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Hybrid Energy Storage System consisting Solar Panel – Battery – Super capacitor for improving the performance of Electric Vehicles

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Abstract

This paper presents a highly reliable, extended range power supply for an Electric Vehicle (EV). The power supply consists of solar PV source , a battery and Ultra capacitor (UC). Main source of power is battery , and is connected with super capacitor during transient phase like overloading and starting . Photovoltaic cell works for the steady condition . The total effect of such arrangement is to improve travel range, reduced size of battery , enhanced excellent response while the overloading condition and battery life . Improved performance which gives optimal use of energy, smooth ride and minimum size of sources of energy. Many stand-alone photovoltaic systems need storage device for providing steady state energy to the load when photovoltaic irradiation are not sufficient. Generally , Batteries are used for such application. Thus, providing a large peak current, like starting of motor , degrades plates of battery , results in devastation of battery. An alternate solution of providing heavy current have to connect battery with super capacitors forming an hybrid energy storage system, for which battery could provide steady state energy also the super capacitor can provide the peak power to connected load. A secondary source, solar panel module is available to charge battery and super capacitor.

Keywords: - *Electric Vehicle, Photovoltaic, Battery, Solar Panel , energy management.*

1. Introduction

Air pollution is a major adverse consequence of conventional automobiles that use conventional fossil fuels like Petrol, Diesel. In urban areas because of congested traffic, the condition becomes complicated . To obtain pollution free environment, more use of renewable resources in vehicle system is beneficial. More use of EV in automobile sector with pollution free emission will reduced the consumption of fuel and preserving the environment . In this direction various are being taken at international level. Companies such as BMW, Ford , Tesla and CODA manufactures hybrid and electric cars. Authors [1] presented interaction of solar panel and battery in such a way it can continuously charged from solar system. This configuration represents the solar system impracticable and tends to ineffective operation. Hybridization of battery and super capacitor has been investigated [2]. In [3], presents an operation of photovoltaic panel - battery – super capacitor hybrid system in e-vehicles. Algorithm for battery , photovoltaic panel has been represented. Method for DC/DC converter is represented so that discharging current of battery should be with in limitation and use of ultra capacitor. Transients, charging , discharging mode of ultra capacitor has been studied **.** In [6], modified construction of an present e-vehicle, will give efficient performance along with super capacitor and battery combination . ultra capacitor are used to supply the high current required during starting and overloading , and helping in increasing life and state of charge of battery.

2. System Configuration

A typical stand-alone system includes energy storage devices, solar panel load and regulator.. Normally , all usable technology uses battery because it is having cheaper cost and easy availability . For battery charging , photovoltaic panel are not ideal because solar system gives inconstant output and the output is not reliable and highly depend on atmospheric conditions, Thus , an charge , discharge duty cycle is not constant, which results in low state of charge of battery. Some applications require a very heavy current for shorter duration e.g. starting of motor ; where need of starting current is 6 to 10 times

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working current of motor. Usually the pulse current requirement is fulfilled by the lead acid battery. Lead acid batteries in such condition are big in size so that battery can supply heavy current . The heavy current requirement need to fulfilled for some seconds at a particular time.

