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Co-Working of Solar Panel – Battery – Super capacitor for Electric Vehicle

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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). Battery is the main source of power, and is supported by the Ultra capacitor during the transient phase such as starting and braking. Solar PV cell works during the steady- state operation. The net effect of this arrangement is improve travel range, reduced battery size, enhanced battery life and excellent response during the dynamic condition. Improved dynamic performance results in smooth ride, optimal energy utilization and optimal sizing of energy sources. Most of the stand-alone photovoltaic systems require energy storage devices to supply continuous energy to the load when there is insufficient solar irradiation. Typically, Valve Regulated Lead Acid (VRLA) batteries are used for this application. However, providing a large burst of current, such as motor startup, degrades battery plates, resulting in devastation of the battery. An alternative way of supplying large bursts of current is to integrate VRLA batteries and super capacitors to form a hybrid storage system, where the battery can supply continuous energy and the ultra capacitor can supply the instant power to the load.**

Index Terms— **Battery, Electric Vehicle, energy management, Photovoltaic Solar Panel.**

I. INTRODUCTION

Electric vehicles have their history since early 20th century even before the ic engines came along. Even though the ic engines have dominated during 20th century, electric vehicles have arisen again quite firmly, mainly due to the environmental concerns related with fossil fuels. but there are similar environmental concerns with electric vehicles too if we consider lead acid batteries whose breakdown is not eco-friendly. the electric bikes which are available and are affordable include a rear wheel bldc (brushless direct current) motor which is suitable and compact. the battery pack is a series combination of cells, a controller which controls the power transaction. traction battery is generally lead acid which are cheaper compared with other types. a potentiometer box is present which acts as accelerator along with other minor circuitry. with these specifications, E-bikes attain 25-40km/hr speed and 50-70km/charge range.

A - MERITS OF PRESENT E-BIKES

A. Good efficiency IC engines are 40% efficient whereas BLDC (Brushless DC) motors equipped in e-bikes are above 90% efficient in power utilization. The motors are strong for use in all weather conditions with almost all types of load conditions.

***B. Eco-friend**ly* If the electric power required to charge the batteries is derived from non conventional sources, then electric vehicles are very eco friendly.

C. Cheaper and Quieter Journey Due to good efficiency, electric energy units required to travel a given distance compared those with power requirement of fossil fuel is too less. Electric vehicles are the quietest of all means of transport.

B - DEMERITS OF PRESENT VEHICLE

A. Lower speed E-bikes don't attain the higher speeds which petrol or Diesel powered vehicles easily do.

B. Longer charging time The batteries requires 6-8 hours for charging in case of cars. Even if we neglect the deficiency of charging stations, 6-8 hours is pretty long duration.

C. Battery issues Lead acid batteries which degrade heavily over time (500–800 charge-discharge cycles). Vehicle with lead acid batteries requires replacement after every 2-3 years. The decomposition of batteries is not eco-friendly.

II. SYSTEM CONFIGURATION

A typical stand-alone system includes a photovoltaic panel, regulator, energy storage system, and load. Generally the most common storage technology used is the VRLA battery because of its low cost and wide availability. Photovoltaic Solar panels are not an ideal source for battery charging; the output is unreliable and heavily dependent on weather conditions, therefore an optimum charge and discharge cycle cannot be guaranteed, resulting in a low battery state of charge (SOC). Certain load applications require heavy current for a period of time e.g. motor starting applications; where starting current requirement is 6-10 times the normal operating current of the motor. Usually the peak current demand is satisfied by the battery. VRLA batteries in this situation are large in order to deal with the high current being removed from the battery. The peak current demand has to be met for a few seconds at a particular time. To increase size of the battery around this can prove costly; in photovoltaic systems the batteries are replaced typically every 3-5 years depending.

