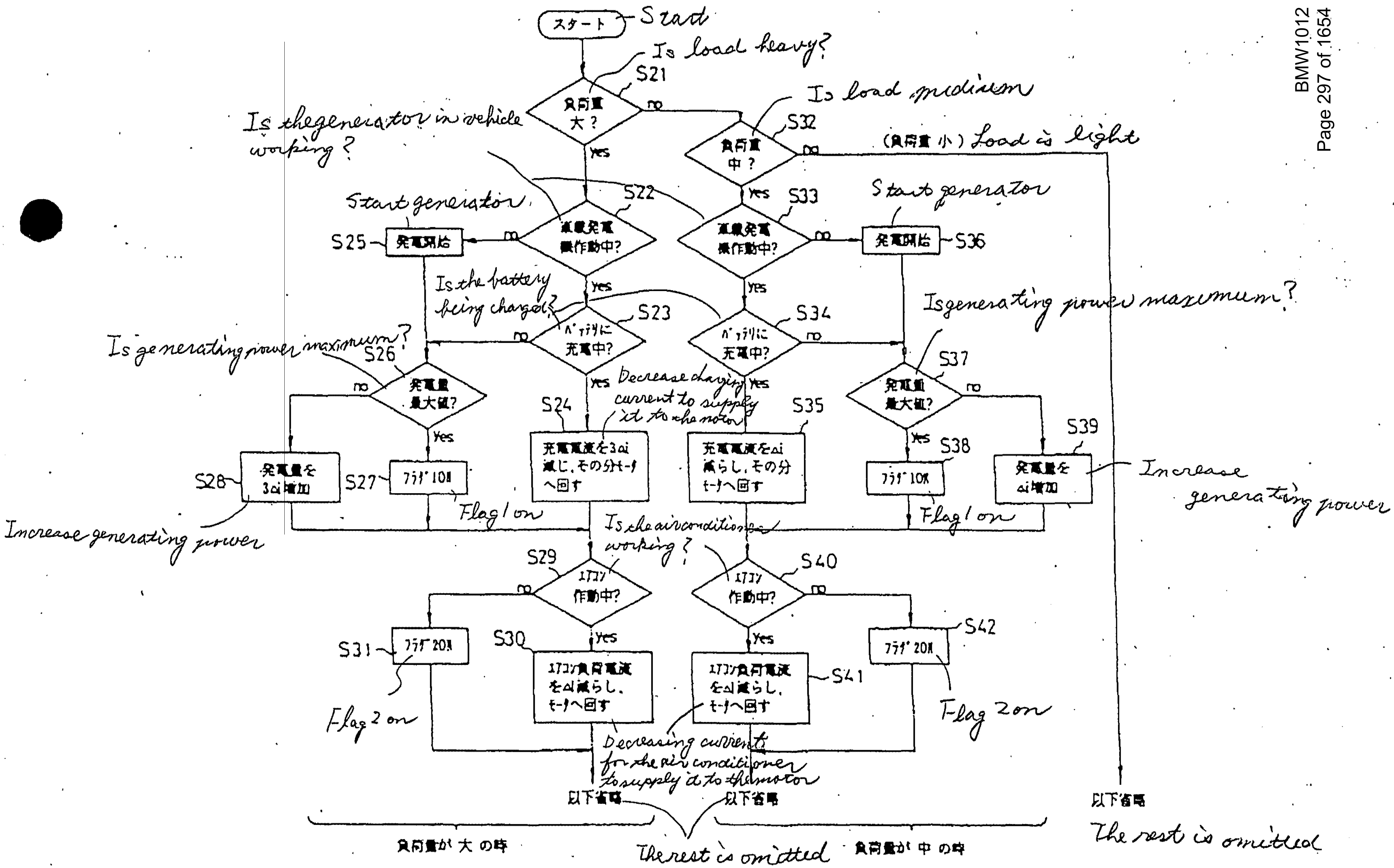
Page 297 of 1654



第4図

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04573417

MOTOR CONTROLLER FOR ELECTRIC AUTOMOBILE EQUIPPED WITH ENGINE DRIVEN GENERATOR

PUB. NO.: 06-245317 [JP 6245317 A]
PUBLISHED: September 02, 1994 (19940902)
INVENTOR(s): FURUYA MASAYUKI
APPLICANT(s): TOYOTA MOTOR CORP [000320] (A Japanese Company or Corporation), JP (Japan)
APPL. NO.: 05-023135 [JP 9323135]
FILED: February 12, 1993 (19930212)
INTL CLASS: [5] B60L-011/02; B60L-009/18; B60L-011/18
JAPIO CLASS: 26.1 (TRANSPORTATION -- Railways); 21.2 (ENGINES & TURBINES, PRIME MOVERS -- Internal Combustion); 26.2 (TRANSPORTATION -- Motor Vehicles); 43.4 (ELECTRIC POWER -- Applications)
JOURNAL: Section: M, Section No. 1714, Vol. 18, No. 633, Pg. 76, December 02, 1994 (19941202)

ABSTRACT

PURPOSE: To obtain a motor controller for electric automobile equipped with an engine driven generator in which abrupt overdischarge of battery is prevented when the engine driven generator is not operating and the service life of battery is prolonged by protecting the battery against damage.

CONSTITUTION: An SOC meter 10 detects charged state of a battery 6 and when the charged state is deteriorated, an engine 1 is driven to start operation of a generator 3. When a decision is made that the generator 3 is not operating normally based on a detection value of a voltmeter 13, an ECU 11 controls an inverter 5 to limit current supply to a motor 7 to 1/3-1/2 of normal level. This constitution prevents overdischarge of the battery 6 upon failure of the generator 3.

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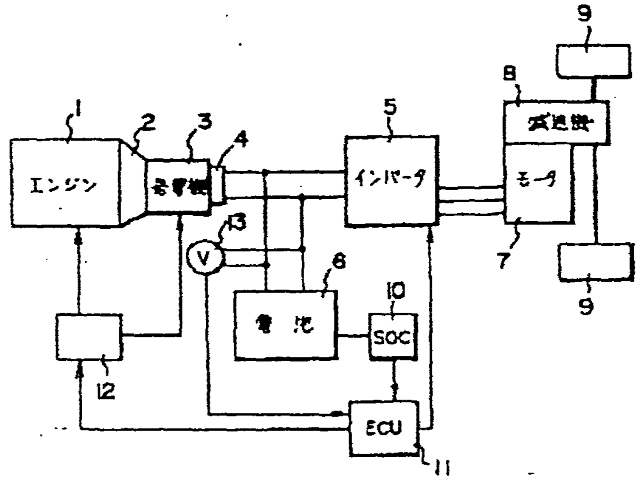
Patent Abstracts of Japan

PUBLICATION NUMBER : JP6245317
PUBLICATION DATE : 02-09-94
APPLICATION NUMBER : JP930023135
APPLICATION DATE : 12-02-93

VOL: 18 NO: 633 (M - 1714)
AB. DATE : 02-12-1994 PAT: A 6245317
PATENTEE : TOYOTA MOTOR CORP
PATENT DATE: 02-09-1994

INVENTOR : FURUYA MASAYUKI

INT.CL. : B60L11/02; B60L9/18; B60L11/18



TITLE : MOTOR CONTROLLER FOR ELECTRIC AUTOMOBILE EQUIPPED WITH ENGINE DRIVEN GENERATOR

ABSTRACT : PURPOSE:To obtain a motor controller for electric automobile equipped with an engine driven generator in which abrupt overdischarge of battery is prevented when the engine driven generator is not operating and the service life of battery is prolonged by protecting the battery against damage.
CONSTITUTION:An SOC meter 10 detects charged state of a battery 6 and when the charged state is deteriorated, an engine 1 is driven to start operation of a generator 3. When a decision is made that the generator 3 is not operating normally based on a detection value of a voltmeter 13, an ECU 11 controls an inverter 5 to limit current supply to a motor 7 to 1/3-1/2 of normal level. This constitution prevents overdischarge of the battery 6 upon failure of the generator 3.

(19)日本国特許庁（JP）　(12) 公開特許公報(A)　(11)特許出願公開番号

特開平6－245317

(43)公開日　平成6年(1994)9月2日

(51)Int.Cl.5	識別記号	庁内整理番号	F I	技術表示箇所
B60L 11/02		6821－5H		
9/18	J	9380－4H		
11/18	A	6821－5H		
	C	6821－5H		

審査請求　未請求　請求項の数1　OL　（全 5 頁）

(21)出願番号　特願平5－23135

(22)出願日　平成5年(1993)2月12日

(71)出願人　000003207
トヨタ自動車株式会社
愛知県豊田市トヨタ町1番地

(72)発明者　古谷　昌之
愛知県豊田市トヨタ町1番地　トヨタ自動車株式会社内

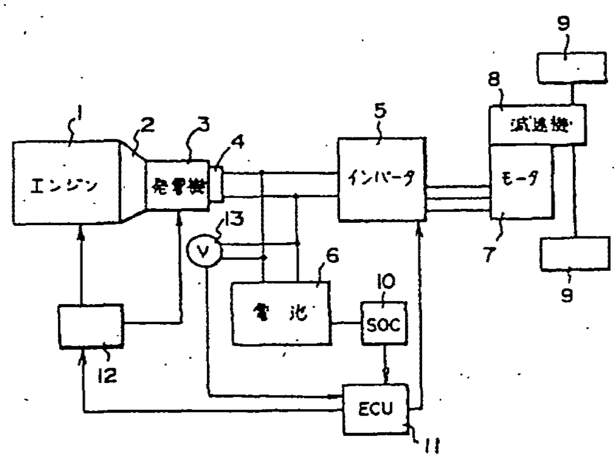
(74)代理人　弁理士　吉田　研二　（外2名）

(54)【発明の名称】　エンジン駆動発電機付電気自動車のモータ制御装置

(57)【要約】

【目的】　エンジン駆動発電機が作動しない場合の電池の急激な過放電を防止し、電池の損傷を低減し長寿命化することができるエンジン駆動発電機付電気自動車のモータ制御装置を得る。

【構成】　SOCメータ10により電池6の充電状態を検出し、充電状態が悪化した場合には、エンジン1を駆動して発電機3による発電を開始する。ここで、電圧計13の検出値により、発電機3が正常に動作していないことを検出した場合には、ECU11は、インバータ5を制御して、モータ7への供給電流を通常の1／3～1／2程度に制限する。これにより、発電機3の故障時における電池6の過放電を防止できる。



全体構成

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【特許請求の範囲】
【請求項1】 電気自動車を駆動するためのモータと、このモータを駆動するための充電可能な電池と、前記電池に電力を供給するエンジン駆動発電機とを有するエンジン駆動発電機付電気自動車のモータ制御装置であって、
電池の充電状態を検出する充電状態検出手段と、
この充電状態検出手段により検出された電池の充電状態値が低下した時にエンジン駆動発電機の作動を指示する作動信号を出力するエンジン駆動発電機制御手段と、
エンジン駆動発電機の作動を検出する発電機作動検出手段と、
上記エンジン駆動発電機制御手段より作動信号および発電機作動検出手段の検出結果より、作動信号が出力されたにもかかわらずエンジン駆動発電機が作動しないと判定されたとき、モータの出力に制限を加えるモータ出力制限手段と、
を備えたことを特徴とするエンジン駆動発電機付電気自動車のモータ制御装置。
【発明の詳細な説明】
【0001】
【産業上の利用分野】この発明は、電池に充電電力を供給するエンジン駆動発電機を有するエンジン駆動発電機付電気自動車のモータ制御装置に関する。
【0002】
【従来の技術】近年、公害防止の観点から電気自動車が注目されている。しかし、電気自動車は、そのエネルギー源として電池を搭載するが、この電池はかなりの大容積、大重量のものであっても、その電気容量で走行可能な距離はそれ程大きくない。そこで、一充電当たりの走行距離を伸ばすために、エンジン駆動発電機を搭載し、発電電力によって電池を充電するエンジン駆動発電機付電気自動車が知られている。
【0003】このエンジン駆動発電機付電気自動車では、エンジン駆動時に排ガスが発生する。このため、電池の充電状態が悪化したときにのみエンジン駆動発電機を作動させ、エンジンの駆動を最小限としている。そこで、低公害性を維持しつつ、バッテリを増加することなく一充電当たりの走行距離を延長することができる。このようなエンジン駆動発電機付電気自動車は、例えば特開昭55－157901号公報に示されている。
【0004】
【発明が解決しようとする課題】ここで、上述のような従来のエンジン駆動発電機付電気自動車においては、エンジン駆動発電機が正常に作動し、ここから電力が供給されることを前提としている。このため、電池の充電状態が悪化した場合にもモータの出力は通常時と同様に制御される。
【0005】ところが、エンジン駆動発電機は絶対に故障しないとはいえない。そこで、エンジンが作動しなかったり、発電機が故障したりし、発電ができなかったり、発電はできても発電量が所定量に達しない場合もある。
【0006】そして、エンジン駆動発電機を作動させるということは、電池の充電状態が悪化していることを意味しており、この状態で通常のモータ駆動を続けた場合には、電池の充電状態はさらに悪化し、走行不能となる。また、このように、走行が不能になるまで、電池が放電すると、過放電により電池を損傷するおそれがあり、電池の容量や寿命の低下を来すという問題点があった。
【0007】この発明は、上記問題点を解消するためになされたものであり、エンジン駆動発電機が作動しない場合に生じる電池の急激な過放電を防止することができるエンジン駆動発電機付電気自動車のモータ制御装置を得ることを目的とする。
【0008】
【課題を解決するための手段】本発明は、電気自動車を駆動するためのモータと、このモータを駆動するための充電可能な電池と、前記電池に電力を供給するエンジン駆動発電機とを有するエンジン駆動発電機付電気自動車のモータ制御装置であって、電池の充電状態を検出する充電状態検出手段と、この充電状態検出手段により検出された電池の充電状態値が低下した時にエンジン駆動発電機の作動を指示する作動信号を出力するエンジン駆動発電機制御手段と、エンジン駆動発電機の作動を検出する発電機作動検出手段と、上記エンジン駆動発電機制御手段より作動信号および発電機作動検出手段の検出結果より、作動信号が出力されたにもかかわらずエンジン駆動発電機が作動しないと判定されたとき、モータの出力に制限を加えるモータ出力制限手段と、を備えたことを特徴とするエンジン駆動発電機付電気自動車のモータ制御装置。
【0009】
【作用】この発明におけるエンジン駆動発電機付電気自動車のモータ制御装置は、電池の充電状態を検出する充電状態検出手段により検出された電池の充電状態値に応じ、電池の充電状態値が低下した時にエンジン駆動発電機制御手段によりエンジン駆動発電機を作動させる信号を出力し、エンジン駆動発電機を作動させ、電池を充電する。
【0010】そして、電池の充電状態値が低下し、エンジン駆動発電機を作動させる信号が出力されたにもかかわらずエンジン駆動発電機が作動しない時は、モータ出力制限手段によりモータの出力に制限を加えることができる。従って、エンジン駆動発電機が作動しない場合には、モータの出力を小さくでき、これによって電池の急激な過放電を防止し、電池の損傷を低減し、長寿命化することができる。
【0011】

【実施例】以下、この発明の一実施例を図について説明する。

【0012】図1において、エンジン1は、動力を発生する原動機であり、増速機2を介して回転速度を増加させた後、発電機3を駆動して発電する。発電される電力は交流なので、整流器4により整流し直流に変換した後、インバータ5および電池6に供給されるようになっている。モータ7は、交流誘導モータであり、インバータ5を介して供給される所定の交流電力により駆動される。モータ7のトルクは減速機8を介してタイヤ9を駆動するようになっている。SOCメータ10は電池の充電状態を検出する充電状態検出手段であり、ECU（電子制御ユニット）11は各種処理を行う。SOCメータ10は電池6の充放電量をカウント（放電電流量を積算）し、電池6の充電状態情を把握し、ECU11に提供する。ECU11は、ドライバからのアクセル信号やブレーキ信号を入力としてインバータ5をコントロールして、モータの出力を制御すると共に、SOCメータ10の充電状態値信号に基づき発電機3を作動・停止させるエンジン駆動発電機制御手段として機能する。すなわち、エンジン発電ユニットコントローラ12にその作動・停止信号を送る。また、電圧計13は、電池6の端子間電圧を計測するものであり、検出値をECU11に供給する。ECU11は、電圧計13の検出電圧により、発電機3の異常を検出する。

【0013】図2は、上記エンジン駆動発電機付電気自動車のモータ制御装置のエンジン発電ユニットコントローラ12の作動・停止制御動作を示すフローチャートである。まず、SOCメータ10により、SOC（State Of Charge：充電状態値）を検出し（S101）、検出したSOCが所定値A（例えば、30～60％程度の任意の値）より大きいかどうかを判断する（S102）。S102においてNO、すなわちSOCが所定値未満の場合、電池6は充電を要する状態なので、発電機3による発電を開始するため、ECU11は発電機3の作動を指令する作動信号をエンジン発電ユニットコントローラ12に送る。そして、エンジン発電ユニットコントローラ12は、エンジン1を駆動開始すると共に、所定の界磁電流を発電機3に供給し、発電を開始する（S103）。なお、S102でYESの場合は、電池が充分な充電状態にあるので発電を行わず、S101に戻ってSOC検出を再度実行する。

