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United States Patent [19]

Ehsani

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[54] **ELECTRICALLY PEAKING HYBRID SYSTEM AND METHOD**

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[73] Assignee: **The Texas A&M University System**, College Station, Tex.

[21] Appl. No.: **312,438**

[22] Filed: **Sep. 26, 1994**

Related U.S. Application Data

[63] Continuation of Ser. No. 51,156, Apr. 22, 1993, abandoned.

[51] **Int. Cl.**[6] **B60K 6/04**

[52] **U.S. Cl.** **180/65.2**; 318/139

[58] **Field of Search** 123/352, 399; 290/9; 180/65.1, 65.2, 65.3, 65.4, 65.8; 318/139

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[57] **ABSTRACT**

A series hybrid electric-combustion system is provided which includes an engine (**16**) operable to generate mechanical energy and translate it to a drive shaft (**21**). A battery (**24**) is included that is operable to store electrical energy and to deliver electrical energy. Also provided is a electric machine (**18**) mechanically coupled to engine (**16**) and electrically coupled to battery (**24**). Electric machine (**18**) has two modes of operations. In the first mode it translates electrical energy from battery (**24**) into additional mechanical energy at drive shaft (**21**). In the second mode of operation, electric machine (**18**) delivers electrical energy to battery (**24**) for storage. Converter (**22**) is also included in the system to convert the electrical energy from electric machine (**18**) for storage and battery (**24**) and also for converting electrical energy from battery (**24**) for use by electric machine **18**. The system also includes command (**12**) for inputting system power requirements and controller (**14**) to control converter (**22**) and engine (**16**) in the modes of operation of the system.

