Solar Charging Scheme for Electrical Vehicle (EV) Based on Hybrid Energy Storage System with Super Capacitor

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Abstract— This paper proposes a design for renewable-energy hybrid electric vehicles that is fed by a photovoltaic (PV) source with a super capacitor (SC) storage device. In recent years, the electrical vehicles have become the focus of research for environment friendly characteristics. As the core technology of the super capacitor influences the development of the EVs. A super capacitor fast charging scheme for electrical vehicle is proposed. It uses solar electric vehicle system which is a combination of battery and super capacitor. The super capacitor bank can be used to storage the energy generated by the photovoltaic EV system. Super capacitor energy storage also allows for fault ride through and the minimization of the power fluctuation. Longer life time in terms of charge cycle is provided by super capacitor and low energy density and high cost and overcome by lead acid battery, but it requires an accurate charge profile in order to increase the lifetime of a battery. The super capacitor guarantees a longer lifetime in terms of large range of operating temperatures combining the two storages is possible to obtain good compromise in terms of energy density. In this paper, an optimization based control strategy is proposed electric vehicle to improve the energy efficiency as well as battery life. A system model will added between the solar panel and super capacitor to improve the system dynamic performance. The high replacement cost of depleted battery banks is an important cost related issue with the energy storage system. One possibility of reducing the power overloading on batteries and the fuel cells is to use super capacitors as load-leveling devices. The fast acting super capacitors relieve fast changes in the battery storage system. The batteries are responsible for meeting the energy requirements and the super capacitors are responsible for meeting the instantaneous power demand. This paper presents software and hardware development of controller for solar powered electric vehicle system using MATLAB/SIMULINK.

Key words: Battery, DC-DC Converter, DC Motor, Hybrid Electric Vehicle, Solar PV Panel, Super Capacitor

I. INTRODUCTION

Hybrid vehicles are one possible solution of decreasing dependence on fossil fuels and reducing air pollution. The electricity may then be stored on board the electric vehicle using a battery, flywheel, or super capacitors. The proposed system consists of solar panel, battery bank, charge controller, ultra capacitor, bi-directional DC/DC converter and DC motor. The DC source is a set of lead-acid batteries and super capacitor which are charged by solar PV panels. The solar charge controller charges the lead acid battery and super capacitor (SC) for Integrated Electric Vehicle applications. Using the Integrated energy source SC and battery and with a proper energy management improves the transient performances. The battery and super capacitors are coupled to DC-bus using buck-boost converters. Super capacitors have low energy density but it's have property of quick charge, large power density, and long cycle life. One of the most prominent is the super capacitor application in hybrid electric vehicle. When a electric vehicle is decelerating, the electric motor acts as a generator producing a short, but high value energy impulse. This is used to charge the super capacitor. Charging the conventional batteries with such a short impulse would be extremely ineffective. An electrical vehicle that employs regenerative braking and suspension has the ability to recover energy which is normally lost during braking. This energy is stored in the battery on board in the form of electrical energy. The energy produced by the electrical vehicle during braking is in significant amounts and must be stored quickly and efficiently. A DC-DC bi-directional voltage-source converter transfers power between the super capacitor bank and the high voltage traction drive supply rail trucks car etc. In order to increase the storage capacity and prolong the battery life, new materials are being utilized now-a-days. For this space photo voltaic systems have become an important choice as with the introduction of super capacitors their investment cost reduces and efficiency increases. The systems using super capacitors have many advantages, like high power density, long life cycle, environment friendly and maintenance free.

Various following advantages for hybrid solar powered electric vehicle by using solar technology:

1) Reduction in conventional vehicle demand in urban city.
2) Minimum the pollution problem in urban city.
3) Give clean energy which will reduce the carbon dioxide emission every month
4) Reduction in fuel demand

Fig. 1: Vehicle of Electrical Department (CTAE)

II. HYBRID ENERGY STORAGE SYSTEMS

For years, the hybrid energy storage systems have undergone intense research with the objective of improving the storage of the electrical batteries. The super capacitors have these complementary characteristics that make them attractive for hybrid energy storage systems. Hybrid systems can significantly reduce overall energy use and environmental impacts, increase the efficiency and reliability of energy production and reduce the cost of providing for the end uses. There are two major structures that super capacitors could be connected to a photovoltaic system.