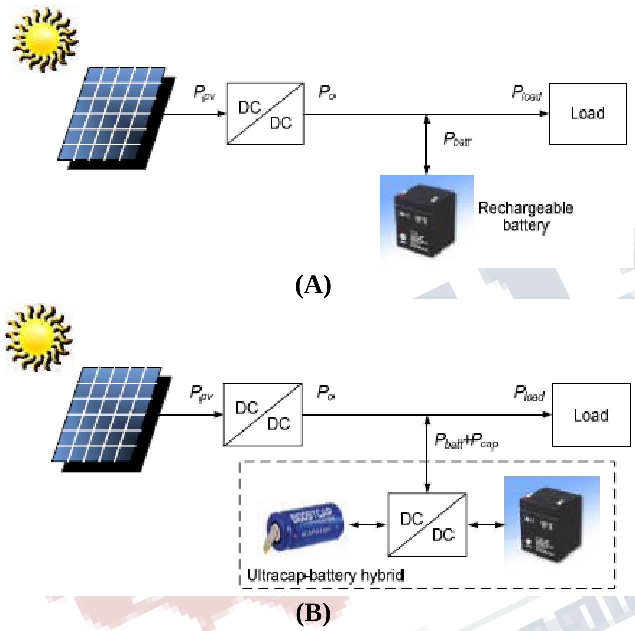

Fig. 1. . Block diagram of (a) conventional and (b) proposed Photovoltaic system.

On the application. By utilizing a battery ultra capacitor hybrid energy storage system as shown in Fig. 1(b) the size of battery can be reduced and a higher SOC can be obtained. The super capacitor has a greater power density than the battery, which allowing the ultracapacitor to provide more power over a short period of time. Conversely, the battery has a much higher energy density than supercapacitor allowing the battery to store more energy and release it over a longer period of time. In Table II the battery and the super capacitor are compared under various headings. In the hybrid system peak power requirements of the load are supplied by the ultra capacitor and the VRLA battery supplies the lower continuous power requirements.

III. SYSTEM COMPONENTS

The following section will give an over view of the major parts of the system that will make up the proposed system.

A. Photovoltaic Solar Panels

The photovoltaic solar panels are semiconductor devices that convert the solar illumination power directly to electricity. PV cells are made of semiconductor materials. When light energy strikes the solar cell, knocked electrons loose from the atoms in the semiconductor material. When electrical conductors are connected to positive and negative sides, forming an electrical circuit, the electrons are captured in the form of an electric current that is, electricity. This electricity can then be used to power a load. PV cells are connected in series (for high voltage) and in parallel (for high current) to form a PV module for desired output.

B. Energy Storage System

The primary energy source for electric vehicle is the battery bank. A number of individual batteries connected in series or parallel. Each battery in the bank is typically of 6 or 12V, and multiple batteries are connected in series or parallel to get the desired system voltage. The overall battery voltage is chosen according to the motor's EMF constant and the desired nominal cruising speed. For the most efficient operation of the drive system, the battery voltage is selected so that the motor controller can operate with minimal PWM (i.e. reduced switching losses), at the maximum desirable speed of the car. In practice however, the battery voltage, especially for lead-acid batteries, fluctuates from full charge to maximum discharge. For this reason, the nominal voltage of battery is usually chosen so that the lowest possible battery voltage is able to sustain a reasonably competitive speed. In this proposed system, the batteries make the entire storage system. Several battery modules will be incorporated to store the solar energy produced through the photovoltaic panels.

Table I Battery Features

Technology		Specifications
1.	Model	BOSS65L
2.	Voltage	12 Volts
3.	Capacity at C/20 [Ah]	65 Ah
4.	Charging Current	4.5 Amps
5.	Weight [kg]	17.4 KG

C. Super capacitor

The super capacitor, also known as double layer capacitor or ultra-capacitor differs from a conventional capacitor , it has a very high capacitance. A capacitor stores energy by means of a static charge . Applying a voltage differential between positive and negative plates charges the capacitor. The charge time of a super capacitor is about 10 seconds. The charge characteristic of super capacitor and battery are similar and the charge current is, to a large extent, limited by the charger. The initial charge can be made very fast, and the topping charge will take extra time. Provision must be made to limit the initial inrush current when charging an empty super capacitor. The super capacitor cannot go into overcharge ,the current simply stops flowing when the capacitor is full. The super capacitor can be charged and discharged an unlimited number of times. Unlike the electrochemical battery, this has a defined cycle life.

