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Renewable Energy with Hybrid Storage based Electric Vehicle Charging Station

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***Abstract*— A hybrid energy system is presented in this article for a solar-powered electric vehicle charging station. A hybrid energy storage system consists of a battery and a super capacitor. If the solar power varies, a sudden shift in supply from the storage system is required; also, power fluctuation is noted when supply is gained from the storage system. A solitary battery cannot compensate for this sudden change in supply. To overcome these concerns, a hybrid energy storage system comprised of a super capacitor and a battery is proposed for solar-powered electric vehicle charging stations. The hybrid energy system also compensates for power fluctuations. The results are obtained using MATLAB SIMULINKS.**

***Keywords*—Solar PV system. Battery. Super capacitor (SC).Electric Vehicle Charging Station. Electric Vehicle. Power Management System..**

I. Introduction

The electrical power demand is increasing compared to the generation of energy because of new loads like electric vehicle (EV) charging station over recent year [1]. Limited number of non-renewable sources and it also possess adverse impact to the environment which enhance renewable-energy base sources in accessible power network. Renewable energy is a clean form of energy which is eco-friendly and sustainable to environment example solar, hydro, wind among this all-sources solar energy has maximum potential, but it has some limitation that it varies according to time of day and the season of the year as well as geographical location. Large capacity photovoltaic (PV) array system can run a constant power generating electric vehicle charging station [2], the bulk of the non-conventional fount are non-uniform in nature and hence power variation in the charging station. It has two ways to manage the power fluctuation either by the support of grid or with the help of hybrid energy storage system (HESS), support from the grid will ultimately enhance the pollution [3][4].

To manage the variation in the flow of power, HESS is proposed in this work. HESS manage the PV side dynamic variation by rotting the lack power balancing into slow and fast varying dynamics. Slow varying dynamics are going to remunerated by the storage battery and fast varying dynamics are remunerated by supercapacitor storage system.

Many literatures suggest power management strategy (PMS) technique to regulate the power between solar and battery and other storage system like fuel cell and fly wheel.

To direct the power flow between the solar energy and the storage battery & supercapacitor a novel energy management system is proposed in this article. The Fig.1. shows the basic topology of EV charging station. The contribution of the paper is

- Solar along with battery and supercapacitor based a DC charging station is proposed.
- Power flow manages efficiently between solar, battery, supercapacitor and EV load.

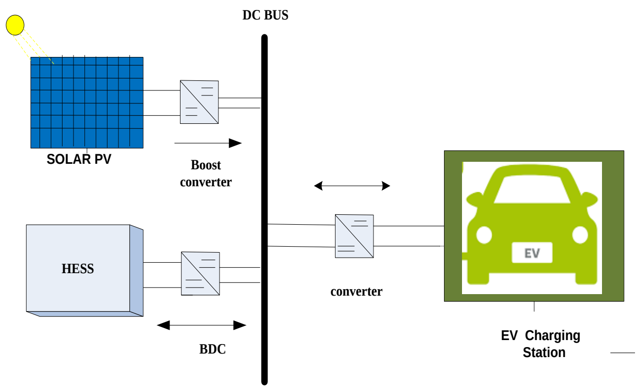

Fig. 1: Basic topology of EV charging station

II. System Configuration

The taken system comprises of PV arrays and a HESS. HESS is a combination of storage battery (SB) and Supercapacitor (SC) energy storage. All the component are connected to a common EV charging station as shown in Fig.1.

A. PV modelling

A photovoltaic system typically includes an array of photovoltaic modules Fig.2. depicts the PV array equivalent circuit model. PV current is expressed by equation (1).

$$Ipv = (y/yref)\ Isref + aisc(Ta - Tref) - Io[exp(vd/vt) - 1] - (Vpv + Rstpv)/Rp \quad (1)$$

Where, γ indicate irradiance measure in $w/m2$, T_a shows temp in SI unit, α_{ISC} coefficient of short circuit current and I_{SREF}, T_{SREF} and γref are rated valu, I_S source current in amp, Ip is current through Rp resistance in amp, I_D is diode current in amps, V_{PV} is PV array voltage in volt, V_D is voltage across diode in volt.