8 Claims, 3 Drawing Sheets

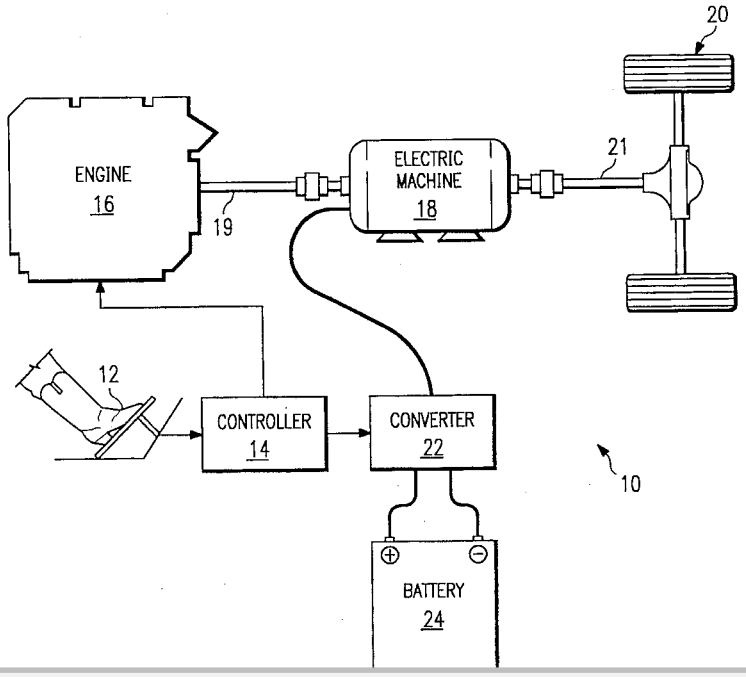


FIG. 1

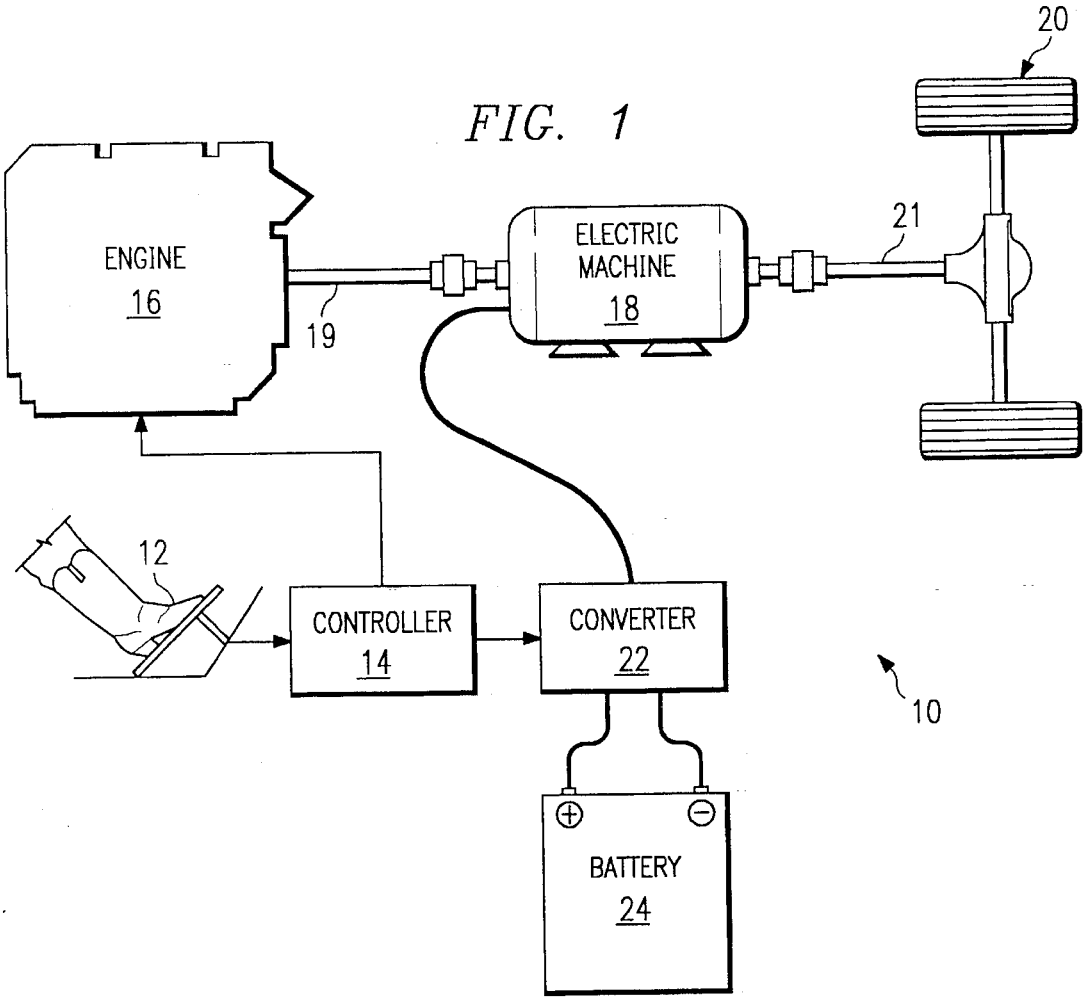


FIG. 2

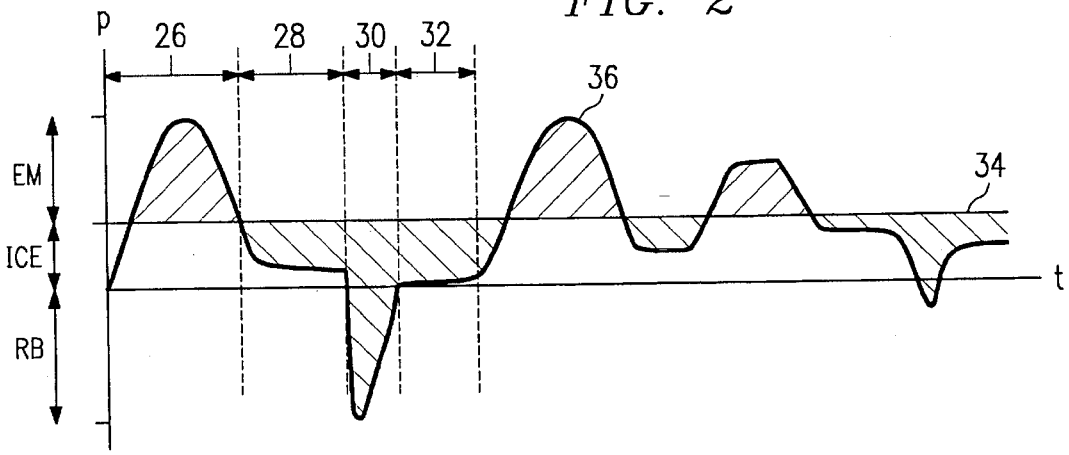


FIG. 3

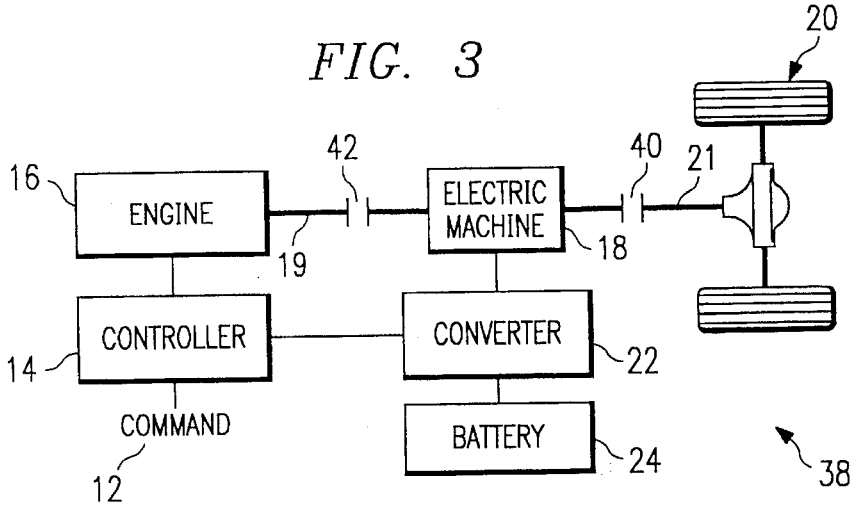


FIG. 4

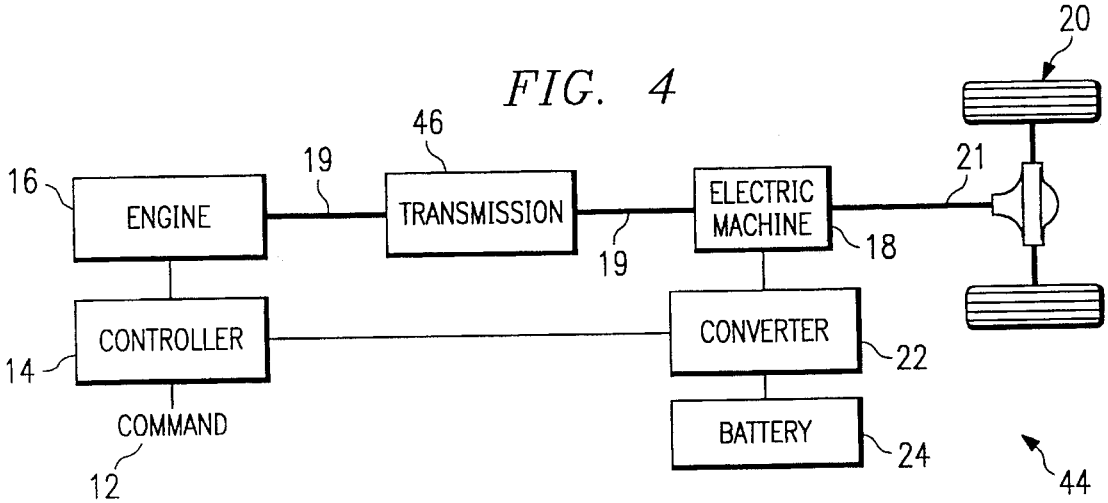


FIG. 5

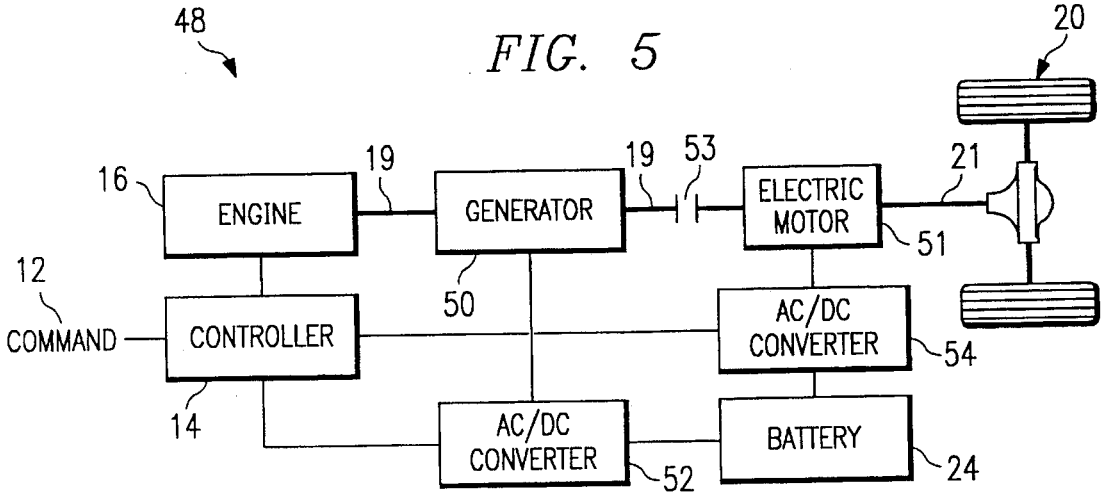


FIG. 6

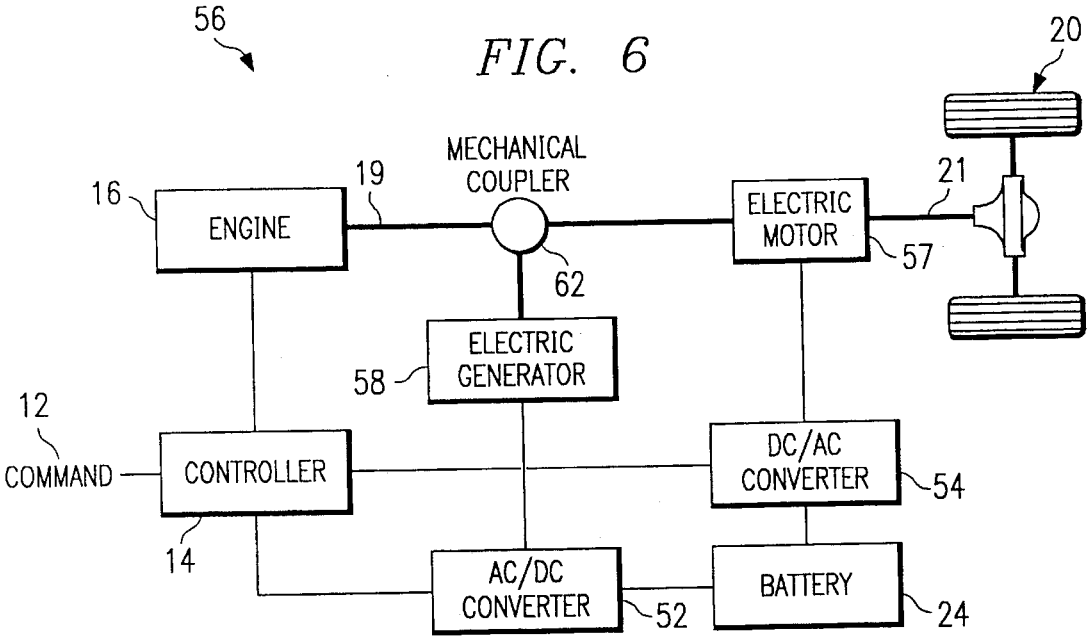
