

SYSTEM AND METHOD FOR STORING INSTANT REGENERATION IN ELECTRIC VEHICLES

FIELD OF THE INVENTION

5 [001] The present invention relates to a system and method for storing instant regeneration during regenerative braking for increasing efficiency of an Electric Vehicle. More particularly, it relates to a system and method for improving the electric truck mileage and energy efficiency.

BACKGROUND OF THE INVENTION

10 [002] In recent years, the production of electric vehicles (EVs) have traditionally gained much attention. This is basically due to highly increased awareness of global warming and also rise in cost of petrol prices. Thus, also due to increased air pollution which is concern in environment and increase in oil prices, the EVs is the first and last choice for the transportation. In battery operated EV, battery is the only source for energy and these batteries are facing problem such as less charging and recharging cycles which leads to poor response in driving range.

20 [003] Further deceleration of a vehicle with a traditional braking system requires that the kinetic and potential energy of the vehicle to be converted into thermal energy or heat through the action of friction. Further the regeneration can occur when the brakes are applied, whether the vehicle decelerates or whether braking is necessary to maintain desired speed (such as on a downhill). Additionally, regeneration can also occur upon other signals. Such as cessation of acceleration (foot off accelerator or similar), as part of cruise control operation, or in any other situation in which kinetic energy should be removed from the vehicle.

30 [004] Statistical data with respect to the urban driving predicts that about one third to one half of the energy required for operation of a vehicle is consumed in braking. With regenerative braking on electric vehicles, this vehicle kinetic energy can be converted back into electrical energy that can be stored in batteries for reuse to propel the vehicle

during the driving cycle. Therefore, regenerative braking has the potential to conserve energy which will improve fuel economy while reducing emissions that contribute to air pollution.

5 [005] In the Conventional pure electric vehicles, while the 'emission free' vehicles can't go the distances or provide the power (for any extended length of time) as that of the Internal Combustion Engine Vehicles. Although the existing knowledge and the arrangement relating to the electric vehicle works well, there is a need for a Pure Electric vehicle that has high mileage and efficient battery system to provide energy for longer period.

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[006] Thereby the present invention provides an Electric Vehicle that focusses on the improvement in terms of increase in mileage of the vehicle through effective utilization of the Regenerative Braking System.

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OBJECTIVE OF THE INVENTION

[007] The primary objective of the present invention is to provide a system and method for improving the mileage of an electric vehicle working at variable speed and torque limit.

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[008] Another objective of the present invention is to improve the energy efficiency and mileage of this electric vehicle wherein the regenerative braking (regenerative braking) method is being used to recover a part of the braking energy into electrical energy.

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[009] Yet another objective of the present invention is to continuously monitor various events to evaluate the favorable circumstances of occurrence of regenerative braking and accordingly storing the energy in the Energy Storage system.

BRIEF DESCRIPTION OF DRAWINGS

- [010] A complete understanding of the present invention may be obtained by reference to the accompanying drawings, when taken in conjunction with the detailed description thereof and in which:
- 5 Fig 1.: Illustrates the power connection of energy consumption and regenerative energy;
Fig 2.: Illustrates the energy storage device of the present invention.
Fig 3 and Fig 4: Illustrates methodology of regeneration in the Electric Vehicle
Fig 5: Illustrates the route of the vehicle during the production of the regenerative energy
Fig 6: Illustrates the graph plotted after computing the values obtained during the
10 regenerative braking.

SUMMARY

- [011] The present invention discloses an electric vehicle with improved mileage by using regenerative braking (regenerative braking) method to recover a part of
15 the braking energy into electrical energy. Regenerative braking is used in an Electric Vehicle (EV) as a way of recouping energy during braking, which is not possible to do in conventional Internal Combustion Engines (ICE) vehicles. Regenerative braking is the process of feeding energy from the drive motor back into the battery during the braking process, when the vehicle's inertia forces the motor into generator mode. In this mode,
20 the battery is seen as a load by the machine, thus providing a braking force on the vehicle. The present invention relates to the usage of re-generative braking can increase the driving range.