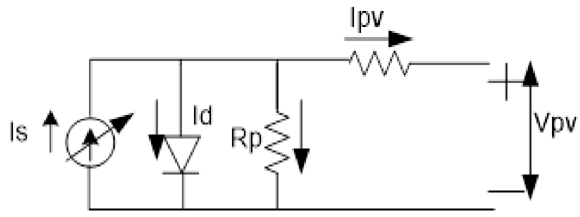

Fig. 2 PV array equivalent circuit

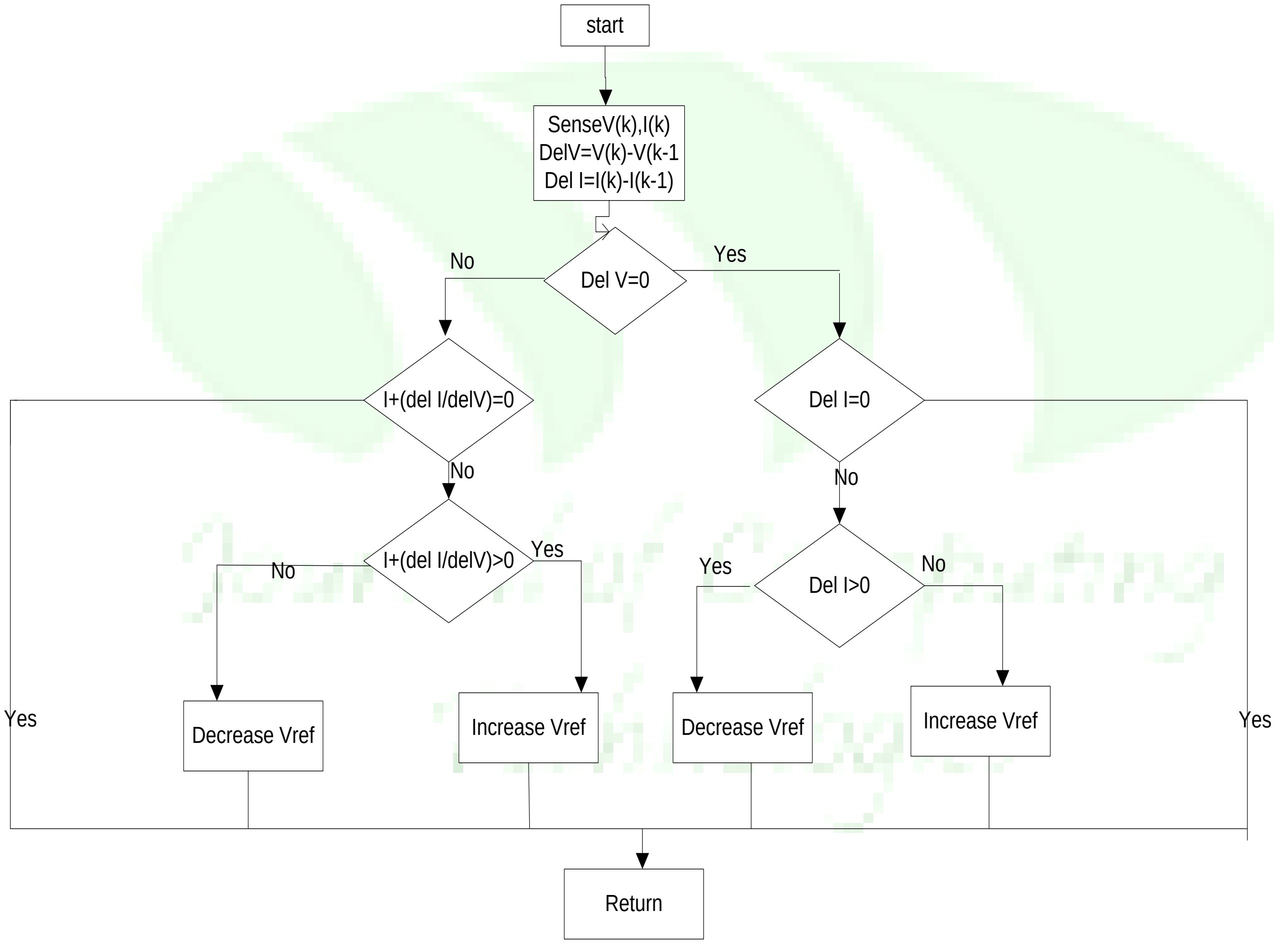

Fig.3. Incremental Conductance MPPT algorithm Flow Chart

Due to the irradiance in PV array, there is variation in the generated power and maximum power point tracking (MPPT). To trace the MPPT, incremental conductance (INC) MPPT method as shown in Fig.3. is performed with an adjustable variable step size. This algorithm itself change the step size to observe the maximum power point (MPP) with step size adaptation coefficient, and a user predefine fix value is not important for the junction of this MPPT method, thus clarify the design of the PV system.[9]

B. Storage battery

A battery is an origin of electric power made up of one or more electrochemical cells. Its equivalent circuit is shown in Fig.4. SB unit are attuned to diminish the output of solar slow power fluctuation. The state of charge (SOC) of the battery is resolved using the method of current integration, where $Q(t_0)$ is the initial charge to the battery at time $t_{o,}$ α is the discharge/charge efficiency and I is the current

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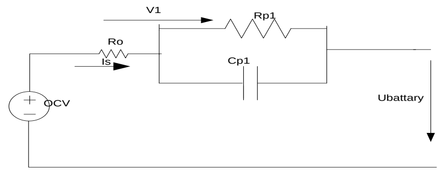

Fig.4. Storage battery equivalent circuit

$$U_{battery} = Vocv - V1 \tag{2}$$

Where, $U_{battery}$ is terminal voltage of SB, Vocv is open circuit voltage and V1 is the voltage drop in the battery

$$SOC(t) = \frac{Q(to) + \int_{to}^{t} a.i.dt}{Rated\ Capacity} * 100 \tag{3}$$

C. **Super Capacitor**