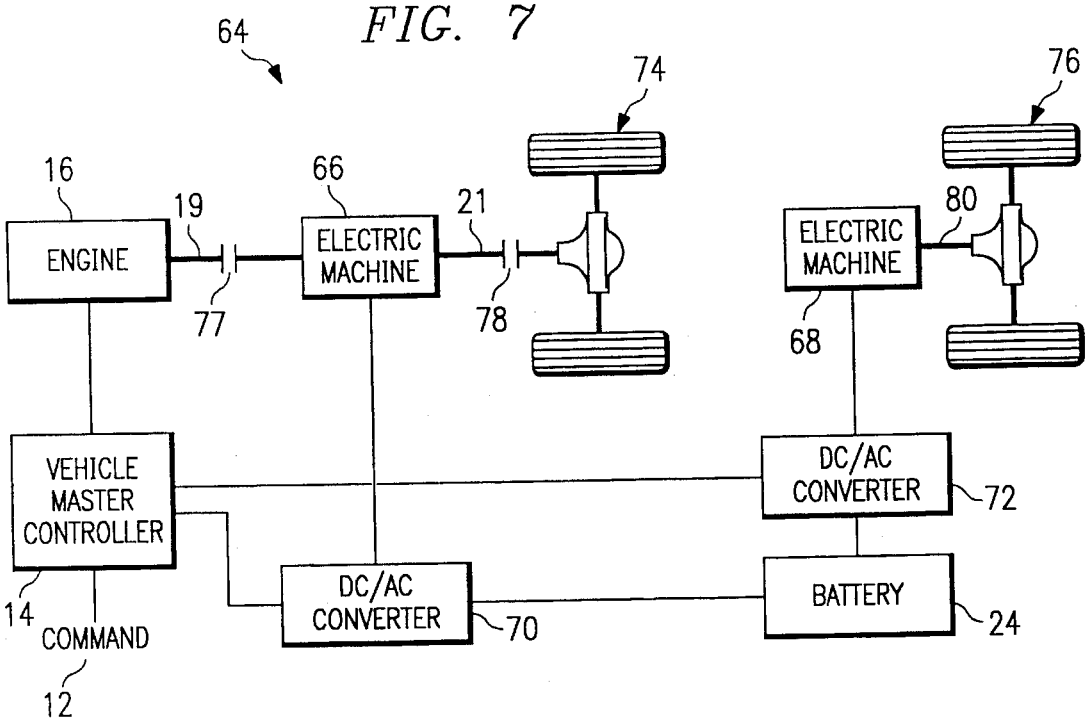


FIG. 7



ELECTRICALLY PEAKING HYBRID SYSTEM AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of application Ser. No. 08/051,156 filed Apr. 22, 1993, entitled "ELECTRICALLY PEAKING HYBRID SYSTEM AND METHOD" by Mehrdad Ehsani, now abandoned.

TECHNICAL FIELD OF THE INVENTION

This invention relates generally to the field of electrical-mechanical systems, and more particularly to an electrically peaking hybrid system and method of generating hybrid electric-combustion power.

BACKGROUND OF THE INVENTION

Technical publications describing developments in technology for electric vehicles are abundant. Some, however, fail to recognize the fundamental limitations in the performance of the electric vehicle in comparison to the internal combustion engine (ICE). Thus, most of the improvements reported are of a short term, single issue nature and fail to address the overall vehicle as a commercial product that is to be competitive with the ICE vehicle. Because of the performance advantages to the ICE, transportation will continue to depend primarily on some form of internal combustion for many years to come.