【0014】そして、S103で発電を開始した後、S104に進み、正常動作か否かを判定する（S104）。この判定は、例えば電圧計13により、電池6の端子間電圧を計測し、これが所定値以上となったことにより、正常動作であることを判定する。なお、正常か否かの判定は、S104の判定がYESの場合は、次にSOCがB（例えば50～80％の任意の値で上述のAより所定以上大きい値）より大きいか否かを判断する（S

105）。S105で、YESの場合、電池が充分な充電状態にあるので、発電を停止する（S106）。一方、S105においてNOの場合は、電池6の充電状態が十分回復していないため、発電を継続するため、S104に戻って正常動作がなされているか否かの判定を繰り返す。

【0015】そして、S104でNOの場合、すなわち、ECU11からエンジン発電ユニットコントローラ12に動作信号が発信されたにもかかわらず、エンジン発電ユニットコントローラ12、発電機3、またはエンジン1の燃料系や点火系の故障によりエンジン1が作動しなくなったり、発電機3が発電しないか所定の出力がでない時には、ECU11に備えられたモータ出力制限手段の機能によりモータ出力に制限を加える。この時の出力制限は、SOCの減り方に応じて、本来の最大出力の1／3～1／2位に設定される。この出力制限は、インバータ5の駆動制御により行い、例えばECU11に入力されたトルク指令値自体を1／3～1／2にし、インバータ5の駆動を制御することによって行う。これによって、モータ7に供給される電流量が制限され、電池の急激な放電を防止することができる。なお、このようなエンジン駆動発電機の異常をドライバーに知らせるために、警報ブザーや警告表示を行うとよい。また、エンジン駆動発電機の自動点検手段を設けておき、エンジン1、増速機2、発電機3、整流器4のいずれの異常かを検出したり、その原因を自動的に検出、表示するようにしてもよい。また、エンジンの始動ミスの場合にはリトライを促したり、自動的にリトライするようにしてもよい。

【0016】以上のようにして、本実施例によれば、電池6の充電状態値が低下しエンジン駆動発電機を作動させる信号が出力されたにもかかわらず発電機3が正常に作動しない時、ECU11に備えられたモータ出力制限手段によりモータ7の出力に制限を加え、電池6の急激な過放電を防止し、電池の損傷を低減し寿命を引き延ばすことができる。

【0017】

【発明の効果】以上説明したように、この発明のエンジン駆動発電機付電気自動車のモータ制御装置は、エンジン駆動発電機を作動させる信号が出力されたにもかかわらずエンジン駆動発電機が作動しない時、モータ出力制限手段によりモータの出力に制限を加える。そこで、エンジン駆動発電機が作動しない場合にモータを高出力で駆動し、電池が急激に放電することを防止できる。このため、電池の過放電を防止し、電池の損傷を低減し、長寿命化することができる。

【図面の簡単な説明】

【図1】この発明の一実施例の全体構成を示すブロック図である。

【図2】この発明の一実施例の制御動作を示すフローチャ

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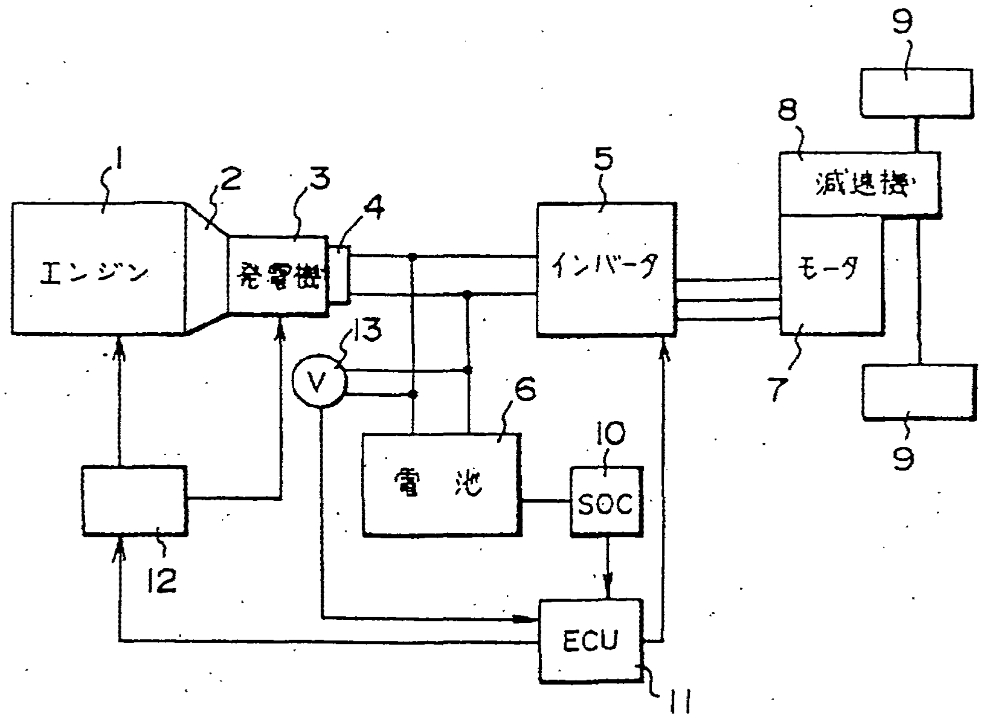
ャートである。

【符号の説明】

1 エンジン
2 増速機
3 発電機
4 整流器
5 インバータ
6 電池
7 モータ
8 減速機
9 タイヤ
10 SOCメータ
11 ECU
12 エンジン発電ユニットコントローラ
13 電圧計

【図1】



全体構成

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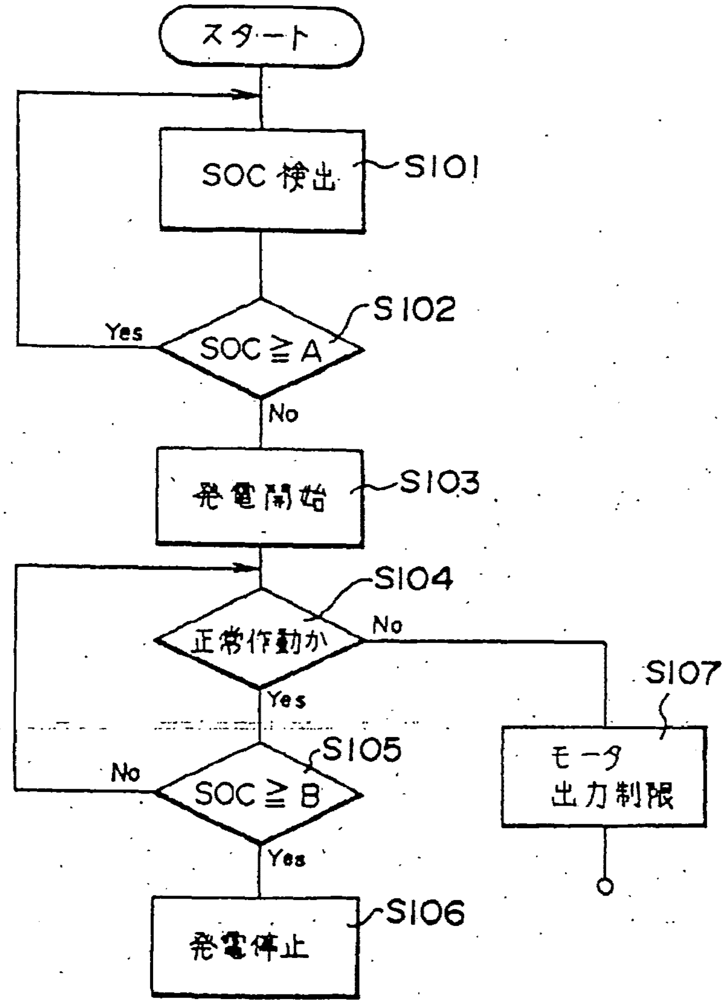
【図2】



制御フロー

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03932230

SERIES-PARALLEL COMPLEX HYBRID CAR SYSTEM

PUB. NO.: 04-297330 [JP 4297330 A]
PUBLISHED: October 21, 1992 (19921021)
INVENTOR(s): FURUYA MASAYUKI
APPLICANT(s): TOYOTA MOTOR CORP [000320] (A Japanese Company or Corporation), JP (Japan)
APPL. NO.: 03-061662 [JP 9161662]
FILED: March 26, 1991 (19910326)
INTL CLASS: [5] B60K-017/04; B60K-006/00; B60K-008/00; B60K-017/356; B60L-011/02
JAPIO CLASS: 26.2 (TRANSPORTATION -- Motor Vehicles); 21.2 (ENGINES & TURBINES, PRIME MOVERS -- Internal Combustion); 26.1 (TRANSPORTATION -- Railways)
JAPIO KEYWORD: R131 (INFORMATION PROCESSING -- Microcomputers & Microprocessers)
JOURNAL: Section: M, Section No. 1375, Vol. 17, No. 106, Pg. 156, March 04, 1993 (19930304)

ABSTRACT

PURPOSE: To provide such a series-parallel complex hybrid car system that is solving any regenerative braking torque shortage at the high speed side of a motor at time of regenerative braking, and capable of securing an almost constant regenerative braking torque ranging from low to high speed rotation.

CONSTITUTION: The system is provided with an engine 1, a generator 3, a traveling motor 9 and a battery 17, while it installs a continuously variable transmission 5 in space between the engine 1 and the motor 9, and simultaneously there is provided a control means 18 which controls the continuously variable transmission 5 so as to make up for a regenerative braking torque insufficient portion at the high speed side of the motor 9 with the resultant torque of friction torque of the engine 1 and regenerative braking torque of the generator 3.

(19)日本国特許庁（ＪＰ）　(12) 公開特許公報（Ａ）　(11)特許出願公開番号

特開平4－297330

(43)公開日　平成４年(1992)10月21日

(51)Int.Cl.⁵	識別記号	庁内整理番号	F I	技術表示箇所
B６０K　17/04	G	8710－3D		
6/00				
8/00				
17/356		8710－3D		
		8710－3D	B６０K　9/ 00	Z

審査請求　未請求　請求項の数１(全　５　頁)　最終頁に続く

(21)出願番号　特願平3－61662

(22)出願日　平成３年(1991)３月26日

(71)出願人　000003207
トヨタ自動車株式会社
愛知県豊田市トヨタ町１番地

(72)発明者　古谷　昌之
愛知県豊田市トヨタ町１番地　トヨタ自動車株式会社内

(74)代理人　弁理士　吉田　研二　(外２名)

(54)【発明の名称】　シリーズ、パラレル複合ハイブリッドカーシステム

(57)【要約】

【目的】回生制動時のモータの高回転側の回生制動トルク不足を解消し、低速回転から高速回転までほぼ一定の回生制動トルクを得ることができるシリーズ、パラレル複合ハイブリッドカーシステムを提供する。

【構成】エンジン１、発電機３、走行用のモータ９、バッテリ１７を備え、かつ、エンジン１とモータ９との間に無段変速機５を設けるとともに、モータ９の高回転側の回生制動トルク不足分をエンジン１のフリクショントルクと発電機３の回生制動トルクとの合成トルクで補うように前記無段変速機５を制御する制御手段１８を備えた。

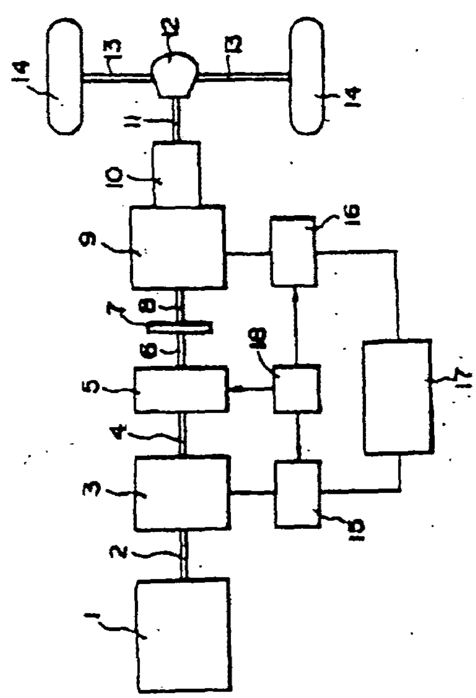

図１

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【特許請求の範囲】

【請求項1】エンジンと、このエンジンにより駆動される発電機と、走行用のモータと、前記発電機とモータとの間で電力の授受を行うバッテリと、前記エンジンとモータとの間に設けられたクラッチと、前記エンジン、発電機、クラッチ及びモータとの間で互いにトルク伝達を行うトルク伝達手段と、前記モータの回転トルクを車輪に伝達するトルク伝達手段とを備えたシリーズ、パラレル複合ハイブリッドカーシステムにおいて、前記エンジンとモータとの間に無段変速機を設け、かつ、前記モータの高回転側の回生制動トルク不足分をエンジンのフリクショントルクと発電機の回生制動トルクとの合成トルクで補うように前記無段変速機を制御する制御手段を備えたことを特徴とするシリーズ、パラレル複合ハイブリッドカーシステム。

【発明の詳細な説明】

【0001】

【産業上の利用分野】この発明は、エンジンとモータにより駆動されるシリーズ、パラレル複合ハイブリッドカーシステム、特にモータの高回転側のトルク不足をエンジンのトルクで補うことができるシリーズ、パラレル複合ハイブリッドカーシステムに関するものである。

【0002】

【従来の技術】近年、省資源、大気汚染や騒音の防止に対する要求が社会的に益々高まりつつある。このような要求に応えるものとして、エンジンと、このエンジンにより駆動される発電機とともに、走行用のモータ及びこのモータに電力を供給するバッテリなどを備えたハイブリッドカーシステム、すなわち複合電気自動車が注目されている。このようなハイブリッドカーシステムとして、従来、実開昭51－103220号、実開平2－7702号、及び実開昭53－55105号公報などに開示された構成の装置が開発されている。上記各公報には、いずれも、走行用のモータとエンジンとがクラッチを介して回転軸で連結された電気自動車の構成が記載されている。

【0003】すなわち、実開昭51－103220号公報の第1図には、モータとエンジンとが回転軸とクラッチを介して連結され、かつ、増速機構を介してエンジンにより駆動される発電機と、この発電機により充電されるとともに、前記モータに電力を供給してこれを駆動する蓄電池を備えた構造の複合電気自動車が記載されている。この装置はクラッチを備えているので、クラッチを切り離したときにはシリーズ走行モード、すなわち、エンジンで駆動される発電機で発電した電力を一旦蓄電池に蓄え、この蓄電池から供給される電力により走行用のモータを回転させる走行モードをとることになる。また、クラッチを接続したときにはパラレル走行モード、すなわち車両をエンジンとモータの両方で駆動し、しかも発電機による発電作用も行う走行モードをとることができるものである。

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【0004】

【発明が解決しようとする課題】従来の課題

上記従来の装置においては、以上のように、クラッチの切り替えによりパラレル走行とシリーズ走行の切り替えが随時可能な構成になっているが、エンジンとモータの結合状態を負荷に応じて変化させ、モータのトルクに応じてエンジンのトルクを制御してエンジンの負荷領域を一定にするような装置は装着されていなかった。

【0005】確かに、パラレル走行モードでは、エンジンの出力とモータの出力とを同時に使用可能であり、加速時や登坂時などのように大きなトルクを必要とする場合に有利であるが、一般に回転数（回転速度）に対するエンジンとモータの最大効率点は等しくなく、モータが比較的高い回転数で高い効率を示すのに対し、エンジンは比較的低い回転数で高い効率が得られる。従って、モータとエンジンとを固定ギア比で連結した場合、エンジンの負荷領域がかならずしも最良な状態にならず、燃費向上の点で好ましくない。

【0006】また、シリーズ走行モードでは、エンジンを発電のためだけに用いるので、エンジンの負荷領域を燃費の良い領域に設定できる反面、車両の駆動用として走行用のモータの出力だけしか使えないので、加速性能が悪くなるという問題点があった。

【0007】更に、モータが、比較的高速回転をしている状態で制動をかける場合、図3（a）に示すように、走行用のモータによる回生制動トルクaが高回転側で大きく低下するので、理想トルク線bに対して図で斜線を施したトルク不足分cだけトルク不足を生じ、ブレーキの効きが悪くなるという問題点があった。従って、上記問題点を解消しなければならないという課題がある。

【0008】発明の目的

この発明は、上記課題を解決するためになされたもので、回生制動時のモータの高回転側の回生制動トルク不足を解消し、低速回転から高速回転までほぼ一定の回生制動トルクを得ることができるシリーズ、パラレル複合ハイブリッドカーシステムを提供することを目的とする。

【0009】

【課題を解決するための手段】本発明に係るシリーズ、パラレル複合ハイブリッドカーシステムは、エンジンと、このエンジンにより駆動される発電機と、走行用のモータと、前記発電機とモータとの間で電力の授受を行うバッテリと、前記エンジンとモータとの間に設けられたクラッチと、前記エンジン、発電機、クラッチ及びモータとの間で互いにトルク伝達を行うトルク伝達手段と、前記モータの回転トルクを車輪に伝達するトルク伝達手段とを備えている。また、前記エンジンとモータとの間に無段変速機を設け、かつ、前記モータの高回転側の回生制動トルク不足分をエンジンのフリクショントル