DETAILED DESCRIPTION OF INVENTION

- 25 [012] The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. The detailed description of the appended drawings is construed as a description of the currently preferred embodiment of the present invention and does not represent the only form in which the present invention may be practiced. This is to be understood that the same or equivalent

functions may be accomplished, in any order unless expressly and necessarily limited to a particular order, by different embodiments that are intended to be encompassed within the scope of the present invention. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief
5 summary or the following detailed description.

[013] Accordingly, those of ordinary skill in the art will recognize that various changes and modifications of the embodiments described herein can be made without departing from the scope of the invention. In addition, descriptions of well-known functions and
10 constructions are omitted for clarity and conciseness.

[014] Features that are described and/or illustrated with respect to one embodiment may be used in the same way or in a similar way in one or more other embodiments and/or in combination with or instead of the features of the other embodiments.

15 [015] The terms and words used in the following description and claims are not limited to the bibliographical meanings, but, are merely used to enable a clear and consistent understanding of the invention. Accordingly, it should be apparent to those skilled in the art that the following description of exemplary embodiments of the present invention are
20 provided for illustration purpose only and not for the purpose of limiting the invention.

[016] It is to be understood that the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise.

25 [017] It should be emphasized that the term “comprises/comprising” when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

30 [018] The present invention is applicable not only to a pure electric vehicle but also to a hybrid vehicle. However, an embodiment in which the spirit of the present invention thereof is

applied to a hybrid vehicle is obvious from an embodiment described hereinafter, in which the spirit of the present invention is applied to a pure electric vehicle. Therefore, an embodiment in which the spirit of the present invention is applied to a pure electric vehicle is hereinafter described in detail.

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[019] The invention described herein is an electric vehicle that may be a truck or any heavy vehicle using electric energy stored in the battery as a power source.

[020] In accordance with the present invention a braking system for optimizing energy regeneration efficiency of an electric truck is disclosed. Herein the efficiency refers to the amount of regenerative braking energy captured than being lost. The various components of the system include a Vehicle Control Unit, a Motor Control Unit (MCU); Energy Regulating Device (ERD), Permanent Magnet Synchronous Motor, Battery Management System or Energy Storage System:

- 15 • Energy Regulating Device (ERD): It consists of MCU which converts the current from AC to DC & DC to AC and further communicates with other devices.
- Motor Control Unit (MCU): It is placed between the battery and the motor where it is used to convert the DC current to AC current for running of the motor. In the case of regeneration, it acts as a rectifier where it converts AC current to DC
- 20 current. The motor used herein is a Permanent Magnet Synchronous Motor.
- Permanent Magnet Synchronous Motor (PMSM motor): It provides supply to drive the wheels and can also be used as a generator without reversing the terminal.
- Battery Management System (BMS) or Energy Storage System: This is a control
- 25 unit for the energy storage device or battery where it monitors the individual cell temperature while charging or discharging to protect the energy storage device. Further BMS maintains the battery condition as per the signal Received from MCU.

30 [021] In accordance with the present invention the motor control unit includes a motor for directly converting electric energy to usable mechanical energy. A motor speed sensor

detects motor speed and a wheel speed sensor detects wheel speed. An inverter controls the motor and a control unit controls the inverter in accordance with the motor speed sensor signal and the wheel speed sensor signal.

5 [022] In accordance with the present invention Fig 1 illustrates the motor of configuration 150 to 270 Kw, 1200 to 2400 rpm and a peak torque of 2400 which drives an electric vehicle, and also performs the function of braking. The Motor Control Unit of the configuration 300 to 380 KW, 500-600 V controls the functioning of the motor, wherein it converts electrical energy into mechanical energy and drives the wheels and vice-versa on braking.
10 The electricity generated is transferred back to the energy storage device having the capacity 250 to 300 KWH at 600 V to improve the efficiency by 19 to 20 %.