The electric vehicle does present, however, certain important a advantages. For example, electric vehicles are suitable for applications that require zero emissions. There is a growing recognition that the discharge from ICE vehicles is a significant contributor to the global atmospheric degradation. To make a short term impact in reducing the atmospheric contamination caused by ICE vehicle exhaust emissions in urban areas, electric vehicles have been mandated by law in some places in this country and around the world. However, this requirement can only be met with sacrifices of performance and at a cost premium, when compared to the conventional ICE vehicle.

Limitations in electric storage batteries present the greatest obstacle to the development of an all electric vehicle that is cost and performance competitive with the ICE vehicle. While progress has been made in battery development, it appears that chemical-electrical storage batteries cannot match the energy storage density and convenience of today's petroleum-based fuels.

The design of an all electric vehicle is driven by the need to minimize the load on the limited battery supply. This has forced extreme designs to reduce road friction, aerodynamic drag, vehicle weight and power requirements of the various auxiliary systems. Since no significant improvement in battery performance is expected for the near future, these design constraints tend to force the introduction of undesirable vehicle tradeoffs. This, in turn, can lead to user dissatisfaction, which can adversely affect the long-term acceptability of the electric vehicle concept.

The present state of the art in electric motor drives has reached a level of maturity. A high level of development has also been reached in batteries and microcomputer controls. However, to have both suitable range and performance, the electric vehicle needs to incorporate some additional energy source. The hybrid electric vehicle is presently the best

The drive train of the conventional ICE automobile consists of an engine, a transmission and a drive shaft that connects to the wheel axle. All of the required power and torque are supplied by the engine at all times. The engine is sized to deliver the maximum power that the driver is likely to ask for, even though most of the time the driver requires much less than the maximum power. This makes the engine much larger than the average demand required. The basic problem with such a large engine is that most of the time it will be running at far less than its maximum power, and therefore below its maximum efficiency. Having a large engine and running it far below its optimum efficiency are the two fundamental reasons for the poor fuel economy of the conventional ICE vehicle.

To partially overcome this problem, a transmission is added to the drive train. This helps to match the variations of speed and power of the vehicle to the engine to some extent. However, the transmission introduces its own inefficiencies which are substantial. The result of this conventional design is that a typical American full-size sedan is equipped with an engine of 160 horsepower or larger. Most of the time, however, the vehicle requires less than 30 horsepower to operate in the city or on the highway. At these power levels, the conventional engine is operating at two to four times below its optimum efficiency. This results in an average fuel economy of about 20 miles per gallon.

Today, no hybrid electric-ICE vehicle drive system has been developed that is competitive with the conventional ICE vehicle both in cost and performance. Therefore, a need has arisen for a hybrid electric-ICE vehicle drive system which provides performance and range comparable to conventional ICE vehicles. Furthermore, to be viable, such a system should operate within the existing infrastructure of fuel supply and distribution, make use of existing component technology, and be price and operating cost competitive with conventional ICE vehicles.

SUMMARY OF THE INVENTION

In accordance with the present invention, an electrically peaking hybrid system and method are provided which substantially eliminate or reduce disadvantages and problems associated with prior systems.

In accordance with the teachings of the present invention, a series-mechanical hybrid electric-combustion system is provided that includes an engine to generate mechanical energy. The engine is coupled to a drive mechanism. The system also includes a battery to store and deliver electric energy, and an electric machine coupled to the engine and the battery. The electric machine has two operating modes. In the first mode of operation, the electric machine translates mechanical energy from the engine and electrical energy from the batteries to drive the drive mechanism. In the second mode of operation, the electric machine delivers electrical energy to the battery for storage.

An important technical advantage of the present invention is the reduction in size of the ICE to approximately one quarter the size used in conventional ICE vehicles. Another important technical advantage of the present invention is the series coupling between the drive train, electric machine, and engine, thereby eliminating the need for a transmission and associated power losses. An additional technical advantage of the present invention is its fuel efficiency, which is typically 2.8 times the current ICE vehicle. Another technical advantage of the system of the present invention is that

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