A. *Solar PV Charging*

PV system often employs an energy storage mechanism so the captured electrical energy may be made available at a later time. Most commonly the storage mechanism consists of rechargeable batteries, but it is also possible to employ more exotic storage mechanism. Energy storage batteries also provide transient suppression, system voltage regulation and a source of current that can exceed PV array capabilities. When battery storage mechanism is employed, it is common to also incorporate a charge controller into the system, so the batteries can be prevented from reaching a charge either an overcharged pr over discharged condition. Super capacitors are connected directly to the intermediate dc link, to overcome this limitation, a dc/dc converter between the dc link and the super capacitors should be used. The focus of this paper is also on the general, technical challenges and issues ahead of plug-in hybrid electric vehicles in relation with the major components which can be used for design consideration of electric motor, battery bank and DC converter. Battery health is damaged by short bursts of discharging current supplied to motors and recharging current generated from the RBS. In a HESS, UCs are used as an energy buffer to smooth rapid power fluctuations in and out of the battery of an EV power density of batteries is lower than UCs so that the higher the discharge rate, the less efficient the energy conversion. Hence, the HESS makes the battery to supply the average power required for operative vehicles. The sudden power surges those are required for the acceleration is provided by the ultra-capacitors. They also accommodate the instantaneous regenerative energy from the regenerative braking system.

B. *Battery Powered Electric Vehicle*

Battery powered EVs are referred to as zero emission vehicles (ZES) as they don’t produce pollution at the point of use, sometimes known as pure EVs. It consists of batteries, motor, and motor controller, transmissions devices and wheels. EV propulsion system with brake energy regeneration and local zero emission demonstrate their best performance in typical stop – and- go city traffic with low- speed cruising. Currently the main barrier to success for BEVs is their short drive range per charge, resulting from very large, expensive and short –lived battery packs.

Hybrid electric vehicles (HEVs): an HEV has two or more energy conversion paths, one of which is bidirectional. HEVs has an electric vehicle storage device as a battery, flywheel or super capacitor that captures some of the energy converted from kinetic energy in braking and stores it for use the next time the vehicle is accelerated. The two types of hybrid electric vehicles:

1) *Series Hybrid Electric Vehicle*

HEV in which only one energy converter can provide propulsion power. The battery – powered electric motor drives the propulsion wheels, while a downsized ICE drives a generator, the output of which is connected to the battery. The battery output is controlled to determine the voltage waveform applied to the motor, and hence how fast the motor spin, which in turn determines the vehicles speed

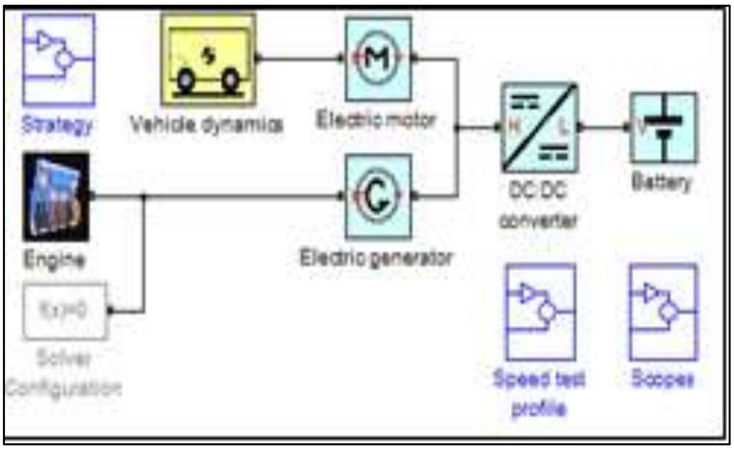

Fig. 2: Series Hybrid Electric Vehicle

2) Parallel Hybrid Electric

Parallel HEV runs on the electric drive in slow city traffic on the engine when cruising at high speed on high ways, and on both when vehicle acceleration is required.

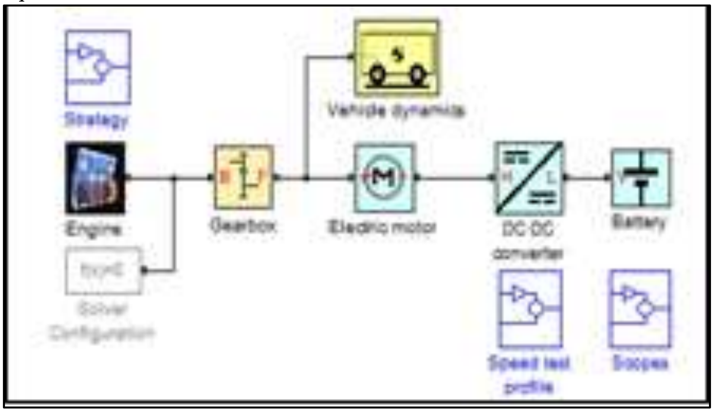

Fig. 3: Parallel hybrid electric vehicle

III. ENERGY SOURCES OF EV PROPULSION SYSTEM

Battery for EV and HEV application are high, specific power, high specific energy, high charge acceptance rate for recharging and regenerative braking, and long cycle life. Battery technology has been undergoing extensive research and development efforts over the past 30, yet there is currently no battery that can deliver an combination of power, energy, and life cycle for high- volume production vehicles.