The main purpose of SC adding in proposed system is to support the SB. it compensates the fast power variation of solar PV system. The role of SC is short term power supply and energy buffer unit, which improves the EV charging station profile. The SOC of the SC bank is defined by the ratio of the total energy (Qc) to the rated energy (Qo) is determined by using equation [3].

$$SOC = \frac{Qc}{Qo} = \frac{\frac{CVVc^2}{2}}{\frac{CV\,max^2}{2}} \tag{4}$$

Where, C is the equivalent capacitor of the SC bank. V_C is voltage and V_{MAX} is the maximum value of SC bank voltage at full charge. The following parameters specifications are given below in Table. 1.

Table.1. Parameters Specifications

Parameters	**Values**
Solar Panel	
Maximum power(W)	250.205
Open circuit voltage V_{OC}(V)	37.3
Short circuit current I_{SC}(A)	8.66
V_{MPP}(V)	30.7
I_{MPP}(A)	8.15
Battery	
Nominal voltage(V)	240
Rated capacity (Ah)	48
Super Capacitor	
Rated capacitor(F)	100
Rated Voltage (V)	300
Rated Voltage (V)	300

III. POWER MANAGEMENT STRATEGY

Fig.5 shows the control block diagram of the proposed power management strategy (PMS). In this system AEMS design, is used maximize the use of power the PV system which is connected to the EV load with a DC-DC boost converter and the HESS is connected via a two-sided converter to manage the discharging/charging. SB system along with SC unit is connected by a two-sided converter to manage the process of charging/discharging. Due to variation in solar irradiance, solar output power fluctuates. Therefore, to synchronize the swinging in the flow of power, HESS is used in this work meet up the EV loads demand. Slow variation in the power is meetup with the SB and fast changing dynamics are meetup by the SC storage system.