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クと発電機の回生制動トルクとの合成トルクで補うように前記無段変速機を制御する制御手段を備えたものである。

【0010】

【作用】次に、本発明の作用を説明する。本発明によるシリーズ、パラレル複合ハイブリッドカーシステムは、まず、エンジンにより駆動される発電機により発電し、得られた電力を一時バッテリに蓄え、次いで、このバッテリに蓄えられた電力を走行用のモータに給電、駆動し、車両を走行させる。バッテリは、前記発電機とモータとの間で電力の授受を行う。前記エンジンとモータとの間に設けられたクラッチを接続すると、前記エンジン、発電機、クラッチ及びモータとの間で互いにトルク伝達が行われ、更に、前記モータの回転トルクを車輪に伝達することにより、エンジンとモータの両方の駆動トルクにより車両が駆動される。また、前記エンジンとモータとの間には無段変速機が設けられており、かつ、この無段変速機を、前記モータの高回転側の回生制動トルク不足分をエンジンのフリクショントルクと発電機の回生制動トルクとの合成トルクで補うように制御手段により制御し、回生制動トルクを一定にすることにより、回生制動時のモータの高回転側の回生制動トルク不足を解消することができる。

【0011】

【実施例】以下、この発明の一実施例を図面に基づいて説明する。図1は、この発明によるシリーズ、パラレル複合ハイブリッドカーシステムの一実施例の基本概念を示す構成図である。

【0012】同図において、1はエンジンであり、出力軸2を介して発電機3に連結され、さらに出力軸4、6、8などからなるトルク伝達手段を介して無段変速機(CVT)5、クラッチ7、走行用のモータ9が順次連結され、互いにトルク伝達されるように形成されている。また、モータ9の回転トルクは、変速機10、出力軸11、差動歯車装置12、アクセル軸13からなるトルク伝達手段を介して車輪14に伝えられる。

【0013】無段変速機5は、出力軸4と6の回転数の比を後述する制御手段により適宜連続的に変えることを可能にするCVT(Continuous Variable Transmission)である。また、出力軸6、8の間に設けられたクラッチ7は、出力軸6と8との間を接続したり、切り離したりする働きをするものである。更に、モータ9は、出力軸8と11との間に変速機10と共に組み込まれ、走行用の電動装置として車輪14を駆動する。

【0014】発電機3は、電力変換器15を介してバッテリ17に接続されて、エンジン1の回転エネルギや車輪14からトルク伝達手段を介して伝達される制動エネルギを電気エネルギに変換し、バッテリ17に貯蔵する。モータ9は、走行時、電力変換器16を介してバッテリ17から電力の供給を受けると共に、回生制動時、電力変換器16を介してバッテリ17に制動エネルギを回生する。18は無段変速機5と電力変換器15、16を制御する電子制御装置(ECU)である。

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【0015】図2に示すように、エンジン1とモータ9とは効率最良領域が異なっており、パラレル走行をする場合にエンジン1とモータ9とを直結、または固定ギア比で結合していたのでは、必ずしもエンジン1をその燃費最良領域で動作させることができない。そこで、この発明では、エンジン1の負荷領域が燃費最良領域をとるように電子制御装置18で無段変速機5の変速比を最適に制御し、エンジン1を動力源として走行する場合にも常に最良の燃費で走行が可能な構成となっている。

【0016】つまり、図2(b)の動作点Aでモータ9が駆動されているときに、登坂や急加速などのためにパワーが必要になったとき、従来技術では図2(a)の動作点Aでそのままエンジン1を駆動することになり、燃料効率が悪くならざるを得なかった。しかし、この発明による上記実施例によれば、無段変速機5のギア比を電子制御装置18によって適正に制御することにより、エンジン1の動作点を図2(a)の点Bにずらすことが可能となり、最良の燃料効率が得られる。

【0017】従って、上記装置を使用する場合、通常はモータ9のみで走行するシリーズ走行モードをとり、また、比較的エンジン1の効率がよい定常走行時や、モータ9だけではパワーが不足する加速時及び登坂時にはクラッチ7を係合してパラレル走行モードとし、かつ、無段変速機5の変速比を適正に制御することにより、駆動力をエンジン1から効率的に供給することになる。

【0018】一方、回生制動時のモータ9のトルク特性は図3(a)の実線部aのようになるのに対し、制動力としての理想的な要求トルク特性は回転数にかかわらず破線部bのようになるから、結局、モータ9の高速回転側で図で斜線を施したトルク不足分cだけ制動力不足となる。そこで上記実施例では、図3(b)に示すエンジン1のフリクショントルクdと発電機3の回生トルクeとの合成トルクfを高回転側で大きなトルクが得られるように無段変速機5の変速比を電子制御装置18によって最適に制御し、前記モータ9の高回転側での制動力不足を補うことができる。

【0019】次に、電子制御装置18による無段変速機5の制御動作について図4、図5を参照して説明する。

【0020】まず、ステップ101でアクセル信号がOFFになると、ステップ102で、現在の車速に対応するモータ9の回転速度が定格回転速度Vnより大きいか否かを判断し、もしYESの場合、直ちにステップ103に進みクラッチ7をONする。続くステップ104では、ステップ103におけるクラッチON動作より時間的にやや遅れて無段変速機5のギヤ比を設定した後、ステップ105でブレーキ信号をONし、制動トルクを発

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生させる（ステップ１０６）。一方、ステップ１０２でモータ９の回転速度が定格回転速度Ｖｎより小さい場合は直ちにステップ１０５にジャンプしてブレーキ信号をＯＮし、制動トルクを発生させる。

【００２１】他方、アクセル信号がＯＮになると、順次、クラッチ７、ブレーキ信号がＯＦＦとなり、モータ９の制動トルクの発生も停止される。

【００２２】以上説明したように、上記実施例は、回生制動時のモータの高回転側の回生制動トルク不足を解消し、低速回転から高速回転までほぼ一定の回生制動トルクを得ることができる。

【００２３】また，パラレル走行の場合には、エンジン１とモータ９の両方を効率最良領域で動作させることができるとともに、低速及び定常走行時にクラッチ７を切ってシリーズ走行をすることにより、回生制動時のエネルギ回収量をエンジンのフリクションの分だけ多くすることが可能である。

【００２４】更に、加速時以外は常にバッテリを充電する状態にしておくことが可能なので、深い放電が少なくなり、バッテリの寿命を向上させることができる。

【００２５】以上この発明の実施例について説明したが、この発明は上記実施例に何等限定されるものではなく、例えば、発電機３をエンジン１及びモータ９と同一軸上に設置せず、適当な増速歯車装置を介して出力軸２に対し並列的に配置するなど、この発明の要旨を逸脱しない範囲内において種々の態様で実施し得ることは勿論である。

【００２６】

【発明の効果】以上説明したように、本発明によるシリーズ、パラレル複合ハイブリッドカーシステムは、エンジンとモータとの間に無段変速機を設け、かつ、モータの高回転側の回生制動トルク不足分をエンジンのフリクショントルクと発電機の回生制動トルクとの合成トルクで補うように前記無段変速機を制御する制御手段を備えた構成により、回生制動時のモータの高回転側の回生制動トルク不足を解消し、低速回転から高速回転までほぼ一定の回生制動トルクを得ることができる効果を有する。

【図面の簡単な説明】

【図１】この発明のシリーズ、パラレル複合ハイブリッドカーシステムの一実施例の基本概念を示す構成図である。

【図２】（ａ）はエンジンの回転数とトルク及び等燃費率との関係を示す特性図、（ｂ）はモータの回転数とトルク及び効率との関係を示す特性図である。

【図３】（ａ）はモータの回転数と回生制動トルクとの関係を示す線図、（ｂ）はエンジンの回転数とフリクショントルク、発電機の回生トルク、及びそれらの合成トルクとの関係を示す線図である。

【図４】この発明によるシステムの動作を示すフローチャートである。

【図５】この発明によるシステムの動作タイミングを示すタイムチャートである。

【符号の説明】

１　エンジン
２，４，６，８，１１　出力軸
３　発電機
５　無段変速機（ＣＶＴ）
７　クラッチ
９　モータ
１０　変速機
１４　車輪
１５，１６　電力変換器
１７　バッテリ
１８　電子制御装置（ＥＣＵ）

【図５】

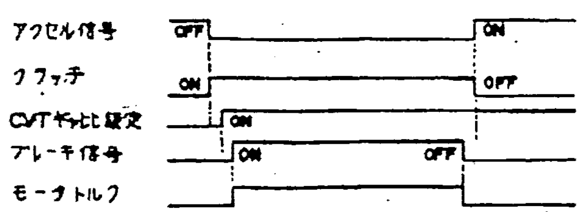

図５

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【図1】

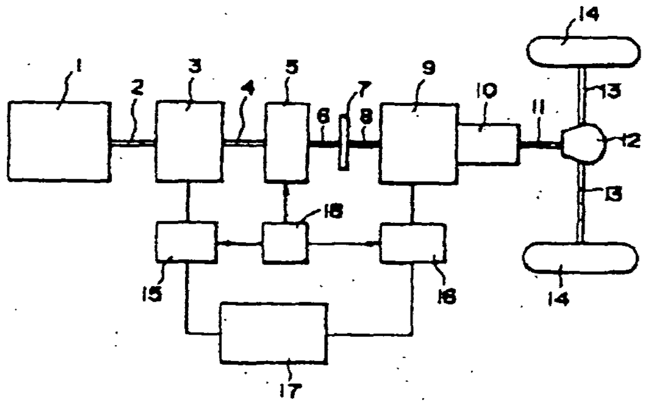
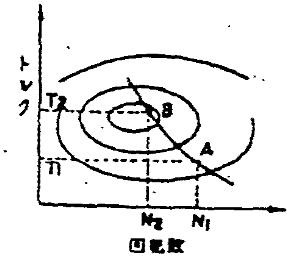
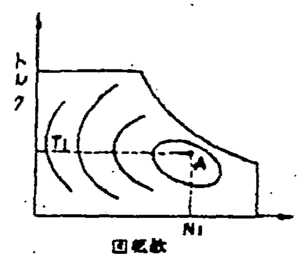


図 1

【図2】



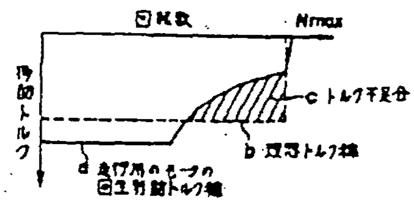
(a) エンジン



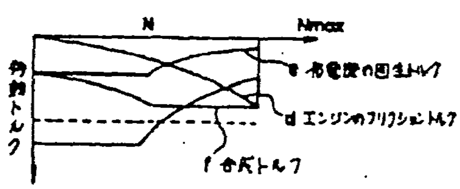
(b) モータ

図 2

【図3】



(a)



(b)

図 3

【図4】

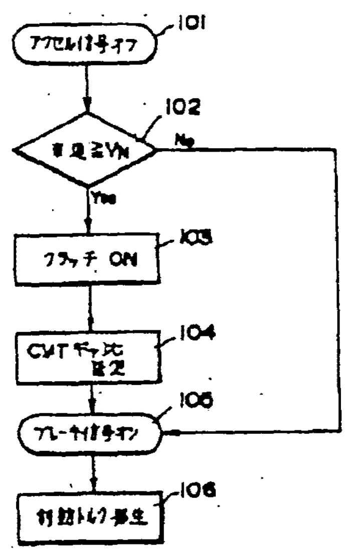


図 4　フローチャート

フロントページの続き

(51) Int. Cl.⁵	識別記号	庁内整理番号	F I	技術表示箇所
B 6 0 L　11/02		6821 －5H		

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⑲ Japanese Patent Office (JP)

⑫ Unexamined Utility Model Publication

⑪ Unexamined Utility Model Publication

51-103220

㊸ Publication Date: August 18, 1976

㊿ IPC

B 60 L 15/20
11/12

㊴ Name of Invention: Control System for a Hybrid Vehicle

㉑ Utility Model Application No: 50-21601

㉒ Filing Date: February 18, 1975

⑪ Applicant: Toyota Jidosha Kabushiki Kaisha

㊼ Scope of Claims for Utility Model

Control system for a hybrid vehicle, in which an output shaft of an engine is connected to a rotating shaft of a motor powered by a battery through a clutch, said battery is charged by power generated by a generator connected to said output shaft of said engine, and a solenoid valve controlled by an electric signal is arranged on an oil tube connected to said clutch, comprising:

rotating speed sensors for detecting rotating speeds of said output shaft of said engine and said rotating shaft of said motor respectively;

a comparator for comparing a rotating speed of said output shaft of said engine detected by said output shaft rotating speed sensor with a rotating speed of said rotating shaft of said motor detected by said rotating shaft rotating speed sensor, outputting an electric signal when said rotating shaft rotating speed is higher or equal than said output shaft rotating speed, and for controlling said solenoid valve to open said oil tube when said comparator outputs said electric signal;

an oil pressure switch for generating an electric signal when oil pressure reaches to a clutch connecting pressure; and

an interrupting means for interrupting a field circuit of said generator when electric signals are generated from said comparator and said oil pressure switch simultaneously.

Brief Description of the Drawings

Figure 1 is a contractual drawing showing an embodiment of a hybrid vehicle according to the present invention.

Figure 2 is a circuit diagram of a control system according to the present invention.

Figure 3 is timing graphs when the operation mode is transferred from the first mode to the second mode

1 ... engine
2 ... output shaft
3 ... clutch
4 ... motor
5 ... rotating shaft
6 ... speed up gear
7 ... generator
9 ... battery
10, 11 ... sensor

12 ... oil pipe
13 ... solenoid valve
18 ... oil pressure switch
19 ... comparator
20 ... AND gate
25 ... inverter
27 ... field coil
31 ... coil

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 510 582 A2**

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: 92106797.1

(51) Int. Cl.5: B60K 6/04, B60K 17/28

(22) Date of filing: 21.04.92

(30) Priority: 23.04.91 IT TO910307

(43) Date of publication of application: 28.10.92 Bulletin 92/44

(84) Designated Contracting States: CH DE ES FR GB IT LI NL SE

(71) Applicant: IVECO FIAT S.p.A.
Via Puglia 35
I-10156 Torino(IT)

(72) Inventor: Filippi, Federico
Via Mazzini, 40
I-10100 Torino(IT)

(74) Representative: Plebani, Rinaldo et al
c/o Studio Torta, Via Viotti 9
I-10121 Torino(IT)

(54) **Vehicle powerplant featuring thermal and electrical drive means.**

(57) A powerplant comprising a combustion engine (1) connected to a transmission (2) via a propeller shaft (3) fitted with a clutch (4); a current generator (7) for supplying current to a storage battery (8), and powered by a countershaft (5) connected to the propeller shaft (3) via a first gear drive (6) upstream from the clutch (4); and an electric motor (10) connected to the propeller shaft (3) via a second gear drive (11) downstream from the clutch (4); a second clutch (12) being provided between the electric motor (10) and the second drive (11).

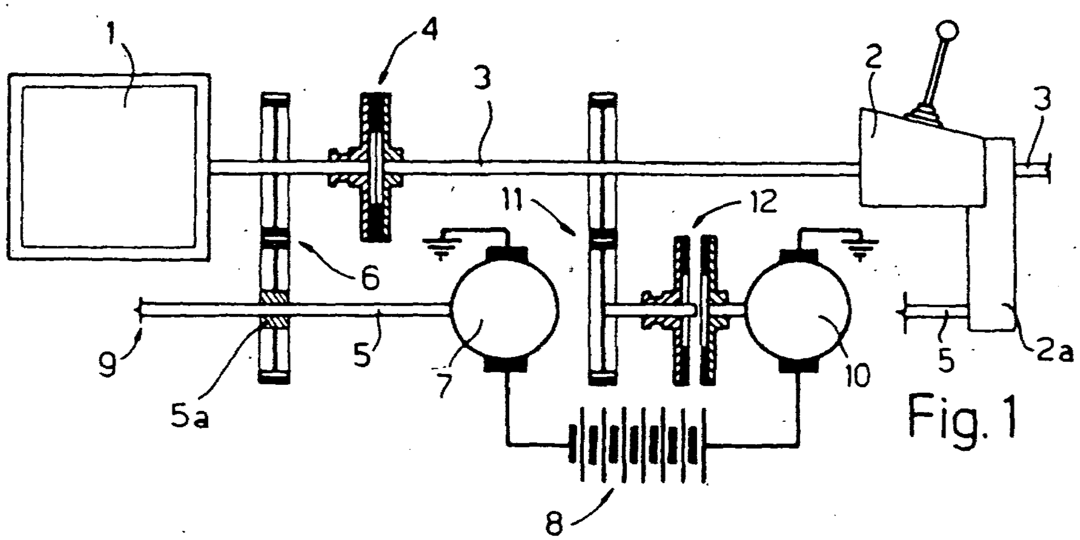

Fig. 1

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The present invention relates to a vehicle powerplant comprising thermal and electrical drive means variously connectable to the input shaft of the transmission as well as to a countershaft controlling accessory devices on the vehicle.