[023] In accordance with the exemplary embodiment of the present invention Fig 2 illustrates the energy storage device consisting of 360 cells (i.e. 10 Modules each module comprising 36 cells). Further in one module all 36 cells are connected in series and 5 modules from total 10 modules are connected in series each. The configuration of the components is described herein:
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(i) Cell specification:- 240 AH, 3.2 V, 5.22 kg, 174.6x207.1x71.6mm;

(ii) Module specification:- 240 AH, 115.2V, 240 Kg;

20 (iii) Battery Box specification :- 480 AH, 576 V;

[024] A simple electrically driven truck powered only by electrical batteries has the disadvantages that the batteries may become depleted while the truck is far from a battery charging station, and even long-distance travel is not possible.

25 [025] The advantage in fuel mileage arises from the use of regenerative dynamic braking, which converts kinetic energy of motion into electrical power during at least a portion of braking and returns the energy to the battery. It has been found that braking losses account for somewhere near half of all the frictional losses experienced by a vehicle in an urban transit setting. The recovery of this at least 60 percent of energy, and returning it to the

batteries for further use, permits to cut-off the need for "secondary" fuel-operated electrical generator.

[026] The motor in the electric truck on running develops counter voltage higher than the
5 battery voltage and inverts the current direction thereby feeding current into the battery, while developing a counter torque that acts as a brake. This phase is called regeneration.

[027] In accordance with the present invention in the electric truck (power source), the electric
10 energy stored in the battery is used as a power source. To improve the electric truck mileage and energy efficiency, the regenerative braking (regenerative braking) method is being used to recover a part of the braking energy into electrical energy. Further vehicle size may be the largest factor in the effectiveness of regenerative braking for the simple reason that heavier vehicles have much more momentum and kinetic energy. Thereby effective usage of the braking power leads to increase in the mileage of the said Electric
15 Truck.

[028] Most of the Electric vehicles may be equipped with the means to transfer energy from the
energy storage system back to the wheels to provide propulsion power to the vehicle. However, the regenerative braking power is usually available at certain vehicle operation
20 periods, with variable duration and recurrence period.

[029] The regenerative power is lost in two cases:
(a) Firstly, if the energy storage device that is to accept electrical energy from the
regenerative power source is at its maximum state of charge (SOC) then at the time
25 of production of regenerative power, the said energy storage device cannot accept any more electrical energy from the regenerative power source and all of the regenerative power produced is lost in vain.
(b) Secondly, if the SOC of the energy storage device is not at its maximum level but is still charged with electrical energy above a particular level, then again, the
30 regenerative power produced will be partly stored.

- [030] In accordance with the present invention, an electric vehicle with improved efficiency in recovering the regenerated energy is provided. More particularly, an Energy Storage System (ESS) that is configured to optimally receive and supply electrical energy is provided. The said ESS is optimized to handle high power discharging and charging functions of the energy storage device triggered by various driving conditions/modes, such as starting, cruising, accelerating, and regenerative braking, and/or partial/full electrical propulsion.
- [031] One way to improve the performance, cycle life, and power characteristics of an ESS is to combine different types of energy storage devices that includes a high-power storage device. Such as a high-power lithium-ion battery or an ultra-capacitor, and a high energy device such as a lead-acid battery. Whereas in the present invention houses only a single energy storage device . The usable energy capacity of an energy storage device is defined as the total energy content that can be stored in the energy storage device given all relevant restrictions and requirements on the use of the components of the energy storage device. The capacity of the single energy storage device of the present invention is 276.4 KWH
- [032] In accordance with the present invention, a control unit of the Electric Vehicle (EV) is configured to selectively connect an appropriate energy storage device to a power network of the Energy Storage System (ESS) based on SOC information. In one embodiment, the SOC of each energy storage device can be manipulated based on the vehicle driving conditions, such as vehicle speed. Battery Monitoring unit (BMU) of the present invention monitors the SOC of the battery sends the information to the BMS. Each Module of the energy storage system comprises 3 BMU, i.e. 30 BMU in total.
- [033] The Energy Storage System (ESS) includes a vehicle control unit that is coupled to a motor control unit. Additionally, ESS includes sensing devices configured for sensing signals of currents, voltages, temperatures, and/or other data arising from monitoring energy storage devices and, any other suitable sensing devices. Further, ESS also includes switching units (not shown) that can serve to disconnect/decouple or connect/couple the above-mentioned components from each another.