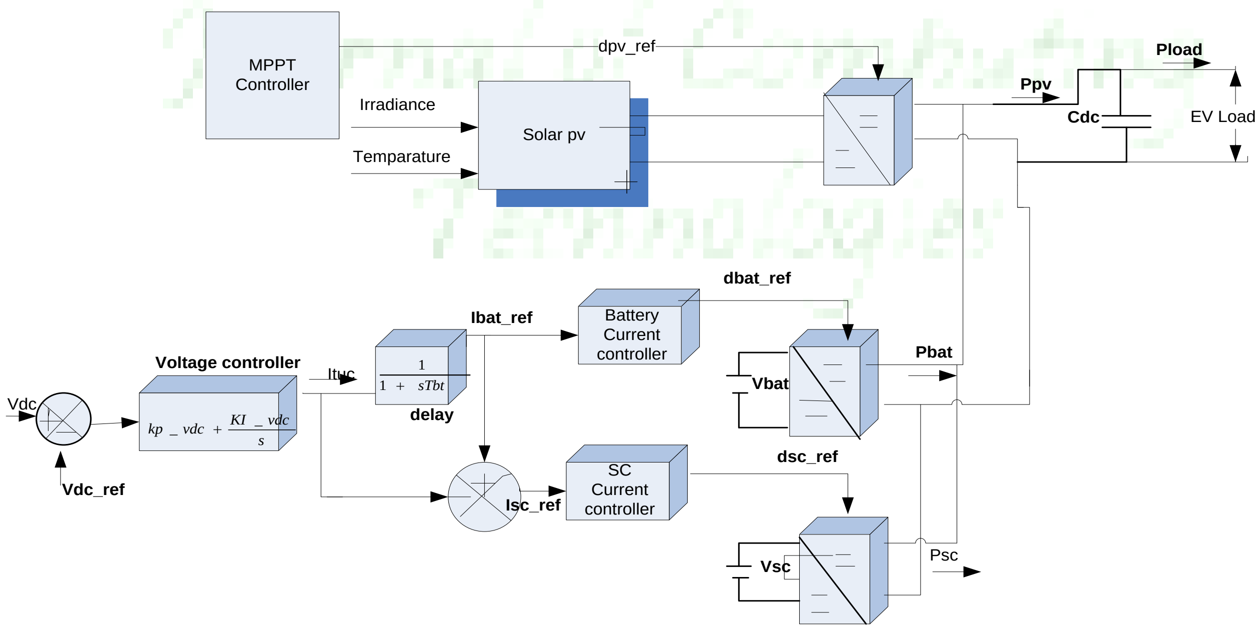

Fig.5. Control block diagram of proposed PMS

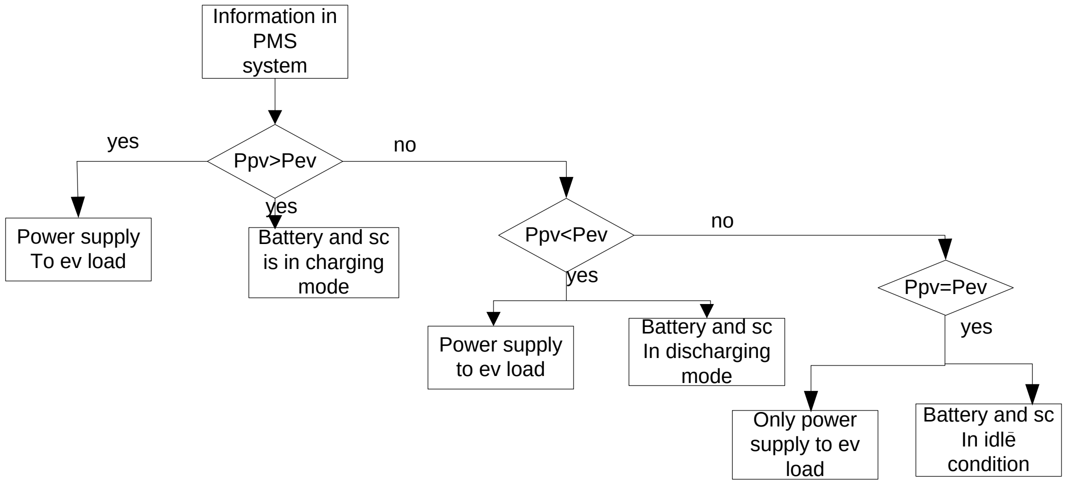

Fig.6: Flow chart of PMS

The PMS works based on the following equation (5), (6) and (7).

