Abstract:

Title: ASYMMETRIC MULTI GENERATOR ELECTRIC VEHICLE POWER SUPPLY UNIT

Fig. 1


Published:

— with international search report (Art. 21(3))

(54) Title: ASYMMETRIC MULTI GENERATOR ELECTRIC VEHICLE POWER SUPPLY UNIT

(57) Abstract: Power supply unit designed to supply electric power on demand to an electric powered vehicle, the power supply unit comprising one single fuel engine, characterized in that it comprises at least two electric generators, each being characterized by a maximum electric power output and each being arranged to be engaged or disengaged with the single fuel engine, so that at least one electric generator of the at least two electric generators may be engaged with the single fuel engine at a time to supply electric power to the vehicle, when the demand does not exceed the maximum electric power output of said engaged electric generator.
ASYMETRIC MULTI GENERATOR ELECTRIC VEHICLE POWER SUPPLY UNIT

The present invention relates to the field of electric vehicles, and in particular to the way of producing electric energy for such vehicles.

It is known to store electricity in electric storage units such as batteries, high capacitors or the like mounted into an electric vehicle, to supply electricity to electric motors. However, due to limited storage capacity, high volume and weight of these storage units, these solutions lead to the need to regularly charge the storage units, and as the range achieved by these vehicles is limited, such vehicles are generally limited to small journeys. Another aspect is the cost of the storage units, which is high, limiting the spread of these vehicles, also affected by the short lifetime of the batteries which need to be changed after some charge and discharge cycles. It should also be borne in mind that the ecological footprint of these storage units is not negligible, as the materials required for manufacturing are often heavy metals, found in rare earths, which have very limited geographic supply sources with vulnerability to supply disruptions.

As a range extender, it is known from document WO2012006197 to install into a vehicle a wind turbine powered by the wind created by the movement of the vehicle, to charge the batteries of the vehicle. However, this system will create additional energy losses by increasing drag, generating turbulences and disturbing the boundary layer, so that it will require more energy to power the vehicle. In parallel, such wind turbine has a low efficiency, to recover energy from wind, so that the global energetic balance is not in favor of such apparatus.

Another way to extend the range of an electric vehicle is to install a heat engine coupled to an electric generator, to charge the storage units when a state of charge of these storage units is below a predetermined value. However, there are losses when the electric energy is converted into
chemical energy in the battery and then back to electric energy. In addition, this system requires the use of an electric generator sized to achieve a high electric power output to meet the highest case for power demand, so that the generator presents high inertia thus high fuel consumption, even when power demand is low, as in cruising at constant speed.

The present invention aims to solve these aforementioned drawbacks and is directed to propose first a power supply unit designed to supply electric power to an electric vehicle, the power supply unit providing a high efficiency across a range of driving conditions.

With this goal in mind, a first aspect of the invention is a power supply unit designed to supply electric power on demand to an electric powered vehicle, the power supply unit comprising one single fuel engine, characterized in that it comprises at least two electric generators, each being characterized by a maximum electric power output and each being arranged to be engaged or disengaged with the single fuel engine, so that at least one electric generator of the at least two electric generators may be engaged with the single fuel engine at a time to supply electric power to the vehicle, when the demand does not exceed the maximum electric power output of said engaged electric generator. The power supply unit presents an adjustable power output, due to the electric generators which may be engaged and disengaged based on the electric demand of the vehicle. Thus, when the demand is low, it is possible to disengage as many generators as possible, to reduce the inertia to the minimum. This will also reduce wear and tear of the disengaged generator, thus increasing its lifetime. In consequence, the fuel engine will have to output less mechanical power, leading to a decrease in fuel consumption. The system has also the inherent advantage to operate the fuel engine at a constant rotation speed, preferably a speed within a range of maximum efficiency for the fuel engine. It may be contemplated to use a conventional fuel engine such as a piston engine supplied with gasoline, or to use an alternative fuel engine, i.e. supplying the fuel engine with ethanol, methanol, bio diesel other bio fuels, or their blends including
diesel or gasoline such as flex fuel. It is also possible to use a turbine or micro turbine supplied with conventional fuels, hydrogen, biogas or the like. In conclusion, the system is optimally demand-driven, or demand-pulled, to achieve a higher degree of optimization, reducing the generation of electricity to what is needed, thereby reducing the need to store electric power and its associated storage units’ weight, and reducing the friction and inertia losses. This embodiment also achieves a simplification of the fuel engine as the operating rotation speed is constant and limited within a specific area, fewer requirements apply to the design of the fuel engine, and many specific requirements may be ignored, such as low and/or high rotation speed which result in more pollution. In other words, since the fuel engine is not operating at low rotation speed or high rotation speed, the invention allows the replacement of an automotive motor by a power generator motor which does not need to be optimized for the complete range of rotation speeds (i.e. from idle speed to red line rpm). It should also be noted that the invention does not need any gear box or power train. Eliminating these components enhances the reliability, lowers the weight and the costs.