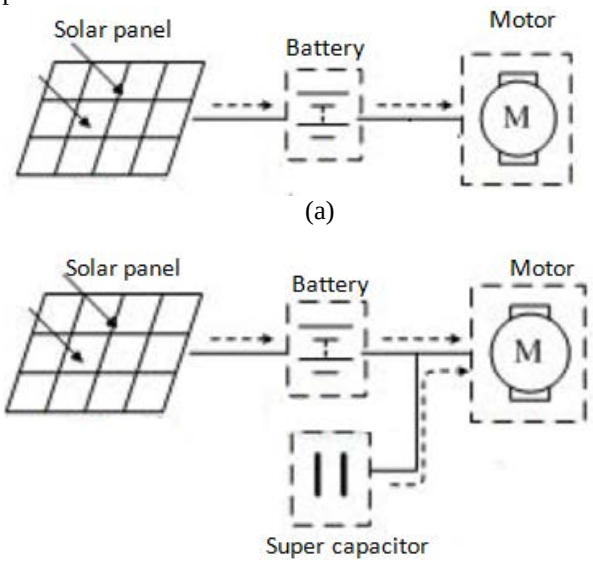

Fig. 1 .Block diagram of (a) conventional and (b) proposed system

Sizing battery around it would be costlier ; in solar system, replacement of battery takes place in 3 to 5 years depend on their use. Using battery- ultra capacitor hybrid storage energy system shown in fig.1(b) reduction in size of battery and higher state of charge would obtained. Power density of super capacitor is higher than battery allowing the ultra capacitor providing peak power for shorter duration. On other side, ,battery having high energy density than super capacitor allowing the battery to store bulk power and supply it for longer duration. In Table 1, the comparison of battery and super capacitor is done . In the hybrid system peak requirement of load is fulfilled by the super capacitor and lead acid battery supplies the less continuous power requirements.

Table 1. Battery Versus Supercapacitor Performance

	Lead Acid Battery	Supercapacitor
Specific Energy Density (Wh/kg)	10-100	1 – 10
Specific Power Density (W/kg)	<1000	<10,000
Cycle Life	1,000	> 500,000
Charge/Discharge Efficiency	70 – 85%	85 - 98%
Fast Charge Time	1 - 5h	0.3 – 30 sec
Discharge Time	0.3 – 3h	0.3 – 30s

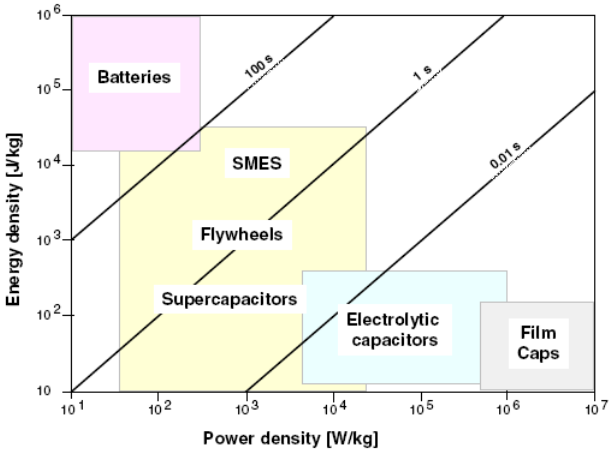

Fig. 2. Comparison of energy density and power density of different energy storage devices

3. System Components

The following section is giving an over view of the major parts of system that is making propound system.

3.1 Photovoltaic Solar Panels

The solar panels are made up of semiconductors which converts the photovoltaic irradiance in to electric power. Solar cells made up of semiconductor, like silicon. In photovoltaic panel , semiconductor generates electric field , one side positive and another negative. As light collapse on PV cell, bound electrons looses the semiconductor material atom. On positive and negative sides , if conductors are attached which forms an electric network , the electrons are catched in current form, electricity. Electric energy used to supply a load . The fig shows current source *Iph*, a series resistance *Rs* and diode.

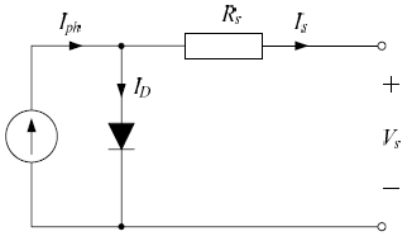

Fig. 3 . Photovoltaic cell model

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3.2 Energy storage system

The primary source of energy of vehicle is battery bank .Bank of lead acid batteries contains various battery are connected in parallel to get higher current .A battery is having voltage of 6V and 12V, and batteries connected in serial to get required rating of voltage. The main technology of storage used in Photovoltaic solar systems is battery . The model of battery is utilized to determine the effects of state of health (SOH), and state of charge (SOC) of battery. Equivalent circuit model of battery is represented in Fig. 3. Lead acid Battery (model no DB12-65) of 12 V , 65 AH having charging current 4.5 Amp has been used .