Table II Super Capacitor Features

	Technology	Specifications
1.	Model	BMOD0430 E016
2.	Rated Voltage	16 V
3.	Capacitance	430 F
4.	Operating temperature range	-40°c to +65°c
5.	Number of cells	6
6.	Voltage across individual cell	2.7 V
7.	Mass	5.50Kg
8.	ESR,DC (mohm)	3.5mohm
9.	ESR,1KHz (mohm)	2.8mohm

$$E_{max} = \frac{\frac{1}{2}CV^2}{3600 * mass} \qquad P_{max} = \frac{\frac{V^2}{4R(1KHz)}}{mass} \qquad E_{stored} = \frac{\frac{1}{2}cv^2}{3600}$$

Where, Emax = Max. energy stored per Kg Estored = Max energy stored Pmax = max power density per Kg.

Table III Super Capacitor Parameters

Parameter	Values
Emax	2.85 Wh/Kg
E stored	15.28 Wh
Pmax	4200 W/Kg
Pd	1600 W/kg

Table IV Battery versus Super capacitor Performance

Parameters	Lead Acid battery	Super capacitor
Specific Energy Density	10-100	1-10
Specific Power Density	< 1000	< 10,000
Cycle Life	1,000	> 500,000
Charge/Discharge Efficiency	70 – 85%	85- 95 %
Fast Charge Time	1- 5 h	0.3 – 30 sec
Discharge Time	0.3 – 3 h	0.3 – 30 sec

IV. SIMULATION RESULTS

The proposed control strategy for the hybrid energy system of electric vehicles is simulated by MATLAB. The circuit diagram consists of battery, super capacitor, solar cell and DC motor as shown in fig.2.

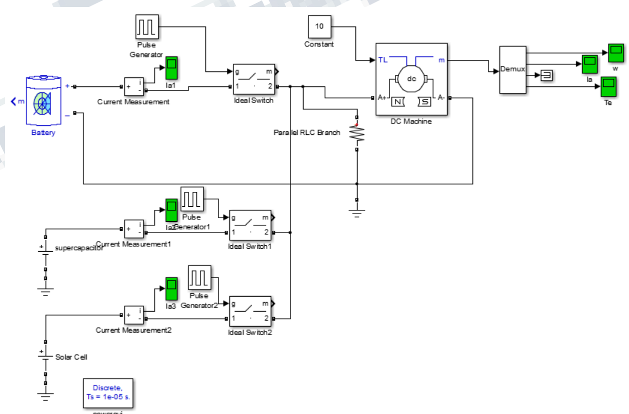

Fig. 2. Interfacing of Solar Panel , Super capacitor and battery with the motor drive in MATLAB Simulink.

When the vehicle is ascending through the slope, supply from the solar panel to motor is not sufficient to drive the motor. As a result the motor speed comes down. At that time the super capacitor supply the power to motor . Simulation results shown in figures 4,5,6 and 7 prove the advantage of using super capacitor. When the vehicle starts , super capacitor provide current to motor for 1 sec , solar panel provides current for 2sec and battery provides current for 2 sec.

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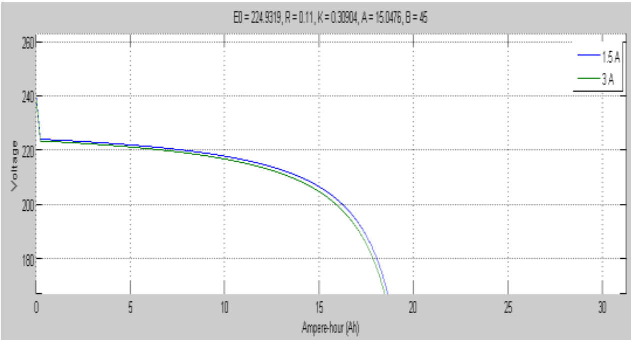


Fig. 3. Waveform for battery discharging.