A. Lead Acid Battery

The lead acid battery has been the most popular choice of batteries for electric vehicles during the initial development stages. The lead acid batteries are being used since the middle of the nineteenth century and are currently in a much matured stage. These batteries (VLRA) provide a path for the oxygen that is liberated at the positive electrode, to reach the negative electrode where it recombines to form lead sulphate. The future of the battery technologies for electric vehicle application depends on factors including system cost, availability of raw materials, mass production capability and life cycle characteristic.

B. Super Capacitor

Super capacitors are derivatives of the conventional capacitors where energy density function more like a battery. The terms ultra capacitor are often interchangeably used. There are two types ultra capacitor

1) Symmetrical super capacitor: Capacitors are devices that store energy by the separation of equal positive and negative electrostatic charges. The power density of the conventional capacitors are extremely high (1012W/m3), but the energy density is very low (50W h/m3).
2) Asymmetrical super capacitor: the asymmetrical ultra capacitor, which can also be termed a pseudo- battery, has higher energy density than a symmetrical ultra capacitor and is also capable of very high pulse power.

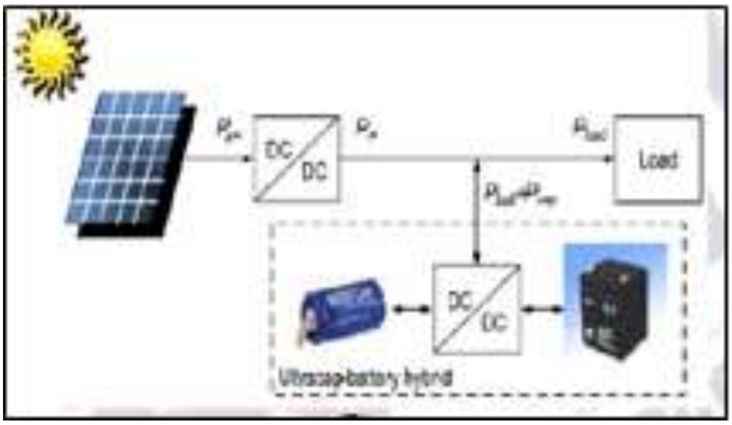

Fig. 4: Solar PV panel using with Battery and super capacitor

IV. Reasons for Battery Super Capacitor Hybridization

A. Power versus Energy

The EV needs variable power. The peak power demand is during acceleration and braking, which is for a very short time as compared to the whole driving cycle. The ratio of peak power to the average power can be over 10:1. For the applications involving high peak to average power, like a virtual source with high specific energy and high specific power a combination of batteries and super capacitors is used.

B. Higher Energy Efficiency

Delivering high power for a short period of time is deadly to batteries, but as the ultra-capacitor is able to deliver or receive energy in peak power situations, it can act as a load leveling device for the battery.

C. Regenerative braking

Hence, by maximizing the energy recovered by the regenerative braking, the range of operation of electric vehicle can be extended. Charge current in batteries are limited to a smaller value compared to discharge current. Super capacitors may have an important role in braking situation, because they can be charged very fast and their life is, to a much higher degree in comparison with batteries, insensitive to charge/discharge profile.

D. Batteries life

Super capacitors have a very long life, significantly higher than batteries. As the cost of the battery is significant in the pricing of the whole car, the life of the batteries is very important for customer's acceptance of EVs.

E. Temperature Range

Super capacitors can operate under a wider temperature range than batteries. When used together, super capacitors can attenuate the reduction in the power available from batteries in extreme temperature conditions.

V. Advantages of Super Capacitors

A. Higher Power Density

In terms of energy density, existing commercial ultra capacitors range from 1 to 10 Wh/kg. Power density for ultra capacitors may typically range from 1000 to 5000 W/kg.

B. High Efficiency

Columbic efficiency of ultra capacitors is as high as 99%.In addition; ultra capacitors have high round trip efficiency.

C. High Current

The equivalent series resistance (ESR) in ultra-capacitors is extremely low, so the ultra capacitor can be charged with a very high current, this feature makes the ultra-capacitors (UG) a good choice for applications involving regenerative braking. In order to successfully absorb the energy from braking, a very high charging current profile is needed.