Vehicles of the aforementioned type are employed over mixed routes allowing of little or no emission, or over which normal emission is permitted. Over the first type, the vehicle is driven solely by the electrical drive means or in controlled manner by the thermal means, whereas, over the second, the thermal drive means are operated normally. Vehicles of this type invariably feature accessory devices (e.g. hydraulic power steering pump, brake and conditioner compressors, auxiliary alternators), and at times also special-purpose devices powered by the above drive means for performing special functions for which the vehicle is designed. Both the accessory and special-purpose devices frequently demand far greater power than that required for operating the vehicle under various driving conditions.

On one known powerplant of this type, the thermal drive means comprise a combustion engine connected mechanically to the transmission input shaft by a propeller shaft fitted with a clutch designed to assume a first and second position wherein the combustion engine is respectively connected to and disconnected from the transmission input shaft.

A countershaft for powering the vehicle accessory devices is connected by a system of gears to the propeller shaft, downstream from the clutch.

The electrical drive means normally consist of a unit designed to operate as both an electric motor and current generator. The rotor element of the unit is connected to the countershaft in such a manner as to be driven by it when the unit is operated as a current generator, and to drive it for rotating the transmission input shaft when the unit is operated as a motor.

Alternatively, the rotor element of the unit is connected directly to the propeller shaft to form a single drive line between the combustion engine and the transmission input shaft, in which case, the drive line is fitted with a second clutch downstream from the unit.

The powerplant also comprises a storage battery to which current is fed by the unit when operated as a generator, and from current is drawn when the unit is operated as a motor.

Powerplants of the type briefly described above provide for two operating modes. In a first, the combustion engine is operated and the clutch (or both clutches, in the case of the alternative configuration described above) is set to the first engaged position, so that both the transmission input shaft and the countershaft are driven by the combustion engine, while the rotor element of the unit, set to generator mode, is rotated by the countershaft for charging the batteries. In the second operating mode, the clutch is set to the second release position, and the unit alone is operated as an electric motor, the rotor element of which thus provides for powering both the transmission input shaft and the countershaft.

Powerplants of the aforementioned type present numerous drawbacks.

Firstly, in the second operating mode, i.e. when operated electrically, the accessory devices are driven solely by the power supplied by the battery, which, if of normal weight and size for the vehicle, provides for accumulating only a limited amount of energy.

Secondly, in the second operating mode, wherein the combustion engine is idle and disconnected from the drive line, current can only be generated for charging the battery when braking the vehicle, and if the unit is designed to operate as a brake, for recovering the energy produced during braking and converting it at least partially into electrical energy.

As a result, the operating range of the powerplant is fairly limited.

It is an object of the present invention to provide a powerplant of the aforementioned type designed to overcome the aforementioned drawbacks.

According to the present invention, there is provided a vehicle powerplant comprising first thermal drive means and second electrical drive means; said first and second means being activated for transmitting motion to the drive wheels of the vehicle via a transmission; said first drive means comprising a combustion engine connected mechanically to said wheels by a drive line fitted with said transmission and with a clutch located between said engine and said transmission and which may be set to a first and second position wherein said combustion engine is respectively connected to and disconnected from said transmission; characterized by the fact that it comprises:

a current generator for supplying electric current to a storage battery, and the rotor element of which is connected to said drive line upstream from said clutch;

an electric motor, the rotor element of which is connected by a first drive to said drive line downstream from said clutch, said electric motor being driven by the current supplied by said battery;

a second clutch located between the rotor element of said electric motor and said drive line, and which may be set to a first and second position wherein said rotor element of said motor is respectively connected to and disconnected from said drive line.

The design and operation of the powerplant

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according to the present invention will be described by way of example with reference to the accompanying drawings, in which:

Fig.1 shows a schematic view of a first configuration of the powerplant according to the present invention;

Fig.s 2 and 3 show a further two configurations of the Fig.1 powerplant.

The powerplant according to the present invention comprises a combustion engine 1, e.g. a diesel engine; and a transmission 2, the input shaft of which is connected mechanically to engine 1 by a propeller shaft 3 fitted with a clutch, e.g. a friction clutch, 4. Clutch 4, which is operable in any manner, e.g. directly by the driver and/or by means of any type of actuator, is designed to assume two positions: an engaged position (Fig.1) wherein the up- and downstream portions of shaft 3 are connected; and a release position (Fig.s 2 and 3) wherein said portions are disconnected.

As shown clearly in the accompanying drawings, the powerplant also comprises a countershaft 5 connected mechanically to shaft 3, upstream from clutch 4, by a drive consisting, for example, of gears 6.

A current generator 7 supplies electric current to a storage battery 8, and presents a rotor element (not shown) connected to and rotated by countershaft 5.

Countershaft 5 or another shaft upstream from clutch 4 also provides for a power takeoff 9 for operating the accessory devices on the vehicle. These, in addition to standard industrial vehicle devices, such as the power steering pump, brake and conditioner compressors and auxiliary alternators, may also consist of special-purpose devices, such as compactors, in the case of refuse collection and disposal vehicles.

The powerplant according to the present invention also comprises an electric motor 10 powered by the current supplied by battery 8, and the rotor element (not shown) of which is connected to propeller shaft 3, downstream from clutch 4, by a second drive consisting, for example, of gears 11. A second clutch 12, which may be the same type as clutch 4, is located between the rotor element of motor 10 and drive 11, and is designed to assume a first engaged position (Fig.3) wherein the rotor element of motor 10 is connected to drive 11, and a second release position (Fig.s 1 and 2) wherein the rotor element and drive 11 are disconnected.

For the reasons explained later on, current generator 7 may conveniently be designed to also operate as an electric motor powered by battery 8, in which case, drive 6 is provided with a clutch 5a of any type, designed to assume a first and second position wherein shaft 5 of generator-motor 7 is respectively connected to and disconnected from drive line 3 immediately downstream from engine 1. Clutch 5a may conveniently be housed in one of the gears of drive 6, as shown schematically in the accompanying drawings.

The powerplant may also comprise a further drive 2a forming part of and possibly comprising pairs of gears housed inside transmission 2, for transmitting motion from drive line 3 to shaft 5 connected to power takeoff 9. Drive 2a is activated exclusively, in known manner, with the gear lever in neutral, so that no motion is transmitted to the wheels of the vehicle.

According to a variation not shown, drive 11 may be driven from a point on drive line 3 downstream from transmission 2, as opposed to upstream as shown in the accompanying drawings, for reducing the size, particularly lengthwise, of the powerplant and so enabling troublefree installation on certain types of vehicle.

The powerplant according to the present invention operates as follows:

In a first operating mode (Fig.1), combustion engine 1 is operated with clutch 4 in the first (engaged) position and clutch 12 in the second (release) position, so that the vehicle is driven by engine 1 connected by shaft 3 to the input shaft of transmission 2. In this mode, clutch 4 is operated normally for shifting transmission 2.

At the same time, drive 6 rotates countershaft 5, which in turn rotates the rotor element of current generator 7 for charging battery 8, and operates the accessory devices on the vehicle connected to power takeoff 9.

This first operating mode therefore provides, thermally, for running the vehicle normally, operating the accessory devices, and charging the battery, and may conveniently be employed over routes involving no particular control of emission.

In a second operating mode, combustion engine 1 is again operated, but with clutch 4 in the second (release) position (Fig.2), so that only countershaft 5 and consequently generator 7 and the auxiliary devices are operated thermally. In this mode, means for controlling the speed and fuel supply of engine 1 may be provided for minimizing emission, thus enabling temporary stoppage of the vehicle for operating the accessory devices and/or charging battery 8.

In a third operating mode (Fig.3), combustion engine 1 is again operated, but with clutch 4 in the second (release) position, clutch 12 in the first (engaged) position, and electric motor 10 activated, so that shaft 3 is disconnected from engine 1 and drive 6, the input shaft of transmission 2 is powered by motor 10 via drive 11, and the vehicle is driven entirely electrically by the power drawn from battery 8. If combustion engine 1 is activated, current generator 7 is also operated simultaneously for charging battery 8, which thus acts as a flywheel for the power supplied by engine 1 and drawn off by electric motor 10.

In this third mode, operation of engine 1 is so controlled as to maintain substantially constant engine speed and output combined with a high degree of efficiency and minimum emission for driving along controlled-emission routes.

An important point to note is that, in all three configurations described, the accessory devices are operated thermally, that is, under high power conditions, with no limitation in terms of autonomy.

Nevertheless, when drive 11 is driven from a point along line 3 upstream from transmission 2, if the power required in said third mode for operating the accessory devices is not such as to limit autonomy, and/or peak power is demanded of takeoff 9 in excess of the average designed for effectively controlling combustion engine 1 (for achieving high efficiency and minimum emission), power takeoff 9 (and, hence, shaft 5) may be controlled by drive 2a transmitting motion from transmission 2 to shaft 5 and so electrically controlling power takeoff 9.

When absolutely no emission is permitted, a fourth operating mode may be employed, which consists in de-activating engine 1 and operating the powerplant as described with reference to Fig.3, in which case, the vehicle is operated entirely electrically by battery 8.

In fourth mode (with engine 1 de-activated), power takeoff 9 may still be controlled electrically, as required for at least operating the accessory devices governing the driveability of the vehicle, such as the power steering pump and brake system devices.

For this purpose, clutch 5a is released and generator 7 set to motor mode and supplied by battery 8 for electrically powering takeoff 9.

When electrically operating the vehicle (third and fourth mode), transmission 2 can only be operated normally by means of clutch 12 if drive 11 is located upstream from the transmission. Moreover, if also designed to function as a current generator, electric motor 10 may provide for electrically braking the vehicle and at least partially recovering and converting the energy produced when braking into electrical energy, which is stored in battery 8.

To those skilled in the art it will be clear that changes may be made to the powerplant as-described and illustrated herein without, however, departing from the scope of the present invention.

In particular, the rotor element of current generator 7 may be connected directly to drive line 3, upstream from coupling 4, instead of via the interposition of shaft 5 and gear drive 6 as described herein.

In this case, shaft 5 may still be connected to line 3 via gear drive 6, as shown in the accompanying drawings, but no longer to the rotor element of current generator 7.

The above further embodiment of the powerplant obviously operates in exactly the same way as described with reference to the accompanying drawings.

Claims

1. A vehicle powerplant comprising first thermal drive means and second electrical drive means; said first and second means being activated for transmitting motion to the drive wheels of the vehicle via a transmission (2); said first drive means comprising a combustion engine (1) connected mechanically to said wheels by a drive line (3) fitted with said transmission (2) and with a clutch (4) located between said engine (1) and said transmission (2) and which may be set to a first and second position wherein said combustion engine (1) is respectively connected to and disconnected from said transmission (2); characterized by the fact that it comprises:

   a current generator (7) for supplying electric current to a storage battery (8), and the rotor element of which is connected to said drive line (3) upstream from said clutch (4);

   an electric motor (10), the rotor element of which is connected by a first drive (11) to said drive line (3) downstream from said clutch (4), said electric motor (10) being driven by the current supplied by said battery (8);

   a second clutch (12) located between the rotor element of said electric motor (10) and said drive line (3), and which may be set to a first and second position wherein said rotor element of said motor (10) is respectively connected to and disconnected from said drive line (3).

2. A powerplant as claimed in Claim 1, characterized by the fact that it also comprises a shaft (5) connected by a second drive (6) to said drive line (3) upstream from said clutch (4), and which provides for a power takeoff (9) for operating the accessory devices of said vehicle; the rotor element of said current generator (7) being connected to said shaft (5).

3. A powerplant as claimed in one of the foregoing Claims, characterized by the fact that said current generator (7) is also designed to operate as an electric motor; said second drive (6) presenting a third clutch (5a) designed to assume a first position wherein said shaft (5) connected to said rotor element of said current

generator (7) is also connected to said drive line (3), and a second position wherein said shaft (5) is disconnected from said drive line (3).

4. A powerplant as claimed in one of the foregoing Claims, characterized by the fact that said first (11) and second (6) drives are gear drives.

5. A powerplant as claimed in one of the foregoing Claims, characterized by the fact that said first drive (11) is connected to said drive line (3) upstream from said transmission (2).

6. A powerplant as claimed in one of the foregoing Claims from 1 to 4, characterized by the fact that said first drive (11) is connected to said drive line (3) downstream from said transmission (2).

7. A powerplant as claimed in one of the foregoing Claims, characterized by the fact that said second clutch (12) is located between said rotor element of said electric motor (10) and said first gear drive (11).

8. A powerplant as claimed in one of the foregoing Claims, characterized by the fact that it comprises a third drive (2a) for connecting said transmission (2) to said shaft (5) providing for said power takeoff (9).

9. A powerplant as claimed in one of the foregoing Claims, characterized by the fact that said electric motor (10) is also designed to operate as a current generator, for electrically braking said vehicle and generating electric current which is supplied to said battery (8).

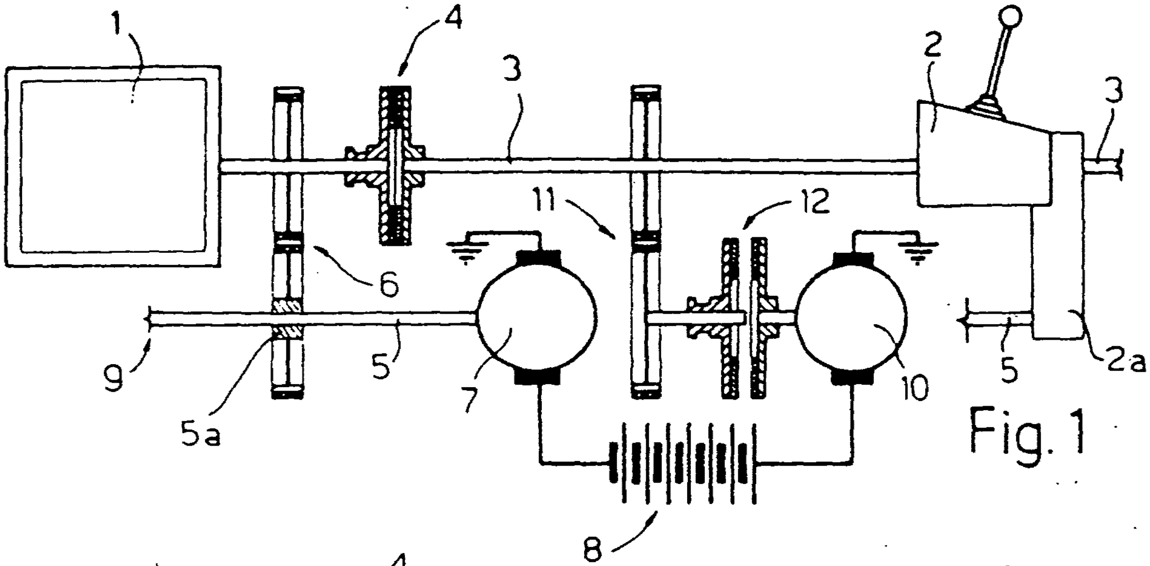


Fig. 1

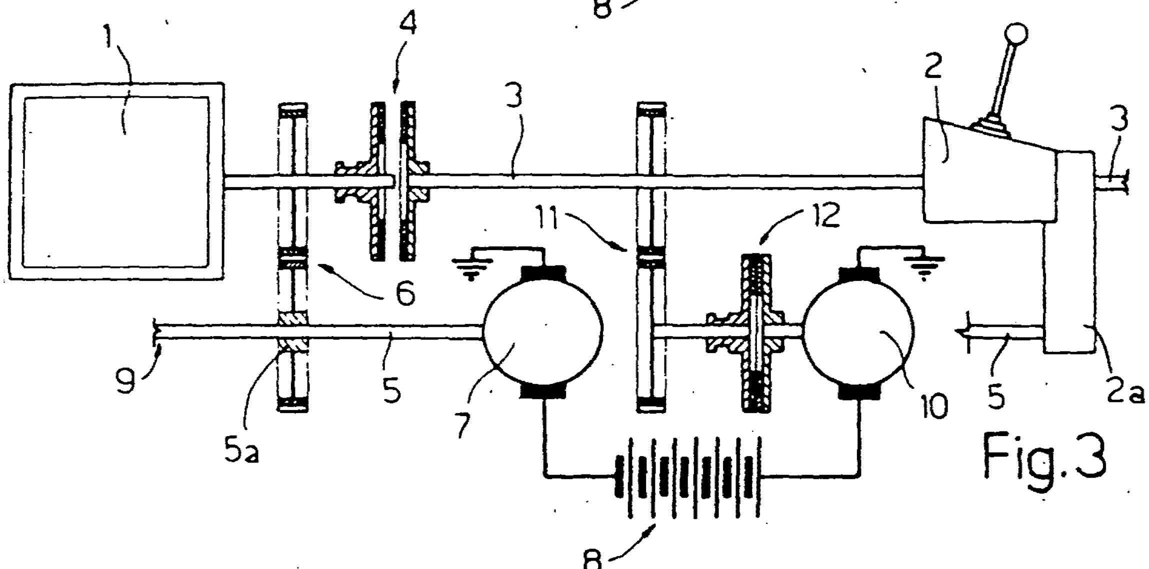


Fig. 3

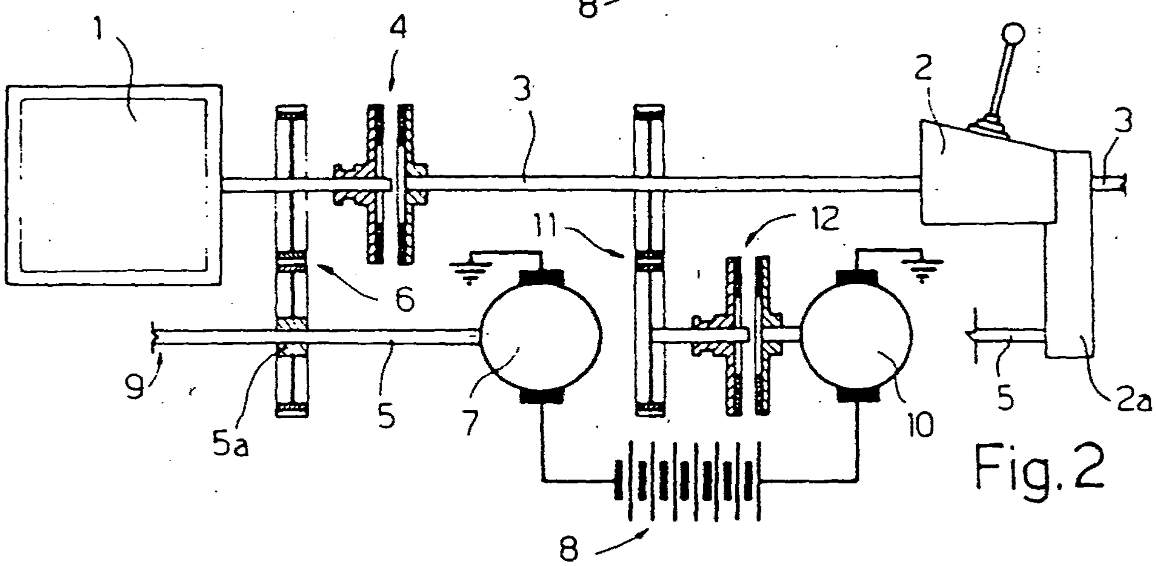


Fig. 2

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 136 055 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 84305672.2