According to one aspect of the invention, the at least two electric generators are asymmetrically sized to supply electric power to the vehicle.

According to one aspect of the invention, a first electric generator of the said at least two electric generators has a first maximum electric power output, and the other electric generator of the said at least two electric generators has a second maximum electric power output strictly greater than the first electric power output. This embodiment increases the total range of power output of the power supply unit, without drastically increasing the cost. In addition, it is possible to calibrate or design each of the electric generators to achieve a level of power representative of particular driving conditions, and to combine the levels to achieve intermediate output levels. In other words, this embodiment allows more flexibility to match the vehicle driving needs.

According to one aspect of the invention, the first maximum electric power output is determined to be greater or equal to a first demand of the
vehicle driving at a speed of 50km/h or less, on an horizontal track, or idling with lights and/or climate control in operation.

According to one aspect of the invention, the second maximum electric power output is determined to be greater or equal to a difference between a second demand of the vehicle driving at a speed over 100km/h on an horizontal track, and the first demand.

According to one aspect of the invention, the power supply unit comprises three electric generators, each having a specific maximum electric power output different from the maximum electric power output of the two other electric generators. With this embodiment, it is possible to supply seven different levels of electric power to the vehicle, with three levels achieved by the engagement of only one electric generator, three other levels achieved by the simultaneous engagement of two electric generators, and a seventh level by simultaneous engagement of the three electric generators.

According to one aspect of the invention, the power supply unit comprises:
- a first electric generator having a maximum electric power output ranging from 2.5kW included to 5kW included,
- a second electric generator having a maximum electric power output ranging from 10kW included to 13kW included,
- a third electric generator having a maximum electric power output ranging from 18kW included to 22kW included.

According to one aspect of the invention, the fuel engine is arranged to operate at a constant rotation speed.

The invention is also related to a vehicle comprising at least one electric motor coupled to a wheel, at least one power supply unit according to the first aspect of the invention, arranged to directly supply electric power to said at least one motor. Such arrangement avoids the need to convert the electric energy into chemical energy and vice versa. The efficiency is not
affected by these conversions, as it is by direct supply of electricity to the motor.

According to one aspect of the invention, the vehicle further comprises at least one electric energy storage unit arranged:

- to be charged by the power supply unit when a state of charge of the electric energy storage unit is below a predetermined value,

- and to supply electric power to the vehicle during phases when the demand is increasing and when the state of charge of the electric energy storage unit is above the predetermined value. This embodiment allows to enhance the comfort of use and the responsiveness of the system for the user, by smoothing the steps between the maximum power output levels.

Other characteristics and advantages of the present invention will appear more clearly from the following detailed description of particular non-limitative examples of the invention, illustrated by the appended drawings where:

- Figure 1 represents a schematic view of a vehicle comprising a power supply unit according to the invention;

- Figure 2 represents a graph of power levels deliverable with the power supply unit of figure 1.

Figure 1 shows an electric vehicle having a front wheel 20 equipped with an electric motor 25 and a rear wheel 30 equipped with an electric motor 35. The vehicle comprises a power supply unit 10 arranged to supply the electric motors 25, 35 with electricity. The power supply unit 10 comprises a fuel engine 15, a first electric generator 11, a second electric generator 12 and a third electric generator 13. The electric generators 11, 12, 13 are arranged to be engaged or disengaged with the fuel engine 15, via a mechanical connection, clutches for example.