D. High Operating Temperature

ultra capacitors can operate over a wide range of temperatures. The range of operating temperatures for ultra capacitors is determined by the electrolyte. As a result a typical ultra capacitor can be operated at temperatures as low as -45ºC. They can be operated at temperature as high as 60ºC.

E. Long Life

The ultra capacitor is good for several hundred thousand charge/discharge cycles, this is many more than can be achieved with batteries, some of which are good for only several hundred cycles. Thus using ultra capacitors in hybrid electric vehicles can improve the fuel economy and decrease vehicle emissions throughout the vehicle life.

VI. Simulation Results

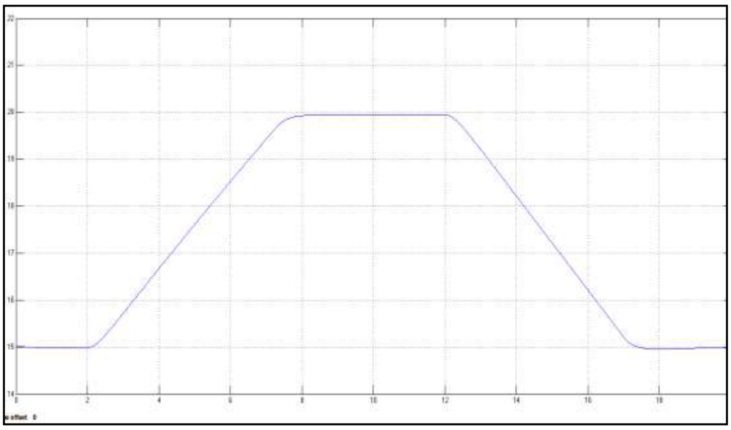

Fig. 5: Electric Vehicle Velocity (m/s)

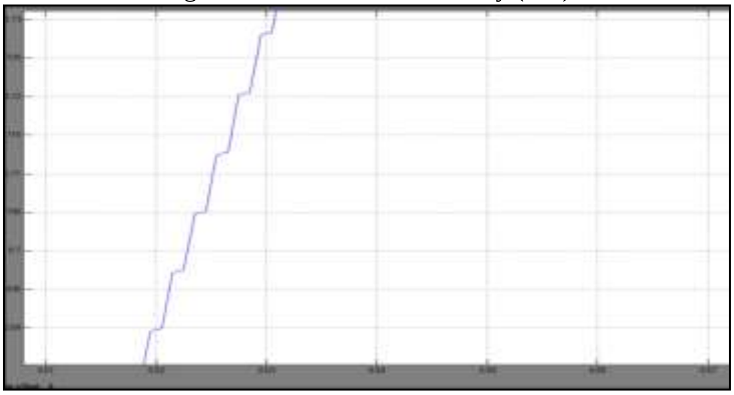

Fig. 6: Super Capacitor of Voltage

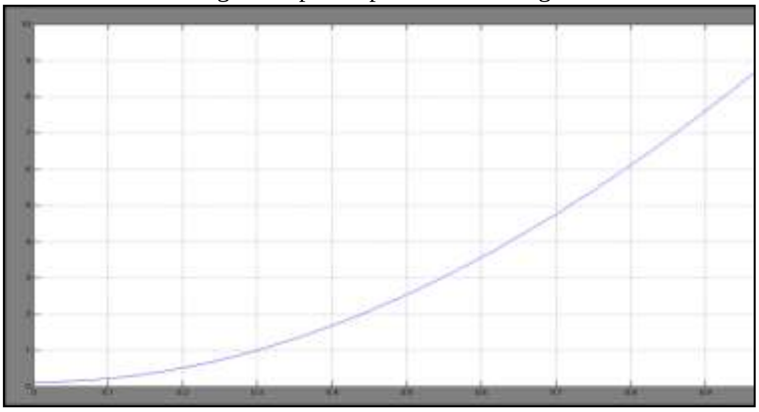

Fig. 7: Battery of Output

VII. Conclusion

In this work a new structure for a photovoltaic system with the integration of super capacitor energy storage was proposed system. A novel fast charging scheme for electrical vehicle is proposed s paper to meet three goals: reflex charging of the battery, dc bus voltage stabilization, limiting super capacitor voltage it uses hybrid energy system which is a combination of battery and super capacitor. The hybrid energy storage system can increase the life span of the batteries by improving their working condition, to shorten the charging time. Super Capacitors are applied to meet the fast changing power demand, while the Lead-acid batteries balance the average energy demand. The integration of the Lead-acid batteries and the Super Capacitor in the storage system is explained.

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