(22) Date of filing: 21.08.84

(51) Int. Cl.⁴: **B 60 K 1/00**

(30) Priority: 01.09.83 GB 8323482

(43) Date of publication of application: 03.04.85 Bulletin 85/14

(84) Designated Contracting States: DE FR GB IT NL

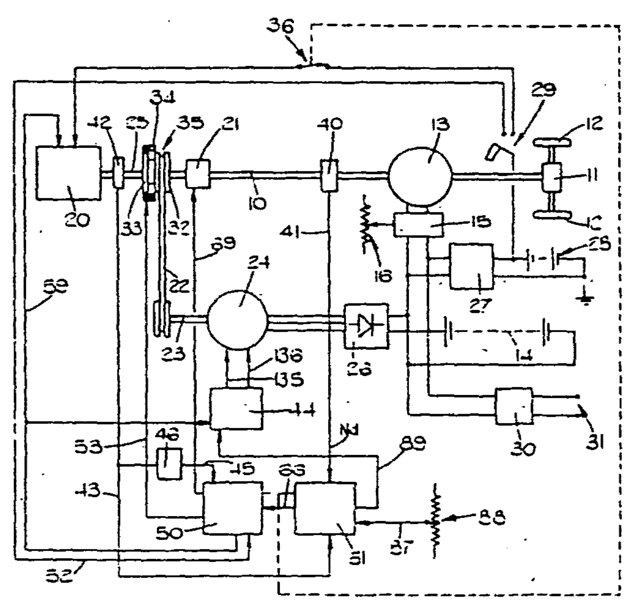
(71) Applicant: LUCAS INDUSTRIES public limited company, Great King Street, Birmingham, B19 2XF (GB)

(72) Inventor: Hammond, John Edward, Highfield Temple Grafton, Alcester B49 6NR (GB)
Inventor: Wooding, Peter Timothy, 12 Croome Close Sparkhill, Birmingham B11 4JG (GB)

(74) Representative: Cuddon, George Desmond et al, Marks & Clerk Alpha Tower Suffolk Street Queensway, Birmingham B1 1TT (GB)

(54) Drive system.

(57) An engine drive shaft (10) may be powered by an electric motor (13) or an internal combustion engine (20). The engine (20) is engageable with the shaft (10) through a clutch (21) and the engine speed is matched with that of the shaft (10) before engagement of the clutch (21) by loading the engine (20) with an electric generator (24) and varying the generator field current until the speeds are equal, when the clutch (21) is automatically engaged.



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DRIVE SYSTEM

This invention relates to a drive system for a and in particular to a system in which a vehicle may be propelled either by an electric motor or by an internal combustion engine.

In such a system it is commonly required to change from electrical to internal combustion power while the vehicle is running, and in known systems it has been the practice to match the engine and motor speeds by operating the engine throttle. However before the engine shaft is engaged with an output shaft of the system the response of the unloaded engine to throttle adjustments results in the engine speed hunting above and below its desired value. The consequent mismatch of the engine and motor speeds is likely to result in damage or severe wear to a clutch used to couple the engine to the output shaft.

According to the invention there is provided a drive system, comprising a main drive shaft for the vehicle, an internal combustion engine, a first clutch for coupling said engine to said drive shaft, means for electrically loading said engine to vary the speed thereof and means for actuating said first clutch only when the speeds of said engine and said shaft are substantially equal.

In one embodiment said means for coupling the engine to the drive shaft includes a rotor shaft of said motor.

In a preferred embodiment said engine speed is controllable by an electric generator, and there is provided means for varying the load applied to said engine by said generator.

In a particular embodiment said generator is connectable to charge said battery.

An embodiment of the invention will now be described by way of example only and with reference to the accompanying drawings in which:-

Figure 1 is a diagram of a vehicle propulsion system according to the invention,

Figure 2 is a diagram of a clutch control circuit forming part of Figure 1,

Figure 3 is a diagram of a speed comparator circuit forming part of Figure 1, and

Figures 4, 5 and 6 show respective parts of a circuit forming part of the system of Figure 1.

As shown in Figure 1 a vehicle drive system includes a main drive shaft 10 which is connected through a known type of differential gear 11 to driving wheels 12 of the vehicle. Drivingly coupled to the shaft 10 is the rotor of an electric motor 13 which can be energised by a battery 14 by way of a control circuit 15. The speed of the motor 13 is adjustable by a suitable control 16.

An internal combustion engine 20 has an output shaft 25 which can be coupled to the shaft 10 by means of an electro-magnetic clutch 21. A non-slipping belt and pulley arrangement 22 is coupled to a further shaft 23.

A three-phase alternator 24 is drivingly coupled to the shaft 23. The arrangement 22 includes a pulley 32 which is loose on the shaft 25. A plate 33 is drivingly coupled to the shaft 25. A stationary electromagnet 34 surrounds the pulley 32 and plate 33 and is energisable to urge the plate 33 and pulley 32 into frictional driving engagement. The pulley 32, plate 33 and electromagnet 34 combine to provide a further clutch 35. Output current from the alternator 24 is supplied to a rectifier circuit 26 whose output is connected across the battery 14.

The battery 14 comprises eighteen 12 volt battery units, providing 216 volts. A dc/dc converter 27 is connected across the output of the battery 14 for maintaining a charge on an auxiliary 12 volt battery 28 which can supply, inter alia, the starter and ignition circuits of the engine 20, through a switch 29. In its fully clockwise position the switch 29 supplies current to a starter (not shown) of the engine 20 through a switch 36.

A battery charging circuit 30 is also connected across the terminals of the battery 14 and can be connected to a 240 volt mains supply through terminals 31.

A transducer 40 is coupled to the shaft 10 and provides, on a line 41, a signal Nd corresponding to the speed of the shaft 10. A further transducer 42 is coupled to the shaft 25 and provides, on a line 43 a signal Ne corresponding to the speed of the engine 20. A limit detecting circuit 46 is responsive to the engine speed signal Ne on line 43 to provide a signal on a line 45 when the signal Ne exceeds a predetermined low value. A circuit 44 is shown in detail in Figures 4 to 6 and acts to regulate the field current of the alternator 24, and thereby the load imposed by the alternator 24 on the engine 20 when the clutch 35 is operated.

The propulsion system can be operated in at least five modes:-

1. With the clutch 21 disengaged and the motor 13 energised by the battery 14 to drive the shaft 10.

2. With the clutch 21 disengaged, the battery 14 energising the motor 13 to drive the shaft 10, the engine 20 running and the clutch 35 engaged to drive the alternator 24 and thereby to maintain the charge of the battery 14 and to provide at least part of the current supply to the motor 13.

3. With the engine 20 running, clutch 21 engaged, clutch 35 disengaged and the motor 13 de-energised by means of its control circuit 15. In this condition the engine 20 is driving the shaft 10 directly and the rotor of the motor 13 acts, effectively, as a flywheel.

4. With the engine 20 running, the clutch 21 engaged and the motor 13 energised to drive the shaft 10. In this condition the engine 20 is supplementing the power output of the motor 13.

5. With the engine 20 running, the clutch 21 engaged and the motor 13 acting as a generator to charge the battery 14.

In any of operating modes 3, 4 or 5 above, the speed of the engine 20 is controlled in a conventional manner by a throttle operated by a pedal.

Operation in modes 3, 4 and 5 will usually be commenced when the vehicle is moving at a substantial speed. It is therefore necessary to match the speed of the engine 20 with that of the shaft 10 before the clutch 21 is engaged. Speed matching is effected by engaging the clutch 35 while the engine 20 is stationary, starting the engine, opening the engine throttle sufficiently to enable its speed to be raised to a level at which the clutch 21 can be operated, and varying the load applied by the alternator 24 to the engine 20, to cause operation of the clutch 21 by circuits 50, 51 shown in detail in Figures 2 and 3 respectively.

As shown in Figure 2 the circuit 50 includes a relay R1 having normally-closed contacts R1a and normally open contacts R1b. A further relay R2 has normally open contacts R2a and normally closed contacts R2b. A third relay R3 has normally closed contacts R3a and normally open contacts R3b. A fourth relay R4 has normally open contacts R4a and a fifth relay R5 has normally closed contacts R5a. When the engine ignition switch 29 (Figure 1) is in its central, normally-running position a signal is provided on a line 52 to the circuit 50.

The line 52 is connected to the clutch 35 through a line 53, by way of the relay contacts R4a. The line 52 is also connected to the line 53 through a series arrangement of the contacts R1a, contacts R2b, diodes 54, 55 connected cathode to cathode and the contacts R5a. The relay R4 is connected in parallel with a RC delay circuit 56 to the junction between the diodes 54, 55. The line 45 is connected through a diode 57 and a resistor 58 to a line 59 connected to the ignition circuit of the engine 20. A series arrangement of two diodes 60, 61 connected cathode to cathode, the contacts R2a and contacts R1a are also connected between the line 45 and the line 52. The relay R2 is connected between earth and the junction of the diodes 60, 61. The relay R3 can be energised from the line 52 through the contacts R1b and a switch 65 arranged in series. The switch 65 is operable by a signal on a line 66 from the circuit 51 (Figure 1). The line 52 can be connected to the relay R1 by means of a manually operable switch 67. Energisation of relay R1 closes contacts R1b and the relay R1 is thereafter maintained energised through a diode 68. The relay R5 is energisable from the line 52 through a series arrangement of the contacts R1b, R3b and a diode 73. The relay R5 is also energisable from the line 52 when the contacts R1b and the switch 65 are both closed. A line 69 to the clutch 21 (Figure 1) communicates with the line 52 when the contacts R1b and R3b are both closed. Indicator devices 70, 71 are energised when signals are present on the lines 53, 69 respectively. A further indicator device 72 is energised when the relay R1 is latched on through the contacts R1b and diode 68.

As shown in Figure 3 the circuit 51 includes a differential amplifier 80 which is responsive to the signals Nd, Ne on lines 41, 43 respectively. An output signal from the amplifier 80 is supplied to a zero-level detecting circuit 81 which provides a signal on the lines 66 to the circuit 50 when the speeds of the drive shaft 10 and engine 20 are substantially equal. An alternative form of the device 81 provides a signal when a difference between these speeds is less than a predetermined amount. For example a signal may be provided on lines 66 when the speed of the engine 20 is less than one or two hundred rpm above or below that of the shaft 10. Output signals from the amplifier 80 are also supplied to a proportional plus integral amplifier 82 whose output is connected through a switch 83 and a resistor 84 to the inverting input of a further differential amplifier 85. The switch 83 is ganged with the switch 67 in the circuit 50 (Figure 2) and the switch 36 in the line to the engine starter (Figure 1), so these switches are operated at the same time and that when the switches 67, 83 are closed, the switch 36 is open. The inverting input of the amplifier 85 is also supplied, through a resistor 86, with an engine speed demand signal on a line 87 from a selector device 88 (Figure 1). The non-inverting input of the amplifier 85 is supplied with the engine speed signal Ne on line 43. The output of the amplifier 85 forms a field current demand signal which is supplied on a line 89 to the control circuit 44 (Figure 1) for the alternator 24, to regulate the alternator field current, and thereby the load imposed by the alternator 24 on the engine 20 when the clutch 25 is engaged.

If the propulsion system is operating in mode 1 above, and it is required to couple the engine 20 to the shaft 10 to operate in any of modes 3, 4 or 5, the switch 29 applies and maintains a signal on line 52 and subsequently starts the engine 20. Return of the switch 29 to its central position maintains the signal on the line 52. This signal passes through contacts R1a, R2b and diode 54 to operate the relay R4 and close the contacts R4a, the resulting voltage on line 53 energising the clutch 35 to couple the engine 20 to the alternator 24. When the engine speed signal Ne exceeds a predetermined low value limit detection circuit 46 provides a signal on line 45 which is applied through the diode 57 and resistor 58 to the line 59, to supply the ignition circuit of the engine 20. At the same time the control circuit 44 provides a field current to the alternator 24, thereby imposing a load on the engine 20.

The signal on line 45 energises the relay R2 (Figure 2), opening the contact R2b and shutting the contacts R2a. Since contacts R4a have been shut, relay R4 is maintained energised through the normally-closed contacts R5a and the diode 55. Closure of contacts R2a maintains the relay R2 energised through the diode 61.

The switch 67 is now operated to energise relay R1 from the supply on line 52, closing contact R1b and opening contact R1a. Relay R2 is nevertheless maintained energised by the signal on line 45 and relay R4 by the latch provided by contacts R4a, R5a. Closure of contacts R1b energises the indicating device 72 through the normally-closed contacts R3a, providing an indication that driving connection between the engine 20 and the shaft 10 has been selected, but has not yet occurred.

When the speed of the engine 20 is substantially equal to that of the shaft 10 the switch 65 is closed, energising relay R3 and closing the contacts R3b. The voltage signal on line 52 is then applied through line 69 to energise the clutch 21. Closure of contacts R3b also energises relay R5 through the diode 73, opening contacts R5a and de-energising relay R4. Contacts R4a open after a delay imposed by the circuit 56, causing the clutch 35 to be disengaged. The alternator 24 is, however, no longer required to load the engine 20, since speed matching has already occurred. Indicator device 72 is de-energised and device 71 is energised to show that the clutch 21 is engaged.

After the ganged switches 67, 83 in circuits 50, 51 respectively have been closed, but before the switch 65 is closed the speed of the engine 20 is varied by adjusting the load of the alternator 24 thereon, by means of the signal on line 87 from the speed selector device 88 (Figure 1). As shown in Figure 3 the engine speed signal Ne and the shaft speed signal Nd on lines 43, 41 respectively are applied to the amplifier 80 and any speed error is subjected to proportional plus integral amplification before being applied through the switch 83 and resistor 84 to the inverting input of the amplifier 85, to which input the signal on line 87 is also applied. The engine speed signal Ne is also applied to the non-inverting input of amplifier 85. The effect is that a required increase in engine speed results in the signal on line 89 being applied to the circuit 44 to reduce the field current of the alternator 24, and hence the load of the latter on the engine 20. When the speed signals Ne, Nd are equal, the resulting zero output from the amplifier 80 is detected by the circuit 81 and provides a signal on the line 66 to operate the switch 65, resulting in energisation of the clutch 21, as described above.

After the clutch 35 has been disengaged it is necessary to prevent the clutch 21 from being disengaged while the engine 20 is running, since the engine would then be unloaded and could overspeed. This requirement is met by the arrangement described, since if switch 67 (Figure 2) is opened while the engine is running the relay R1 nevertheless remains energised through the contacts R1b and the diode 68. The contacts R3b are thus maintained shut by relay R3 and the clutch 21 remains energised.

Additionally, since relay R1 remains energised the contacts R1a are open. Contacts R4a are also open and the clutch 35 cannot be re-engaged with the engine 20 running.

In order to de-energise the relay R1 and disengage the clutch 21 it is necessary to operate the switch 29 to remove the voltage supply from line 52. If, with the switch 67 open the switch 29 is first operated to remove the voltage on line 52, de-energisation of relay R1 closes contacts R1a and opens contacts R1b. Relay R3 is de-energised, contacts R3a close and contacts R3b open, and clutch 21 is disengaged. If switch 29 is subsequently shut while the speed Ne of the engine 20 is above that required to provide the signal on line 45, relay R2 remains energised and contacts R2b are open. Relay R4 cannot therefore be energised through contacts R1a and the clutch 35 cannot be engaged while the engine speed Ne is above its predetermined low value.