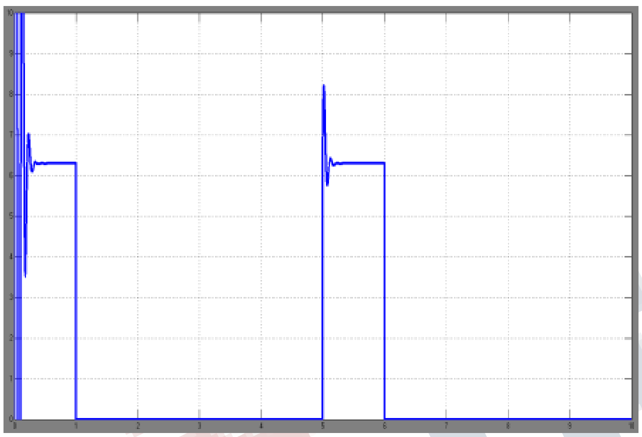


Fig. 4. Pulse for Super capacitor Current (Amp) Time (sec)

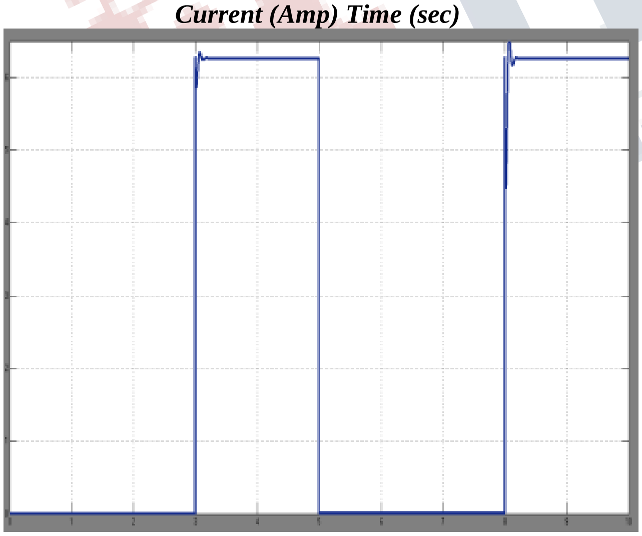


Fig. 6. Pulse for Battery Current(Amp) Time(sec)

Speed of motor is maintained by Super capacitor , solar panel and battery.

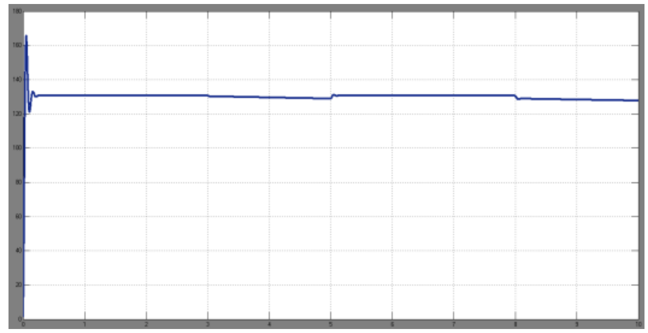


Fig. 7. Waveform of Speed of DC motor Speed Time(sec)

V. PROPOSED DESIGN

The proposed system consists of solar panel, battery, super capacitor, DC machine and switches as major components. Solar panel acts as the energy source for the system. As a backup system the possibilities of super capacitor is utilized. In this proposed system. The load DC motor of 12 V , 10 amp , 5000 RPM is driven by Super capacitor of 16 V ,430 Farad at starting , at steady state if solar panel of 12 V , 100 Watt is available ,then by solar panel otherwise by battery of 12 V , 65 Ah. A lead acid battery; the battery can be charged from the following two ways i] from DC energy from the PV solar panel ii] from energy stored in the super capacitor. Super capacitor can be charged from the PV solar panel. The super capacitor is used to discharge, supply impulse current in accelerating and climbing mode. According to the configuration of this energy system many advantages can be achieved as following. First, the battery could power the motor directly without voltage drop, which would improve the efficiency. Second, the large current discharging of battery is avoided, thus the life-span is extended. Third, the introduction of solar panel could absorb energy from sunlight, which would enhance the utilization of green energy. Fourth, the introduction of regenerative braking, and also recovering energy during braking, hence utilizes, the energy, wasted in the brakes.