Fig 4. BOSS65L Battery Model

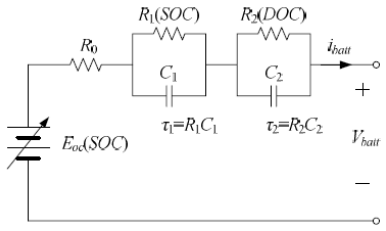

Fig 5. Battery model

Where ,SOC stands for state of charge of the battery
DOC stands for deep of charge of the battery
C(iavg) is the current-dependent capacity of battery
E0 is the OC voltage when the battery is in state of full charge.

3.3 Super Capacitor

The super- capacitor, is known as double layer capacitor or ultra capacitor different by conventional capacitor whose capacitance is very large. It stores energy in the form of a stable charge. Applying a voltage difference in between plates which charge capacitor. Super capacitor requires 10 sec for charging. The charging characteristic of super- capacitor is same as battery and charging current is controlled by charger. The super capacitor can charge and discharge for an no. duty cycles. The lead acid battery, which has a fixed cycle. Super capacitor of 16 V , 430 Farad having mass 5.50 Kg has been used . This Super capacitor can stores 2.85 Wh/Kg energy.

$$E_{\max} = \frac{\frac{1}{2}CV^2}{3600 * mass}$$

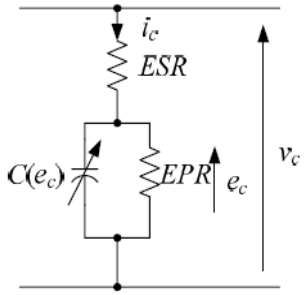

Fig. 6. Supercapacitor equivalent circuit model

Fig. 7. BMOD0430 E016 Super capacitor Model

4. Battery Voltage Control Through LED

Battery having open circuit voltage 12.63 V, it will operate upto 12 V . Microcontroller gets 5V supply voltage using IC 7805 . Potential divider circuit is giving 25% of available battery voltage . This voltage appears at ADC0 pin of Microcontroller (ATmega 32 A) .From the blink of LED , the available battery voltage is known .Figure 8 represents Flow Chart of Battery Voltage . Program written in assembly language and then It is loaded in microcontroller as per flow chart shown in figure8. Here AVR microcontroller gets a battery voltage and initialize it . Microcontroller compares value with store value of 2.98 V (25% of 12 V).If it matches, microcontroller makes LED glow continuously .if not microcontroller compares it with value of 2.75 V(25% of 11 V) . If it matches,

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microcontroller makes LED glow for 1 sec ,if not ,for value of less than 2.75 , microcontroller makes LED glow for 0.1sec.Same procedure for super capacitor is carried out for knowing the super capacitor available voltage.

