PROVISIONAL PATENT APPLICATION

of

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for

IMPROVEMENTS IN HYBRID VEHICLES

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.

Background of the Invention

This application discloses a number of improvements over and enhancements to the hybrid vehicles disclosed in the inventor's U.S. patent 5,343,970 (the "'970 patent"), 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, 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 aspects and 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.

Objects of the Invention

It is an object of the present invention to provide further improvements over the hybrid vehicle shown in the '970 patent.

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.

Other aspects of and improvements provided by the present invention will appear below.

Summary of the Invention

According to the present invention, 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 when appropriate, connected by a functionally-conventional clutch or mechanical interlock operated by the microprocessor responsive to the vehicle's mode of operation and to input commands provided by the operator of the vehicle. As in the '970 patent, an internal combustion engine is provided, sized to provide sufficient torque for the maximum cruising speed desired, and is used for battery charging as needed. 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. 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 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 for starting; this allows starting the engine with a near-stoichiometric mixture, significantly reducing undesirable emissions and improving fuel economy at start-up.

As noted, the two motors are separated by a functionally-conventional clutch, that is, a clutch which either joins the two motors together for rotation at the same speed, or separates them completely. As the motor shafts can be controlled to rotate at essentially the same speed when the clutch is engaged, the clutch need not allow for slip therebetween. Accordingly, a friction clutch, as normally provided for road vehicles, is not required, and a less-expensive simple mechanical interlock can alternatively be employed. Engagement of the clutch is controlled by the microprocessor, e.g., by a hydraulic actuator, responsive to the state of operation of the vehicle and the current operator input.

For example, during low-speed operation, the clutch will be disengaged, so that the traction motor is disconnected from the engine; the vehicle is then operated as a simple electric car, i.e., power is drawn from the battery bank and supplied to the traction motor. If the batteries become depleted, the starter motor is used to start the internal combustion engine, which is then runs at relatively high torque output (e.g., between about 50 - 100% 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. If 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, and the clutch is engaged, so that the engine and starter motor can provide additional torque. The engine is sized so that it provides sufficient power to maintain a suitable highway cruising speed 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 ito electrical power during descent or deceleration.

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 proper state of operation of the vehicle based on these and other inputs and controls the various components of the hybrid drive train accordingly.

In the preferred embodiment, the engine and the two motors all rotate 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. It is nonetheless within the scope of the invention to operate one or more of these components at differing rotational speeds; for example, the starter motor might drive the engine through a small pinion geared to a relatively large 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 belt or gear reduction unit. However, in all cases, the rotational speeds of the two motors and the engine, and of the road wheels, are fixed with respect to one another; no multi-speed transmissions between the motors and engine and the road wheels are required by the hybrid power train of the invention.

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 poles and the accompanying power circuitry provides current of three or more, preferably five, phases, allowing the vehicle to function even after failure of one or more components.

During substantially steady-state operation, e.g., during highway cruising, the control system operates the engine at varying

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