The switch 36, being ganged to the switches 67, 83, prevents the engine 20 from being started when the switch 67 is closed, since if this occurred the clutch 21 would be engaged while the engine 20 was running unloaded by the alternator 24, by way of the clutch 35.

As described above the control circuit 44 controls the field current of the alternator 24 in accordance with the magnitude of the signal online 89. The circuit 44 comprises well-known circuit arrangements which operate in a known manner, and which do not of themselves form part of the invention. The circuit 44 will therefore be described only insofar as to enable its operation to be understood.

As shown in Figures 4, 5 and 6 the circuit 44 may be considered as comprising parts 44A, 44B and 44C. Part 44A is an amplifier stage responsive to the signal on line 89 from the circuit 51 (Figure 3) and to the ignition voltage on line 59 (Figure 1). Two amplifier circuits 100, 101 respond to the signal on line 89 to provide a signal on a line 102. A semiconductor switch arrangement 103 is responsive to the ignition voltage signal on line 59, absence of this signal connecting the line 102 to an earth rail 104. A buffer circuit 105 is responsive to the signal on line 102 to supply a signal on a line 106 to the part 44B (Figure 5).

As shown in Figure 5 the signals on line 106 is applied to the inverting input of an amplifier 95 whose other input is connected to a feedback line 122. The amplifier 95 forms one element of an integrated circuit of the type available from Motorola under the designation MC3301, the numerals adjacent the amplifier indicating the terminals to which respective connections are made. The amplifier 95 has associated externally connected components to provide an integrating term and its output is supplied on a line 96 to an oscillator circuit 97 which also forms an element of the aforementioned Motorola integrated circuit.

The frequency of the output of oscillator 97 is dependent on the magnitude of the signal on line 96 and typically is in the range of 100 Hz to 1 KHz. The oscillator output is applied to the base of a npn transistor 110, through a resistor 98 which forms part of a resistor-capacitor network 99 connected between a +12v rail 111 and an earth rail 112, and provides a suitable bias at the output of oscillator 97. The transistor 110 is connected between the rails 111, 112 through a +8V regulating circuit 107 and the arrangement is such that a negative signal on the base of transistor 110 results in a positive voltage on a line 113. A diode, resistor and capacitor network 114 acts as a voltage pulse shaping circuit for the signals on line 113.

The signals on line 113 are applied through a potential divider 115 to a line 116 to the base of npn transistor 117 which is connected between the rails 111, 112 so that a positive signal on its base results in a low level signal on the base of a pnp transistor 118. Transistor 118 is connected between the rails 111, 112 so that in response to the low level signal on its base it provides a positive signal on the base of a npn transistor 119, causing the latter to conduct.

The transistor 119 is connected between the rails 11, 112 in series with the primary of a transformer 120. The transistors 117, 118, 119 and their associated capacitors and resistors comprise a voltage to current switching circuit which provides current pulses in the primary of the transformer 120, these pulses having the frequency of the oscillator circuit 97. A capacitor 130 and resistor 131 in series between the transformer primary and the rail 112 act to suppress voltage spikes.

The secondary winding of the transformer 120 is centre-tapped and is connected to a network 132 of resistors, diodes and zener diodes which shape the transformer output current pulses to provide drive pulses to the base of a power transistor 133, and also provide protection against excessive voltage on the base of the transistor 133. The transistor 133 is connected through the primary winding of a transformer 134 between the negative terminal of the 216 volt battery 14 (Figure 1) and a lead 135 to the field winding of the alternator 24. A second lead 136 from the field winding is connected to the positive terminal of the battery 14. A diode 137 is connected between the lines 135, 136 so as to be reverse biased with respect to the dc voltage on these lines, and acts as a so-called "free-wheel" diode to maintain the field current during intervals when the transistor 133 is switched off.

As described the primary winding of the transformer 134 is connected in the -216 volt line. Switching of the transistor 116 in response to the pulses on line 115 results in current pulses through the primary of the transformer 120. These pulses have the frequency of the output of the oscillator 109 and are detected by the secondary of the transformer 134.

A resistor, capacitor and diode network 138 forms a compensated peak-to-peak detection circuit which provides a feedback signal on the line 122, this signal comprising a dc level proportional to the peak-to-peak magnitude of the current pulses through the primary of the transformer 134.

The arrangement is such that the magnitude of the signal on line 122 is dependent on the magnitude of the field current. An increase in the field current demand signal on line 106 results in an increase in frequency of the field current, and a signal corresponding to the increased current is fed back to the amplifier 95 on the line 122 to provide a new steady-state condition.

CLAIMS

1. A propulsion system for a vehicle, comprising a main drive shaft (10) for the vehicle, an internal combustion engine (20), an electric battery (14), an electric motor (13) energisable by said battery (14), a driving coupling between said motor (13) and said shaft (10), and a first clutch (21) operable to couple said engine (20) to said drive shaft (10), characterised in that there is provided an apparatus (24, 35, 44) for electrically loading said engine (10) to vary the speed thereof, and a control device (50, 51) for operating said first clutch (21) only when the speeds of said engine (20) and said shaft (10) are substantially equal.

2. A system as claimed in claim 1 in which said apparatus for electrically loading the engine (20) comprises an electric generator (24) and a device (35) for providing a driving connection between said engine (20) and said generator (24).

3. A system as claimed in claim 2 in which said device for providing the driving connection is a second clutch (35).

4. A system as claimed in claim 3 in which said second clutch (35) is electrically operable and which includes a first switching device (R4) operable to energise said second clutch (35).

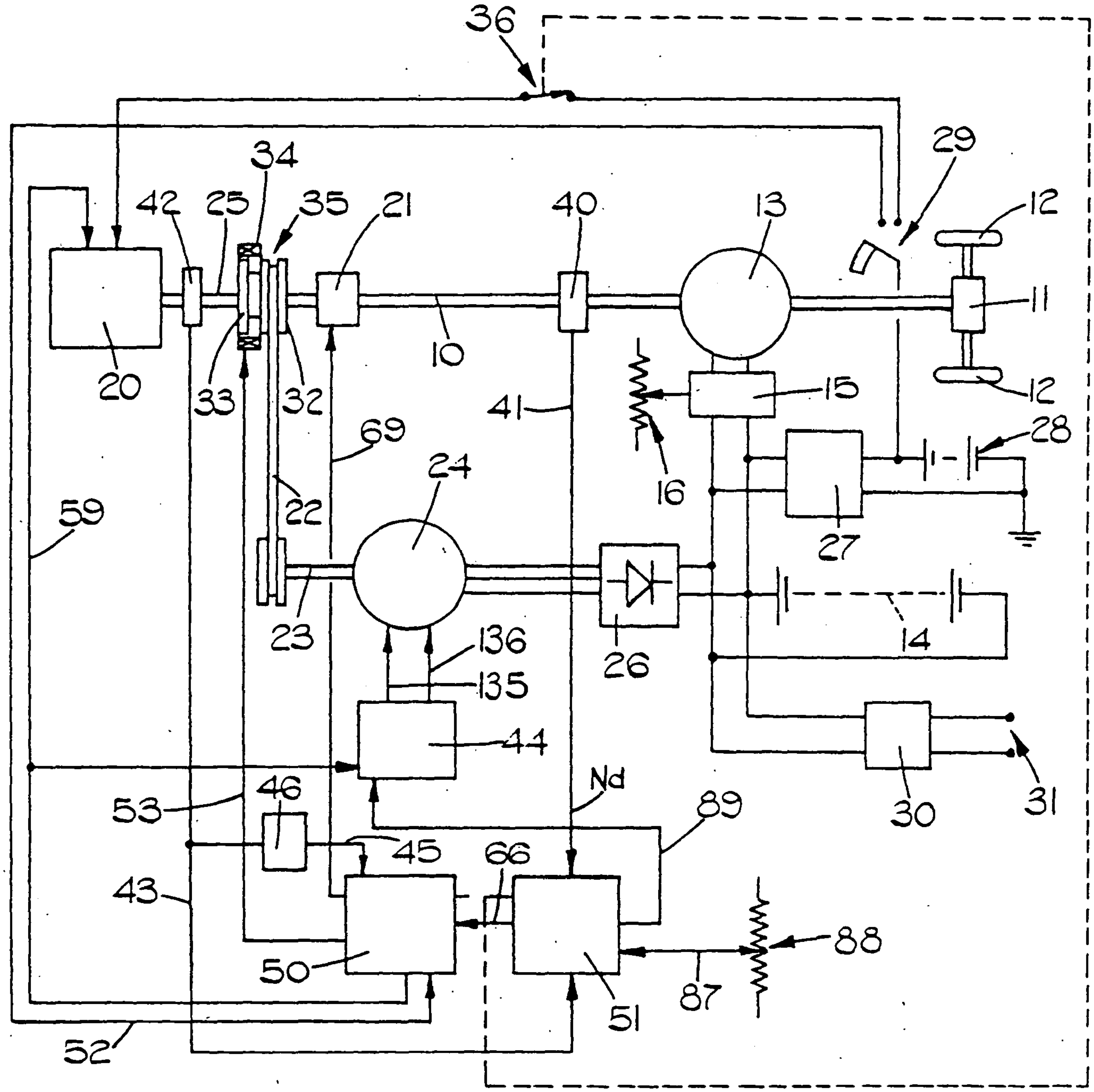
5. A system as claimed in claim 4 which includes means (R2, 60) responsive to the speed of the engine (20) for maintaining said first switching device (R4) operated to energise said second clutch (35) when said engine speed exceeds a predetermined value.

6. A system as claimed in claim 4 or claim 5 in which said control device (50, 51) includes a control circuit (51) for providing a first control signal when the speeds of said engine (20) and said drive shaft (10) are substantially equal, said first switching device (R4) being responsive to said first control signal to de-energise said second clutch (35).

7. A system as claimed in claim 6 in which said first clutch is electrically energisable to couple said engine (20) to said drive shaft (10) and which includes further switching devices (R3, 65) responsive to said first control signal to energise said first clutch.

8. A system as claimed in any of claims 2 to 7 in which said control device (50, 51) includes means (85) for generating a second control signal dependent on a difference between desired and sensed values of engine speed, and which includes a field current regulator (44) for said generator (24), said field current regulator (44) being responsive to said second control signal.

9. A system as claimed in claim 8 which includes means (80, 82, 84) for modifying said second control signal in response to the speed of said drive shaft (10).


36
29
34
42
25
35
21
40
13
12
11
12
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33
32
10
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15
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28
69
24
22
27
59
23
26
136
14
135
44
30
31
Nd
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89
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66
43
88
50
87
51
52

FIG. 1.

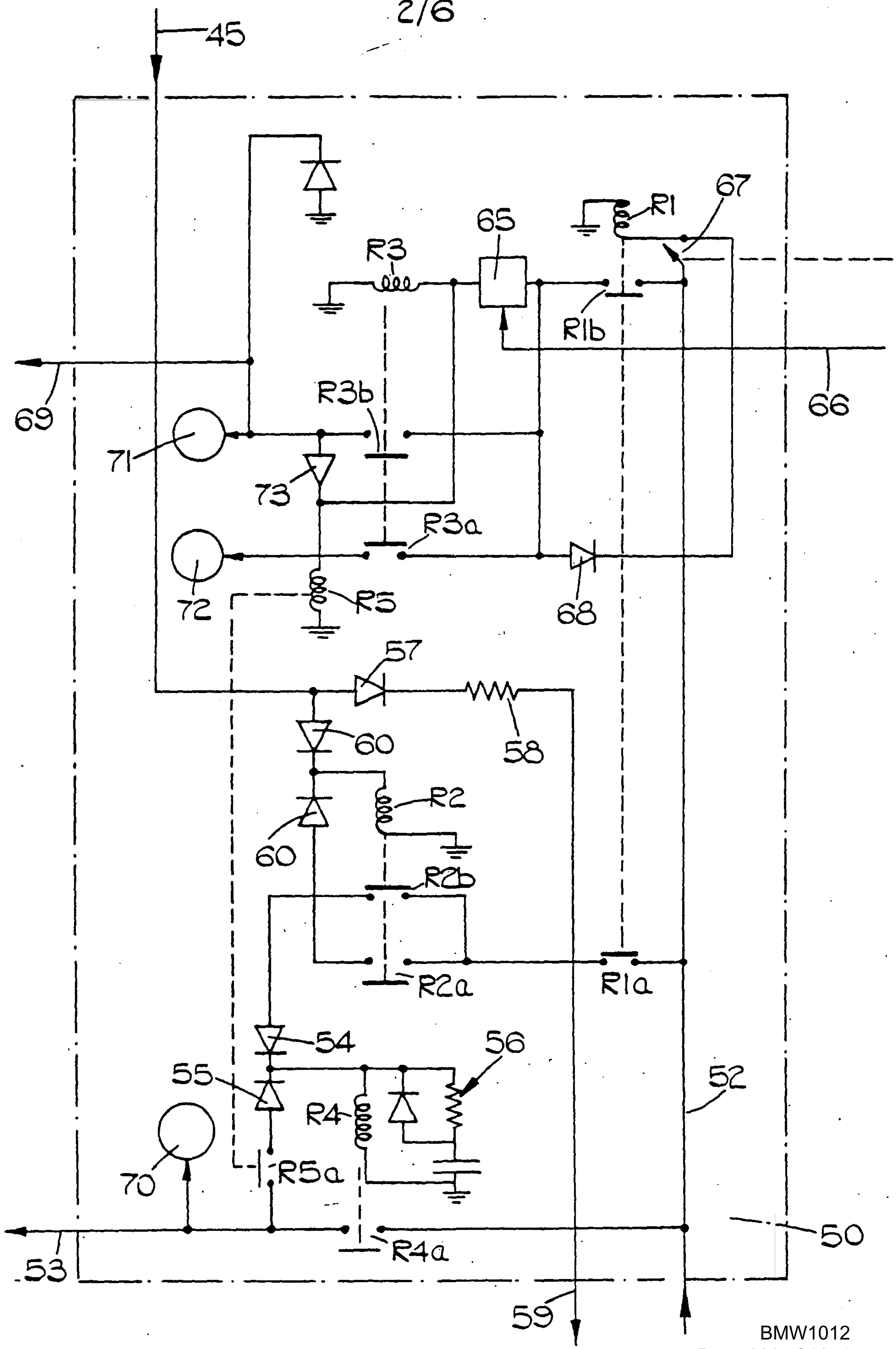
45
R1
67
65
R3
R1b
66
69
R3b
71
73
R3a
72
R5
68
57
60
58
R2
60
R2b
R2a
R1a
54
56
55
R4
52
70
R5a
50
R4a
53
59

FIG. 2.

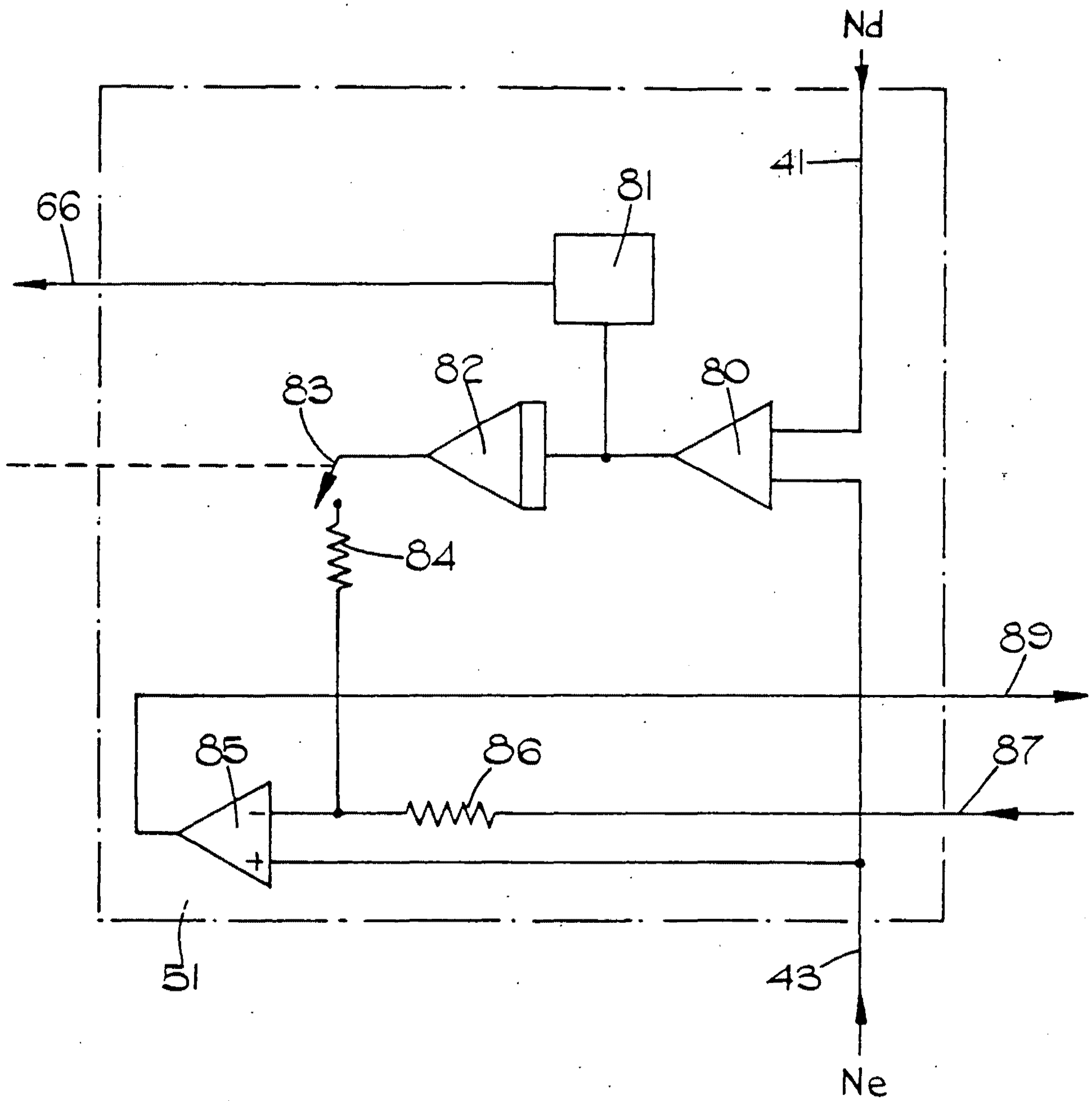

FIG.3.