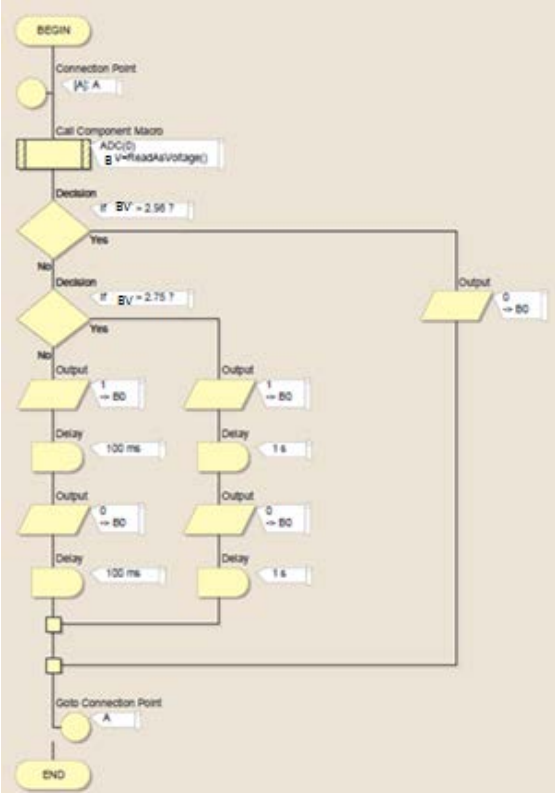

Fig. 8 . Battery voltage control flow

5. Experimental Setup of the System

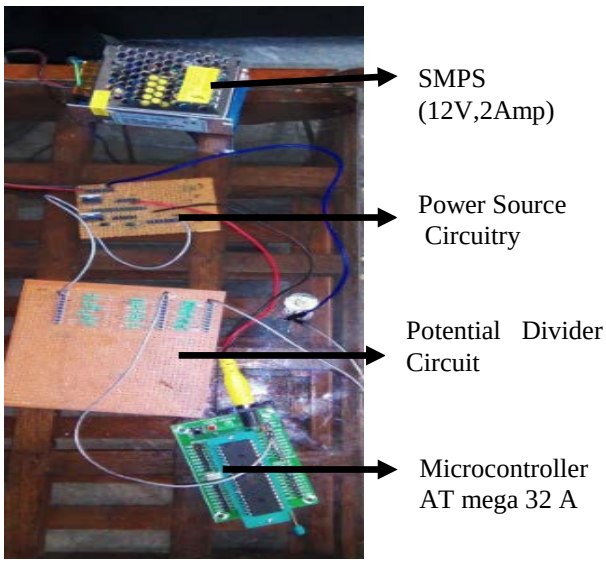

Fig. 9. Experimental setup for ADC Read and LED glow

Table 2. Battery voltage verses status of charge

Blinks of LED	Battery Voltage	Status
LED blinks continuously	12 V – 12.63 V	Battery is completely charged
LED blinks after every 1 Sec	11 V – 12 V	Battery is partially charged
Led blinks After every 100msec (0.1 sec)	< 11 V	Battery needs charging

5. Proposed Fabrication at GHRCE in Consultation with Professional Engineer

Based upon a analysis of obtained disadvantages , modified construction of electric vehicle presented in figure 10. Identification of battery voltage through controller is done. The 120 W 12V 10 Amp DC motor, driven by a 100 W , 12 V Solar Panel , 12V 65Ah battery and super capacitor consists of 16V, 430F connected in parallel with battery which is used to drag max energy from super capacitor . Microcontroller senses different functions and take corresponding action. The heart of electric vehicle is controller which performs control action and power in each small part of system.

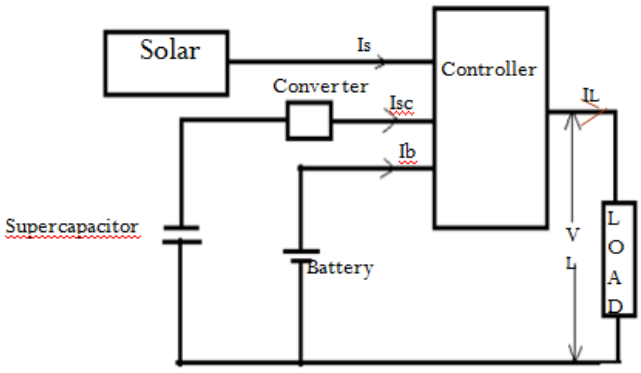

Fig. 10. Block diagram of propound circuit shows interface of solar and battery, SC system with the motor .

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6. Conclusion

According to the energy configuration, following advantages are made;

1. Provides better conditions for working and increase battery's operating life and SOC.
2. The battery can supply power to motor directly without voltage drop, thus improves efficiency.
3. The heavy current battery discharging is minimised, therefore life of battery is increased.
4. The introduction of green photovoltaic panel extract energy from sun, which increases ue of green energy.
5. Introduction of regenerative braking, i.e., recovering energy from brake , used energy, wasted in the brakes.
6. In the total project (undertaken by the college interacting with the consultant, with action period of march 2015 – march 2016), intelligent charger for vehicle-to-grid power will be action.The scheme includes bidirectional energy meter.

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