The fuel engine 15 may be a conventional fuel engine such as a piston engine supplied with gasoline, but it may be contemplated to use an alternative fuel engine, i.e. supplying the fuel engine 15 with ethanol,
methanol, bio diesel, other bio fuels, or their blends including diesel or gasoline such as flex fuel. It is also possible to use a turbine or micro turbine charged with hydrogen, biogas or the like.

The fuel engine 15 is set up to operate at a constant rotation speed, chosen to have a maximum efficiency, and drives a belt, a gear or another connection so that any of the first, second or third electric generator 11, 12 or 13 may be engaged with the fuel engine.

A control unit in the vehicle monitors the electric demand of the vehicle, which depends from the driving conditions (acceleration, driving on an horizontal surface, climbing a hill...), and controls the power supply unit 10 and the engaged electric generators, in the aim to lower as much as possible the losses in the system.

Each of the first, second and third electric generators 11, 12 and 13 has a predetermined maximum electric power output and the control unit continuously compares the electric demand of the vehicle to the above mentioned predetermined maximum electric power outputs and their combinations, to engage or disengage any of the first, second or third electric generator 11, 12 or 13 so that the total electric power output of the power supply unit is just greater to the electric demand, but with the lowest number of engaged electric generator as possible. The control unit also monitors the battery state of charge and its predetermined level, controlling when power is directed into it to maintain its predetermined state of charge and when power is drawn out of it to meet driving needs. The consequence of this strategy is to lower the inertia and friction within the driven chain of the power supply unit, and to avoid the need to keep charged a larger battery. Consequently, the electric storage capacity may be reduced, thereby saving weight, cost and space in the vehicle, and also limiting the dependency to the strategic material essential to this component (lithium and other heavy metals).

Each of the electric generators 11, 12 and 13 has a specific maximum electric power output, so that the combination of engagement with the fuel engine 15 result in non linear increments of total electric power output,
widening the total output range of the power supply unit 10, similarly to a truck gear box assembly, combining the effects of two gear boxes in serial. Figure 2 give a graphic representation of the output levels of the power supply unit 10. However, two or more electric generators of equal capacity may also be used alone, or in combination with electric generators of other capacities.

The vehicle of Figure 1 also comprises an electric storage unit, which may be a battery 40. As shown, the battery 40 may be connected to the power supply unit 10 (via a rectifier, not shown, if the electric generators 11, 12, 13 are alternators), in the aim to be charged if its state of charge is below a predetermined value for example. The battery 40 may also supply electric current directly to the electric motors 25, 35 if necessary, to supply energy during a phase when the demand is increasing faster than the power supply unit 10 can respond to the demand. The responsiveness of the system constituted by the battery 40 and the power supply unit 10 is enhanced, as well as the ability of the vehicle to accelerate according to a will of the driver.

Figure 2 shows a graph of the achievable levels of the total electric power output P of the power supply unit versus the quantity of engaged electric generators 11, 12, 13 with the fuel engine 15. The following figures have been chosen for this example: the first electric generator 11 presents a maximum electric power output of 3kW, the second electric generator 12 presents a maximum electric power output of 12kW, the third electric generator 13 presents a maximum electric power output of 20kW.

Then, if only one of the three electric generators 11, 12, 13 is engaged with the fuel engine 15, the power supply unit 10 may deliver 3kW (first electric generator 11 engaged), or 12kW (second electric generator 11 engaged), or 20kW (third electric generator 13 engaged) maximum. If two of the three electric generators 11, 12, 13 are engaged with the fuel engine 15, the power supply unit 10 may deliver 15kW (first and second electric generators 11 and 12 simultaneously engaged), or 23kW (first and third electric generators 11 and 13 simultaneously engaged), or 32kW (second...
and third electric generators 12 and 13 simultaneously engaged) maximum. If the three electric generators 11, 12 and 13 are simultaneously engaged, the power supply unit 10 may deliver 35 kW maximum. This graph illustrates the flexibility of the system according to the invention, and its ability to respond to various situations of driving conditions without generating and storing excess energy in a larger battery.