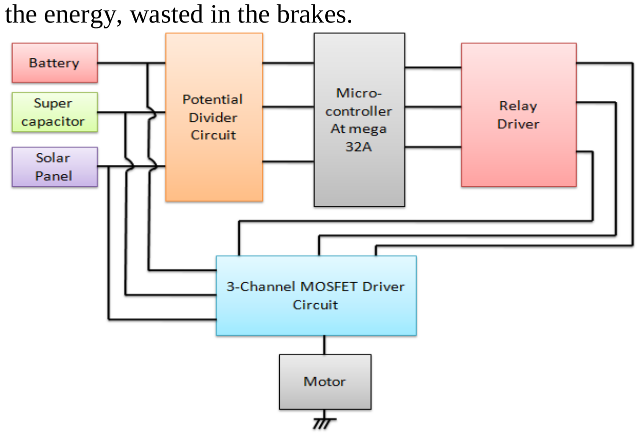


Fig. 8. Block diagram of proposed design of electric vehicle.

A. Potential Divider Circuit

Battery, Super capacitor and Solar panel are connected to the Resistance circuitry. Resistances of 150KΩ, 47KΩ and 3 KΩ are used. Time (sec)

Let, Battery Voltage = 12 V Total resistance = 200KΩ Drop across 150KΩ = 8V Drop across 50KΩ = 4V Potential Divider Circuit gives 25% of the available battery , super capacitor or solar panel voltage.

B. Microcontroller AT mega 32a

Supply Voltage to the microcontroller has been taken from mode changing circuit .Mode changing Circuit decides the mode of working i.e., vehicle mode , charging mode ,inverter mode . Microcontroller read voltages of battery , SC and SP Battery , SC, SP are set to operate at their minimum value at 12 V, 11 V and 12V respectively . 25% of battery , super capacitor and solar panel voltages are coming to input port of microcontroller where the output port gives either 0 V or 5V. Microcontroller circuitry senses various parameters and performs switching and controlling action. The controller is the heart of e-vehicle which regulates controlling actions and power through each subsystem.

C. Relay and Mosfet Driver Board

The output of relay has gone to the MOSFET board where Battery, Super capacitor, solar panel and motor are connected. According to the availability of sources , motor will be feeded by sources.

VI. SEQUENCE OF OPERATION

A. Super capacitor –Super capacitor uses for peak power requirements of the load . It will operate at starting , for 1 sec till its voltage reduces to 11 V which is set at program .

B. Solar Panel – Solar panel used for steady state requirements of the load. Solar Panel having open circuit voltage 16.23 V , it will operate till its voltage reduces to 12 V.

C. Battery – Battery used for steady state requirements of the load. Battery having open circuit voltage of 12.63 V ,it will operate till its voltage reduced to 12 V , it can drive motor for 31.5 minutes.

As battery voltage reaches to less than 12 V , battery will be out of service . Then controller will check whether solar panel is available or not , if available motor will be driven by SP , if not, as all sources are out of service .Storage elements (battery and super capacitor) requires charging . Mode will change from vehicle mode to Charging mode.

VII. EXPERIMENTAL SETUP OF THE SYSTEM AT GHRCE IN CONSULTATION WITH PROFESSIONL ENGINEER

Based upon a detailed analysis of above demerits, a proposed modified design of e-vehicle as shown in figure 5. The 120 W 12V 10 Amp DC motor, driven by a 100 W , 12 V Solar Panel , 12V 65Ah battery pack and the super capacitor bank consisting of a 16V, 430F to be connected in parallel with the battery pack which is designed to harvest the maximum energy from it. In this setup the motor is driven from battery and super capacitor .Microcontroller circuitry senses various parameters and performs switching and controlling action. The controller is the heart of e-vehicle which regulates controlling actions and power through each subsystem. A small onboard solar panel could charge the super capacitor through an auxiliary battery.