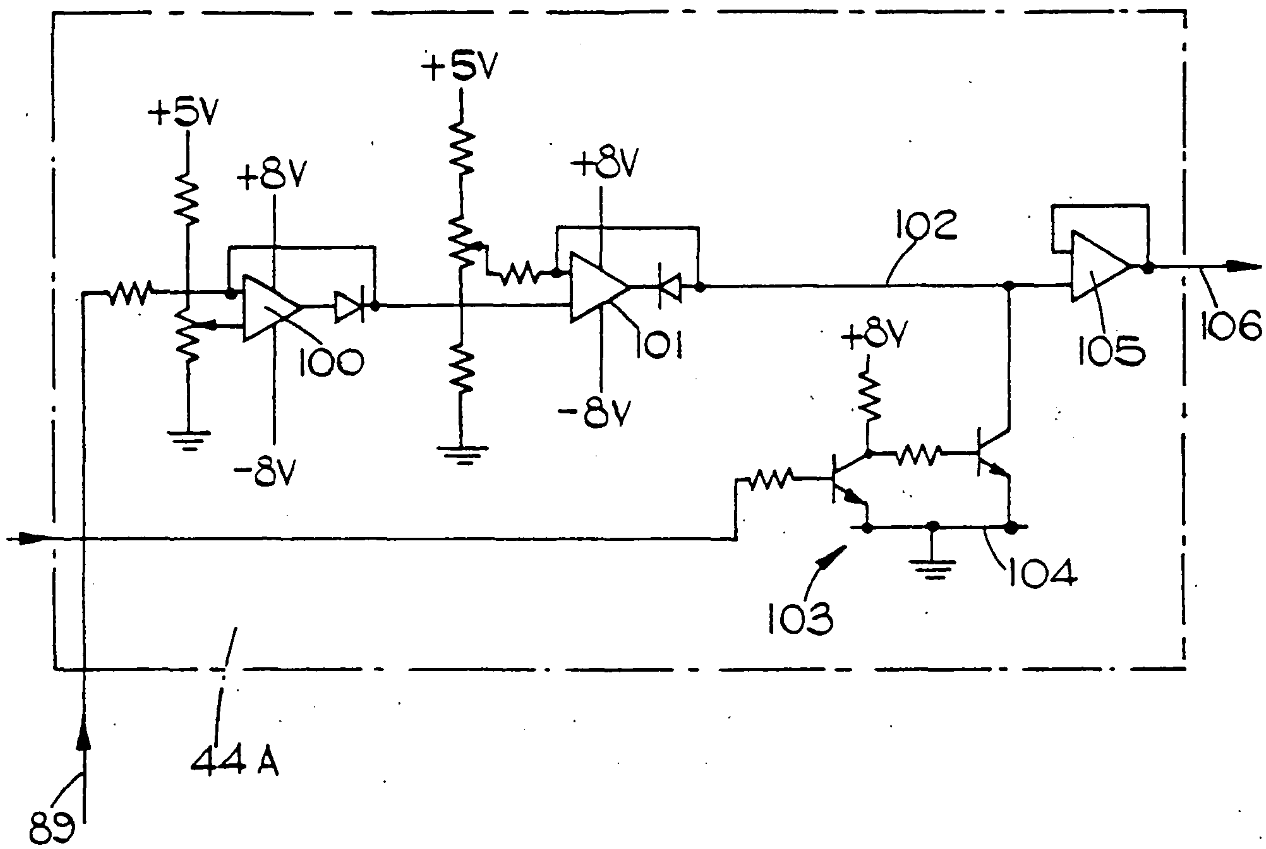

FIG. 4.

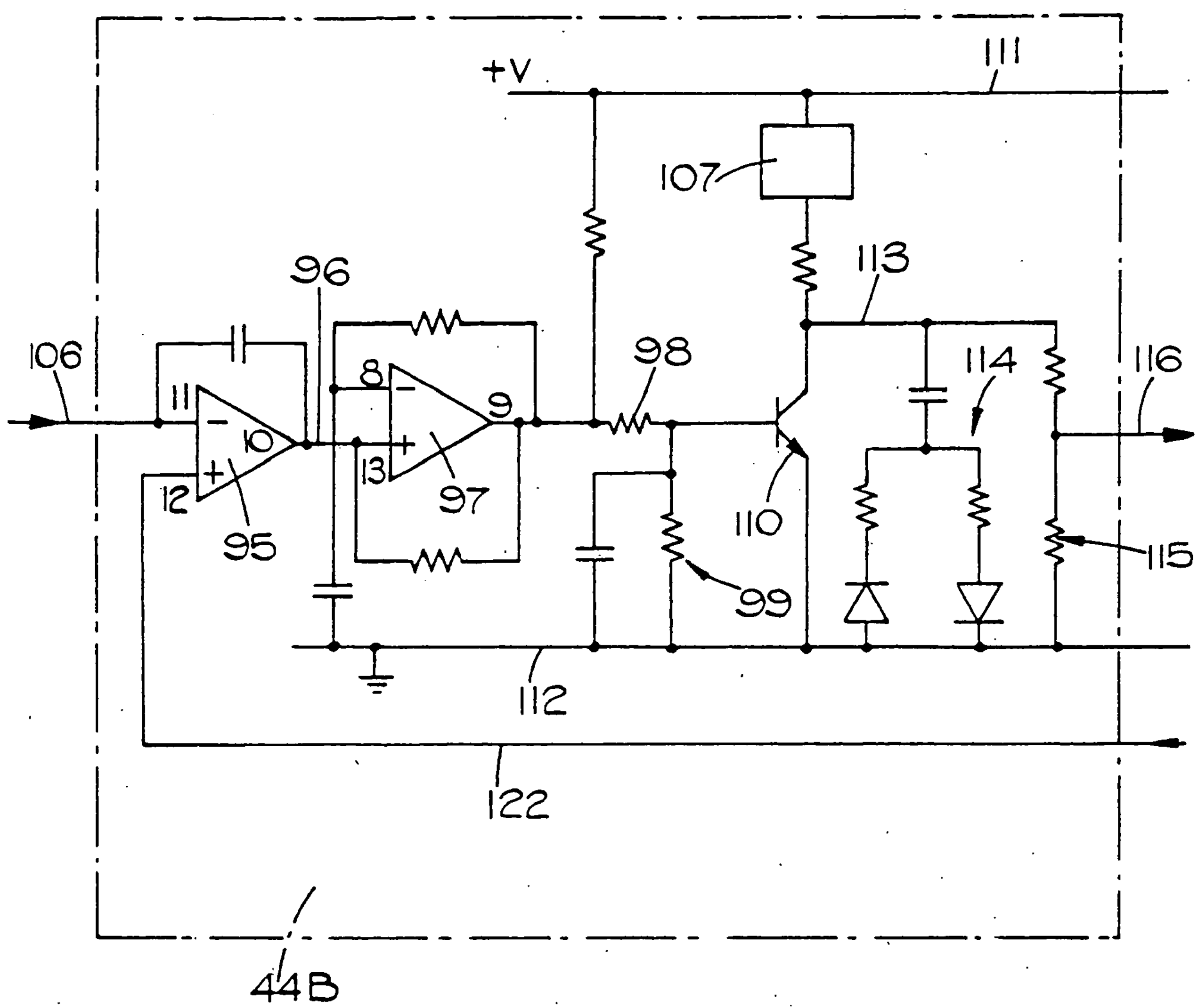
+V
111
107
96
113
106
98
114
116
11
8
9
10
13
12
97
110
95
99
115
112
122
44B

FIG.5.

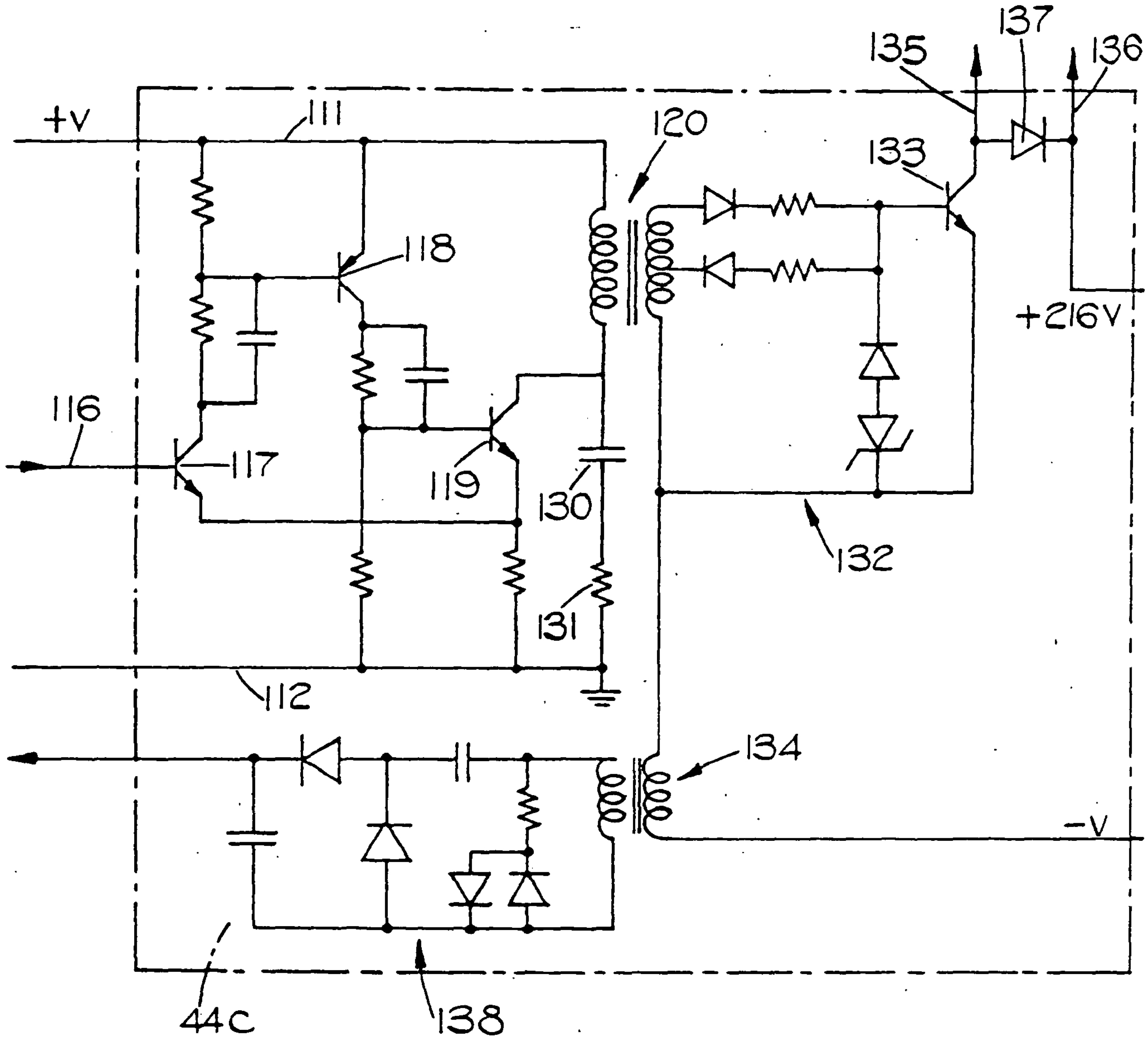
+V
111
120
135
137
136
133
118
+216V
116
117
119
130
132
131
112
134
-V
44c
138

FIG.6.

European Patent Office

EUROPEAN SEARCH REPORT

0136055

Application number

EP 84305672.2

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl 4)
A	AT - B - 321 729 (ROBERT BOSCH GMBH) * Fig.; page 2, line 50 - page 3, line 28 * --	1-3	B 60 K 1/00
A	DE - A - 2 309 680 (GES GESELLSCHAFT FUR ELEKTRISCHEN STRASSENVERKEHR MBH) * Fig.; page 6, paragraph 2 - page 7, line 11 * --	1,3-6, 8	
A	WO - A1 - 83/00 464 (STEWART) * Fig. 1; claim 1; page 9, line 1 - page 10, line 1 * --	1	
A	DE - A - 2 258 707 (ROBERT BOSCH GMBH) --		TECHNICAL FIELDS SEARCHED (Int. Cl 4)
A	DE - A - 1 917 581 (YARDNEY) ----		B 60 K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	15-11-1984	DENK

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

EPO Form 1503 03.82

(51) Int. Cl. 2: B 60 K 1-04 OCT - 1975

(19) BUNDESREPUBLIK DEUTSCHLAND

DEUTSCHES PATENTAMT

WEST GERMANY
GROUP 316
CLASS 180
RECORDED

DT 25 17 110 A1

(11) Offenlegungsschrift 25 17 110

(21) Aktenzeichen: P 25 17 110.2

(22) Anmeldetag: 18. 4. 75

(43) Offenlegungstag: 30. 10. 75

(30) Unionspriorität:

(32) (33) (31) 19. 4. 74 Italien 68260 A-74

(54) Bezeichnung:

FIAT M1043W/45 *DT 2517-110
Hybrid drive vehicle with constant torque turbine - having comparator circuit to distribute generator output to drive and to battery
FIAT SPA 19.04.74-IT-068260
Q13 (30.10.75) B60k-01/04

The turbine drives a generator/alternator which either charges the battery or drives the electric transmission, or both. The battery is connected to the transmission by a first current loop whose current is monitored. A current dependent signal is fed to a comparator circuit, along with a reference signal. The comparator output activates the turbine starter when the current exceeds a set level. A second control system regulates the alternator so that a constant load is generated, with the load split between the battery charging and the drive. This enables the turbine to run at optimum setting, with minimal exhaust emission, while a smaller capacity battery can be used.
1. 75 as 517110 (11pp).

(71) Anmelder:

(74) Vertreter: ...ng.:

(72) Erfinder: ... Turin (Italien)

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(51) Int. Cl. 2: B 60 K 1-04 OCT 0 - 1975

(19) **BUNDESREPUBLIK DEUTSCHLAND**

DEUTSCHES PATENTAMT

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GROUP 316
CLASS 180
RECORDED

DT 25 17 110 A1

(11) **Offenleg**

VARI- M1074W/45 ★DT 2517-789
Vehicle hydrodynamic transmission unit - has torque convertor and pu

(21)

(22)

(43)

Adaptive braking system modulator
BENDIX CORP 22.04.74-US-462690
Q18 (30.10.75) *US3902-764 B60t-08/02

The adaptive braking system is provided with a brake pressure modulating valve which is responsive to output signals generated by an electronic control unit to control braking pressure communicated to the brakes of the vehicle when an incipient skidding condition exists. The modulator is responsive to the output signals to decay braking pressure, and upon termination of the incipient skidding condition the modulator permits braking pressure to increase. The modulator includes a device responsive to the initial signal generated by the electronic controller to restrict communication into the modulator to a predetermined rate, thereby limiting subsequent pressure increase to the predetermined rate. 22.4.75 as 517778 (18pp).

(30) Unionspriorität:

(32) (33) (31)

(54) Bezeichnung: Kraftfahrzeug mit Mehrfachantrieb (Hybridantrieb)

(71) Anmelder: Fiat S.p.A., Turin (Italien)

(74) Vertreter: Fincke, H., Dr.-Ing.; Bohr, H., Dipl.-Ing.; Staeger, S., Dipl.-Ing.; Pat.-Anwälte, 8000 München

(72) Erfinder: Savonuzzi, Giovanni; Brusaglino, Giampiero; Moncalieri, Turin (Italien)

DT 25 17 110 A1

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zeuger und/oder der Batterie gespeist. Bei diesem System ist eine Steuervorrichtung vorgesehen, die die Turbine automatisch starten läßt, wenn die Batterieladung eine vorgegebene Höhe unterschreitet; dann liefert der von der Turbine angetriebene Wechselstromerzeuger Strom für den Antriebsmotor des Fahrzeugs und für die Wiederaufladung der Batterie, bis der Ladungszustand der Batterie ein Niveau erreicht hat, das es erlaubt, den Motor wieder aus der Batterie zu speisen; nun wird die Turbine automatisch angehalten.