For example, if the vehicle weights 900kg, and presents a cross sectional area, times a drag coefficient, of 0.65m², the power required for driving at 50km/h onto an horizontal track is estimated to be less than 3kW. Then, only the first electric generator 11 will be engaged with the fuel engine and may suffice to supply the electric power demanded by the vehicle. If this vehicle drives now at 100 km/h on the same track, the required power is estimated to be around 12kW, then only the second electric generator 12 will be engaged with the fuel engine and may suffice to supply the electric power demanded by the vehicle. In another situation, the vehicle may need to climb a slope of 10%, at a speed of 50km/h. It is estimated that the required power is around 16kW. Then, the first and second generators 11, 12 will be engaged to supply 15kW and the battery 40 will supply the extra power for the short time to climb this slope. If the vehicle is driving at 100km/h on a motorway and the driver whishes to overtake another vehicle at a speed of 140 km/h, the required power will be approximately 28kW, and the control unit will order to the system to engage the second and third electric generators 12, 13 to fulfill the electric demand. As seen, this system is flexible and the inertia of the driven elements is limited to the minimum required to sufficiently power the vehicle. Fuel savings are thus achieved, in combination with the fact that the fuel engine is operated at a constant rotation speed where its torque and power characteristics are optimum, thus reducing need for a large, heavy and expensive battery and a fuel engine with the performance requirements of a conventional automobile fuel engine for direct power driving.
It is understood that obvious improvements and/or modifications for one skilled in the art may be implemented, being under the scope of the invention as it is defined by the appended claims. In particular, the invention mentions the possibility to use three electric generators, but it may be contemplated to use only two or many more electric generators to increase the levels of maximum power output and thus the flexibility of the system, keeping in mind that heavy trucks can use up to twenty gears to optimize their driving.
1. Power supply unit (10) designed to supply electric power on demand to an electric powered vehicle, the power supply unit (10) comprising one single fuel engine (15), characterized in that it comprises at least two electric generators (11, 12, 13), each being characterized by a maximum electric power output and each being arranged to be engaged or disengaged with the single fuel engine (15), so that at least one electric generator (11, 12, 13) of the at least two electric generators (11, 12, 13) may be engaged with the single fuel engine (15) at a time to supply electric power to the vehicle, when the demand does not exceed the maximum electric power output of said engaged electric generator (11, 12, 13).

2. Power supply unit (10) according to the preceding claim, characterized in that the at least two electric generators (11, 12, 13) are asymmetrically sized to supply electric power to the vehicle.

3. Power supply unit (10) according to any one of the preceding claims, characterized in that a first electric generator (11) of the said at least two electric generators (11, 12, 13) has a first maximum electric power output, and in that the other electric generator (12, 13) of the said at least two electric generators (11, 12, 13) has a second maximum electric power output strictly greater than the first electric power output.

4. Power supply unit (10) according to the preceding claim, characterized in that the first maximum electric power output is determined to be greater or equal to a first demand of the vehicle driving at a speed of 50km/h or less, on an horizontal track.

5. Power supply unit (10) according to the preceding claim, characterized in that the second maximum electric power output is determined to be greater or equal to a difference between a second demand...
of the vehicle driving at a speed over 100km/h on an horizontal track, and the first demand.

6. Power supply unit (10) according to any one of the preceding claims, characterized in that it comprises three electric generators (11, 12, 13), each having a specific maximum electric power output different from the maximum electric power output of the two other electric generators (11, 12, 13).

7. Power supply unit (10) according to the preceding claim, characterized in that it comprises:

- a first electric generator (11) having a maximum electric power output ranging from 2.5kW included to 5kW included,
- a second electric generator (12) having a maximum electric power output ranging from 10kW included to 13kW included,
- a third electric generator (13) having a maximum electric power output ranging from 18kW included to 22kW included.

8. Power supply unit (10) according to any one of the preceding claims, characterized in that the fuel engine (15) is arranged to operate at a constant rotation speed.

9. Vehicle comprising at least one electric motor coupled to a wheel, at least one power supply unit (10) according to any one of the preceding claims, arranged to directly supply electric power to said at least one motor (25, 35).

10. Vehicle according to the preceding claim, characterized in that it further comprises at least one electric energy storage unit arranged:

- to be charged by the power supply unit (10) when a state of charge of the electric energy storage unit is below a predetermined value,
- and to supply electric power to the vehicle during phases when the demand is increasing and when the state of charge of the electric energy storage unit is above the predetermined value.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. H02J7/00 H02J7/14 B60L11/12

ADD.

According to International Patent Classification (IPC) or both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H02J B60L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search: 18 February 2014

Date of mailing of the international search report: 28/02/2014

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