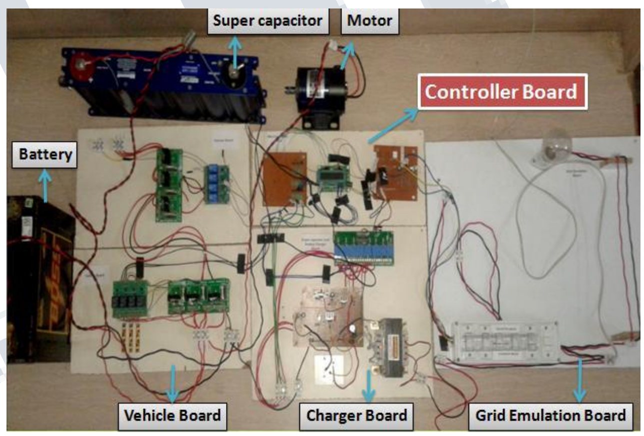


Fig. 9. Experimental setup showing interfacing Super capacitor and battery with the motor drive .

Table V Co-Working Of Battery And Super Capacitor To Drive Motor

Mode of operation	**Current through Super capacitor**	**Current through Battery**
At Starting	5.1 Amp	0 Amp
Switching from Super capacitor to battery	0.2 Amp	4.5 Amp
At Steady State	0 Amp	4.5 Amp

VIII. COMPARISON OF DIFFERENT MODES

The table below gives the comparison of various modes.

Table VI Comparison of Different Modes

SR.NO	MODES OF OPERATION	COMMENT
1	When the vehicle is running through a plane	Solar panels deliver the supply to motor load and super capacitor.
2	when the vehicle is ascending through the slope	Supply from the solar panel to motor is no sufficient to drive the motor. As a result the motor speed comes down. At that time the super capacitor supply the power to motor.
3	when the vehicle is descending through the slope	Back EMF is greater than the supply voltage (Eb>V) then DC machine act as a DC generator and store the power in battery.

IX. CONCLUSION

At current levels of technology, installing a super capacitor provides a feasible method to improve the performances of the vehicles. The results of the proposed systems show that the performance of the vehicle was improved in the following aspects.

A. Provide better working conditions for the battery and increase its operating life.
B. The battery could power the motor directly without voltage drop, which would improve the efficiency.
C. The large current discharging of battery is avoided, thus the life-span is extended.
D. The introduction of solar panel could absorb energy from sunlight, which would enhance the utilization of green(Solar) energy.
E. The introduction of regenerative braking, and also recovering energy during braking action , hence utilizes, the energy, wasted in the brakes.
F. Since the super capacitors have the ability to provide a large current in short time acceleration, performance of the vehicle will improve.
G. The solar panel will also help extending the range of the vehicle. So even if the vehicle is parked somewhere where there is no charging facility, a sheer standing vehicle is getting charged up for the solar panel.
H. 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.

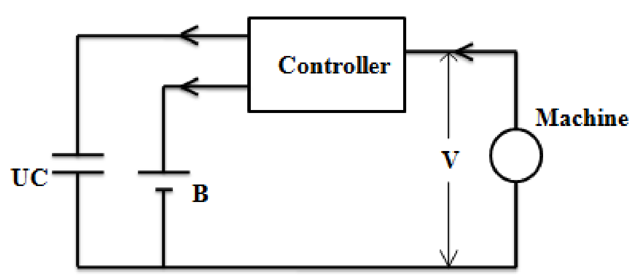
X. SCOPE OF FURTHER WORK

A. Intelligent Charger for Electric Vehicle

V2G is a version of battery-to-grid power applied to vehicles. Battery-powered or hybrid vehicle which uses its excess rechargeable battery capacity to provide power to the electric grid in response to peak load demands. A solar vehicle which uses its excess charging capacity to provide power to the electric grid when the battery is fully charged. Intelligent charger for vehicle-to-grid power can be done .The scheme will includes bidirectional energy meter.

B. Regenerative Braking for Electric Vehicle

A regenerative brake is an energy recovery mechanism which slows a vehicle converts its energy into a form which can be either used immediately or stored until needed. In addition to improving the overall efficiency of the vehicle. The battery and super capacitor will get charged from the machines power.



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