Die Erfindung stellt eine Weiterentwicklung eines derartigen Systems dar. Der Erfindung liegt die Aufgabe zugrunde, ein besonders wirtschaftlich arbeitendes System der oben angegebenen allgemeinen Art zu entwickeln, mit dem die Ausnützung der in den Fahrzeugbatterien gespeicherten Energie wirkungsvoller erfolgen kann. Auf diese Weise wird der Gesamtwirkungsgrad des Systems verbessert, so daß man ein Fahrzeug vorgegebener Größe, das mit einem Elektromotor vorgegebener Stärke ausgerüstet ist, mit Batterien geringerer Kapazität ausstatten kann; derartige Batterien sind kleiner und leichter und bedeuten somit für das System einen weiteren Vorteil.

Ferner liegt der Erfindung die weitere Aufgabe zugrunde, eine Einrichtung zum Steuern der Leistung des Wechselstromerzeugers anzugeben, derart, daß die verlangte Ausgangsleistung der Turbine konstant gehalten wird, was zu einer Herabsetzung der Abgasemissionen der Turbine selbst führt.

Gemäß der Erfindung ist ein Antriebssystem für Kraftfahrzeuge vorgesehen, mit einer Elektromotoranlage für den Antrieb mindestens eines Fahrzeugrades, einer Turbine, einem von der Turbine angetriebenen Wechselstromerzeuger, der, wenn er angetrieben wird, Strom an den Motor abgibt, und einer Batterie, die über eine erste Speiseleitung mit der Motoranlage verbunden ist; das Antriebssystem ist dadurch gekennzeichnet, daß eine auf den aus der Batterie über die genannte erste Speiseleitung fliessenden Strom ansprechende Einrichtung vorgesehen ist, ferner eine Komparatorschaltung, der ein Bezugssignal sowie ein Signal zugeführt wird, das den aus der Batterie über die genannte erste Speiseleitung entnommenen Strom repräsentiert, ferner eine die Turbine in Betrieb setzende Startvorrichtung, die durch das Ausgangssignal der Komparatorschaltung gesteuert wird, um die Turbine zu starten, wenn der über die genannte erste Speiseleitung aus der Batterie entnommene Strom einen durch das Bezugssignal bestimmten Wert übersteigt, und schließlich eine Steuerung, die den Betrieb des Wechselstromerzeugers derart zu steuern vermag, daß der Wechselstromerzeuger, wenn er angetrieben wird, eine praktisch gleichbleibende Leistung über eine an die erste Speiseleitung angeschlossene zweite Speiseleitung abgibt.

Bei einem System dieser Art wird ein Energiefluß zwischen Turbogenerator und Elektromotor, Turbogenerator und Batterie und Batterie und Motor und umgekehrt hergestellt, ohne daß besonders zu betätigende Schaltvorrichtungen benutzt werden, vielmehr ausschließlich gemäß den Energieverhältnissen des Systems und den Fahrleistungsansprüchen, die von der Art abhängen, in der das Fahrzeug gefahren wird.

Nach einem wesentlichen Merkmal der Erfindung weist die Steuereinrichtung zum Steuern der Ausgangsgröße des Wechselstromerzeugers einen Leistungsmeßfühler auf, der auf die Ausgangsgröße des Wechselstromerzeugers anspricht und ein Ausgangssignal an einen Steuerkreis abgibt, dessen Ausgangsgröße den Erregerkreis des Wechselstromerzeugers so beeinflußt, daß die Ausgangsleistung des Wechselstromerzeugers und daher die von der Turbine abgegebene Leistung konstant bleibt.

Dieses System ermöglicht die Steuerung der Ausgangsleistung

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des Wechselstromerzeugers ohne Verwendung kostspieliger Bauelemente, wie Dioden, Regeldioden usw., und läßt die Turbine mit gleichbleibender Ausgangsleistung arbeiten, was dann eine Herabsetzung der Emission schädlicher Abgase aus der Turbine zur Folge hat. Die Steuerung der Startvorrichtung für die Turbine erfolgt über einen Komparator, dessen einem Eingang ein Signal zugeführt wird, das den aus der Batterie über die erste Speiseleitung geführten Strom repräsentiert, während dem anderen Eingang des Komparators das Bezugssignal zugeführt wird, so daß, wenn der von der Batterie abgegebene Strom über einen vorgegebenen Wert hinausgeht, die Turbine selbsttätig gestartet wird; aus diesem Grund kann man Batterien von geringerem Gewicht verwenden, denn der aus der Batterie entnommene Strom kann begrenzt werden. Wegen der Begrenzung der Stromstärke verlängert sich die Lebensdauer der Batterie, denn eine schnelle Entladung durch hohe Ströme läßt sich vermeiden.

Eine Ausführungsform der Erfindung soll nun im einzelnen beispielshalber anhand der Zeichnung beschrieben werden, die ein schematisches Blockschaltbild der Erfindung wiedergibt. Die Figur zeigt einen Motor M (an dessen Stelle auch eine Gruppe von Motoren treten kann), der über ein Kraftübertragungssystem T mit einem Rad R (oder einer Anzahl Räder) eines (nicht gezeichneten) Kraftfahrzeugs verbunden ist. Der Motor M erhält Strom aus einer Batterie B über eine Speiseleitung 10 und einen üblichen Regler RE, oder von einem Wechselstromgenerator A über eine Speiseleitung 12; der von dem Wechselstromerzeuger A herkommende Strom fließt ebenfalls durch den Regler RE. Die beiden Speiseleitungen 10 bzw. 12, die von der Batterie bzw. dem Wechselstromerzeuger in den Regler laufen, sind an einem Verbindungspunkt 14 zusammengeführt, so daß der Regler RE nur einen einzigen Stromeingang hat, gleichgültig, ob der Strom von der Batterie B oder von dem Generator A geliefert wird. In dem Regler befindet sich eine übliche Schaltung von

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Regeldioden, die durch Signale durchlässig getriggert werden, die von einem Steuerkreis 16 herrühren, der seinerseits durch Eingangssignale aus zwei Vorrichtungen 18 bzw. 20 gesteuert wird, die auf das Fahrpedal (18) bzw. eine Bremse (20) des Fahrzeugs ansprechen. Das Steuersystem aus Regler RE, Steuerkreis 16 und den Meßfühlern 18, 20 ist an sich bekannt: ein Beispiel eines derartigen Steuersystems ist in unserer italienischen Patentanmeldung No. 67045-A/72 beschrieben.

Die Leitung 10 ist an den Pluspol 22 der Batterie B angeschlossen, und der Minuspol 24 der Batterie B ist geerdet. Ein Strommeßfühler 26 liegt in der Leitung 10 und liefert ein Signal, das von einer Leitung 28 an einen Eingang eines Komparatorkreises 30 geführt wird. Eine Leitung 32 führt das Ausgangssignal von dem Meßfühler 26 in eine den Ladungszustand berücksichtigende Schaltung 34, die ausserdem Informationen über die Spannung Vb an dem Pluspol der Batterie B, die Temperatur P der Batterie B und den Druck G des in der Batterie entwickelten Gases erhält: die Schaltung 34 verarbeitet Informationen, die in den Signalen dieser Parameter enthalten sind, die die Ladungsverhältnisse der Batterie charakterisieren, und veranlaßt die Erzeugung von zwei Signalen; eines dieser Ausgangssignale wird über eine Leitung 36 in die Steuerschaltung 16 geführt, die den Regler RE steuert, und das andere Ausgangssignal gelangt über eine Leitung 38 zu einer Startvorrichtung 40 für eine Turbine TU, die den Generator A antreibt.

Die Datenverarbeitungsschaltung 34, die die Signale verarbeitet, die eine Aussage über den Ladezustand der Batterie liefern, und die beiden Ausgangssignale liefert, und die Art und Weise, wie diese Ausgangssignale den Kreis 16 und die Startvorrichtung 40 steuern, sind im einzelnen in dem Italienischen Patent No. 977 869 beschrieben.

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Dem anderenEingang des Komparators 30 wird ein Bezugssignal S zugeführt; der Wert dieses Signals bestimmt den Maximalwert des von der Batterie zu liefernden Stroms. Wenn bei schnellem Anfahren des Fahrzeugs aus dem Stillstand oder bei starkem Beschleunigen des bereits in Bewegung befindlichen Fahrzeugs der aus der Batterie B entnommene Strom den durch das Signal S festgelegten Wert übersteigt, so liefert der Komparator 30 ein Signal an die Startvorrichtung 40, die die Turbine TU anlaufen läßt. Die Batterie braucht daher niemals starke Ströme zu liefern, und infolgedessen hat sie eine längere Nützungslebensdauer: ausserdem läßt sich nun für einen bestimmten Motor und ein Fahrzeug bestimmter Größe eine deutlich kleinere Batterie verwenden als sie in einem üblichen System der oben allgemein beschriebenen Art erforderlich wäre.

Der Ausgang des Generators A gelangt über einen Leistungsfühler 42, der auf einen Steuerkreis 44 wirkt, um den Erregerkreis 46 des Generators zu steuern; ein Übersteuereingang L für den Erregerkreis 46 ist vorgesehen, um eine stärkere Erregung zu erreichen, falls das von Zeit zu Zeit erforderlich ist. Auf diese Weise arbeiten Generator und Turbine normalerweise mit gleichbleibender Leistung, und infolgedessen wird die Abgasemission der Turbine herabgesetzt.

Wie sich aus der vorstehenden Beschreibung ergibt, kann man die Turbogeneratoranlage in Abhängigkeit von dem Energiebedarf des Motors ein- oder abschalten; dieser Energiebedarf kann unter Umständen die Leistungsgrenze des Generators übersteigen. Wenn beispielsweise die maximale Stromlieferung der Batterie größer als die Maximalleistung des Generators oder gleich dieser ist, kann der dem Motor von Generator und Batterie zugeleitete Gesamtstrom, weil der Generator der vollständig geladenen Batterie keinen Strom zuführt, grösser sein

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als der Maximalstrom, den der Generator liefern kann.

Das beschriebene System erreicht einen hohen Wirkungsgrad. Wenn man erreichen will, daß die Luftverunreinigung auf einen kleinstmöglichen Wert herabgesetzt wird, sollte in dem System eine Turbine verwendet werden, die häufig und sofort angelassen werden kann, ohne daß eine wesentlich grössere Abgasemission stattfindet, als wenn sie ständig liefe.

Die konstruktiven Einzelheiten können gegenüber den beschriebenen zahlreiche Abweichungen zeigen. Beispielsweise ist es möglich, zwischen den Komparator 30 und die Startvorrichtung 40 einen Zeitgeber, z.B. einen RC-Kreis, zu schalten, um zu verhindern, daß der Turbogenerator eingeschaltet wird, wenn ein erhöhter Strombedarf nur während sehr kurzer Zeit besteht.

Patentansprüche:

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Patentansprüche:

1. Antriebssystem für Kraftfahrzeuge, mit einer Elektromotoranlage für den Antrieb mindestens eines Fahrzeugrades, einer Turbine, einem von der Turbine angetriebenen Wechselstromerzeuger, der, wenn er angetrieben wird, Strom an den Motor abgibt, und einer Batterie, die über eine erste Speiseleitung mit der Motoranlage verbunden ist, dadurch gekennzeichnet, daß eine auf den aus der Batterie über die genannte erste Speiseleitung fliessenden Strom ansprechende Einrichtung vorgesehen ist, ferner eine Komparatorschaltung (30), der ein Bezugssignal sowie ein Signal zugeführt wird, das den aus der Batterie über die genannte erste Speiseleitung entnommenen Strom repräsentiert, ferner eine die Turbine (TU) in Betrieb setzende Startvorrichtung (40), die durch das Ausgangssignal der Komparatorschaltung (30) gesteuert wird, um die Turbine (TU) zu starten, wenn der über die genannte erste Speiseleitung (10) aus der Batterie (B) entnommene Strom einen durch das Bezugssignal bestimmten Wert übersteigt, und schließlich eine Steuerung (42, 44), die den Betrieb des Wechselstromerzeugers (A) derart zu steuern vermag, daß der Wechselstromerzeuger (A) eine praktisch gleichbleibende Leistung über eine an die erste Speiseleitung (10) angeschlossene zweite Speiseleitung (12) abgibt.

2. Antriebssystem nach Anspruch 1, dadurch gekennzeichnet,

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daß die Steuerung (42, 44) zum Steuern der Ausgangsgröße desWechselstromgenerators einen Leistungsfühler (42) aufweist, der auf die Ausgangsleistung des Wechselstromerzeugers anspricht und Ausgangssignale auf einen Steuerkreis (44) gibt, dessen Ausgangsgröße den Erregerkreis (46) des Wechselstromerzeugers derart beeinflußt, daß die Ausgangsleistung des Wechselstromerzeugers und daher die von der Turbine (TU) gelieferte Leistung konstant bleiben.

Für: FIAT SOCIETA PER AZIONI

PATENTANWÄLTE
DR.-ING. H. FINCKE, DIPL.-ING. H. BOHR
DIPL.-ING. S. STAEGER

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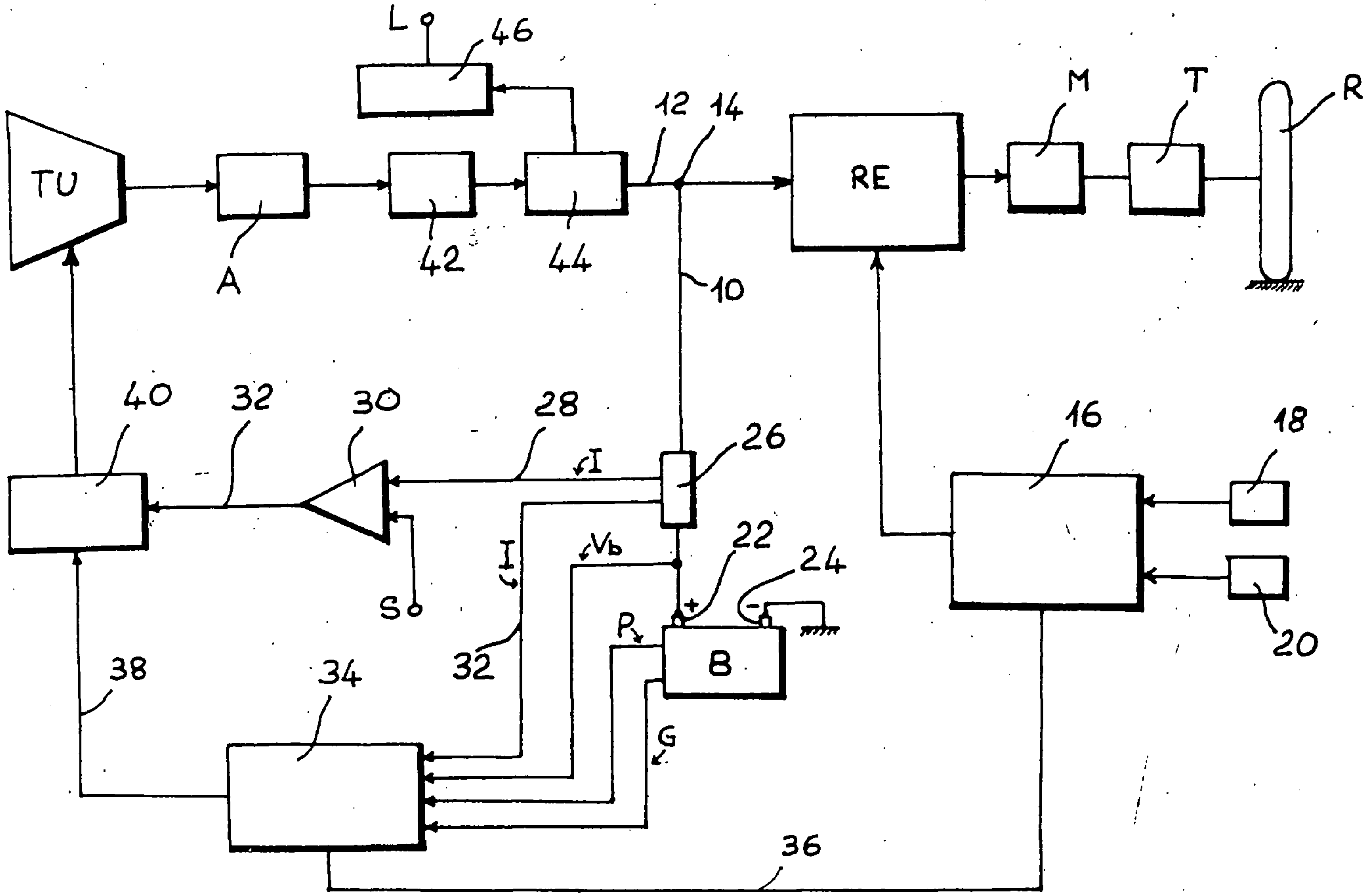

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