[034] In accordance with the present invention, the said energy storage device provides power to vehicle accessories. The various components i.e. vehicle control module, motor control unit, regulation device can be configured to communicate with one or more of units to establish a level of mechanical energy associated with historical, current, predicted vehicle and drivetrain function, (i.e. regenerative braking). The data, from one or more of unit's other sources of data is to be obtained by vehicle control module and data unit, may be needed by motor control unit and regulation device to perform their control and regulation functions.

[035] In accordance with the present invention Fig 3.and Fig 4. illustrates the function of the regeneration method in the Electric Vehicle. As the driver removes the foot from the acceleration pedal, the motor control unit sends the signal to the battery management system. Simultaneously BMS also sends the signal to Battery Management Unit (BMU) to check the SOC of the battery to determine whether to switch on the charging or not. Further, the motor control unit stops the current supply and motor is forced to run at an rpm (rotation per minute) due to torque generated by the motor connected to the wheel. Thereafter the speed at which vehicle is running decreases due to rolling resistance and drag forces. The power generated is explained through the equation below:

$$P(KW) = Rpm \times Torque(850N.m)/9550 = V(600V) \times I (Amp)$$

[036] Therefore, the said motor acts as a generator and starts producing alternating current wherein the motor control unit acts as rectifier (AC to DC). The motor control unit analyzes the alternating current and voltage $380 \pm 15\%$ and further the said MCU converts the AC to DC voltage (450V-750V) and AC to DC current (0 – 450A). The motor control unit further sends the message through communication PCB to the battery monitoring system to switch on the charging mode (if the current & voltage is greater than a limited value i.e. 450 to 750V and 0 to 450Amp then MCU limits the charging current and avoids the damage of cells). BMU also sends the signal to the BMS to start the charging and therefore, the discharging of the battery stops and during the regenerative process the battery is in charging state based on the SOC.

- [037] In accordance with the present invention, based on the received data, energy regulating device i.e. MCU and BMS together determine the favorable circumstances for regenerative braking and at the same time calibrating if there is greater than optimal amount of energy in the storage device is suitable to accept the regeneration power. Further during the function of a motor, the motor control unit will ensure that sufficient charge exists in energy storage device to ensure that partial or full electrical propulsion is provided.
- 10 [038] In accordance with the present invention, the regenerative braking may also be estimated in part from the type of driving that is being experienced which, in turn, may be determined from speed and acceleration trend information including minimum/average/maximum speed and acceleration as well as from heading and turn information.
- 15 [039] Alternatively, the route or route type (such as city, Suburban, or rural driving pattern) may be detected by the vehicle or energy storage system by an internal or external GPS receiver and the like. Further the vehicle data including power request, route data, and climate control data, and other data noted above from vehicle monitoring unit or elsewhere is provided.
- 20 [040] In accordance with the present invention when vehicle goes to the downhill and or on terrain then the regeneration power is maximum. Further reaction time between the power consumption and regeneration is zero.
- 25 [041] In an exemplary embodiment of the present invention Fig 5 illustrates a vehicle having 55 Ton, 360 HP motor, 6*4 and motor max torque 2400 N.m load running at an average speed of 40KMPH, has SOC 100% at Start Point. Further the readings are taken on the route consisting Highway, Gradients, Downhill, Traffic, Rural Area Roads, Wet Road, Traffic Light, Toll Etc.
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[042] While the vehicle is in the running condition at the rate of 100 ms per message, the data is transferred, the generated Data is 8 bits/msg in extended format, further the said data is computed to get the power values. In the computed data the positive values define the power consumption and negative values defines the power generation by the motor so, frequency of power generation divided by the Frequency of total power (consumption + generation) gives the % of power regeneration.

[043] Figure 6 illustrates the graph between power and time based on the data computed above. The graph represents no gap between the transition of power consumption (+ve power) and power regeneration (-ve power). Therefore, the system of the present invention is most efficient and as due to regeneration power, the said vehicle achieves atleast 20% (19.80%) extra power which increases the mileage of truck.

[044] While this invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.