$$Ppv \pm Phss = Pev \tag{5}$$

$$Phss = Pbat + Psc \tag{6}$$

$$Phss = Ppv - Pev \tag{7}$$

Where, Ppv are the power supplies by solar panel, $Pbat$ is power supplies by storage battery,Psc is power supplied by SC. Positive sign indicates battery and supercapacitor in discharging mode and negative sign shows the both SB and SC in charging mode. Here, power is provided by PV array to the EV load. MPPT controller is used to optimize the power. But due to variation in irradiance in solar system, the power is decreasing. To compensate EV demand, HESS is controlled by voltage controller and delay is used for SB due to the time response in it. Current I_{BAT} is the current from SB. Slow changing dynamics are remunerated by SB and fast changing dynamics are remunerated by SC. I_{SC} current through SC. Flow chart of PMS is shown in Fig.6. Whenever the solar power becomes greater than the load demand, only Solar PV system supply to EV charging station and also supply to battery and SC for charging. Whenever the solar power is less than the load demand, Solar PV system and HSS supply to EV charging station. When HSS is supplying the power then both SB and SC are in discharging mode. In case, the solar power and load demand are equal than only Solar PV system supply power to EV charging station. Both SB and SC are in idle condition.

IV. Result and Discussion

In this proposed EV charging station, PV system and HESS is used for an EV load. PV power varies due to irradiance according to Fig.7. in every one sec, initially solar PV panel have 2000W, at t= 1sec solar power decrease to 1500W, and so on. From t=4 sec to t=5 sec solar PV has minimum power of 150W. In this Fig.10. proposed system that is constant DC EV load of 1000W continuously takes power from solar PV system up to t=2 sec and after this EV load power is taken from solar PV and HESS in time duration of t=2 sec to t=5sec. To compensate the solar power variation and meetup the charging station demand a battery and supercapacitor is used in the system. after t=3sec solar power continuously decrease and solar power less than load demand. To fulfil the load demand both battery and supercapacitor is used. SC support instantly at t=3sec and t=4sec as shown in Fig.9.Battery has a delay time because of battery time constant. Battery compensates solar power fluctuation for long duration as shown below in Fig.9. Fig.10. clearly shows the characteristic of SB with and without SC. It helps to improve the lifespan of the SB**.**

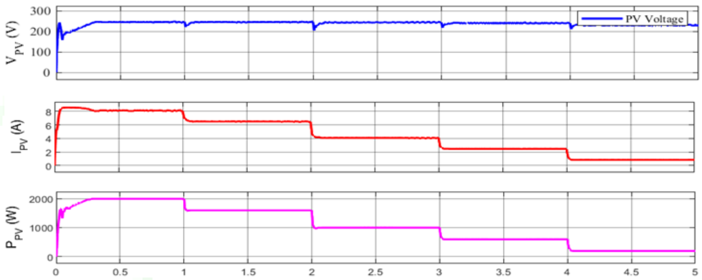

Fig.7. PV result (a)PV voltage, (b)PV current, (c) PV power

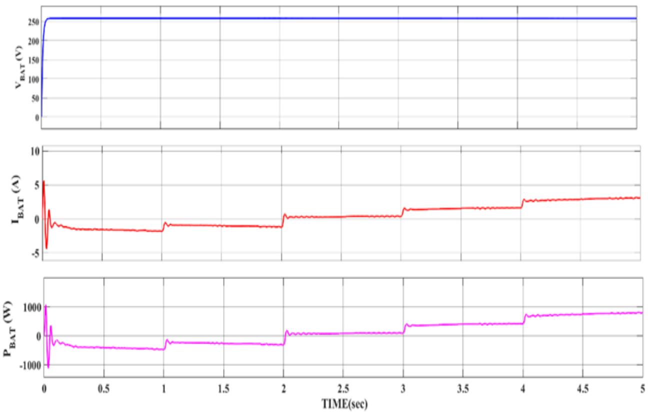

Fig.8 Battery waveform (a) Voltage waveform of battery, (b) Current waveform of battery, (c) Power waveform of battery

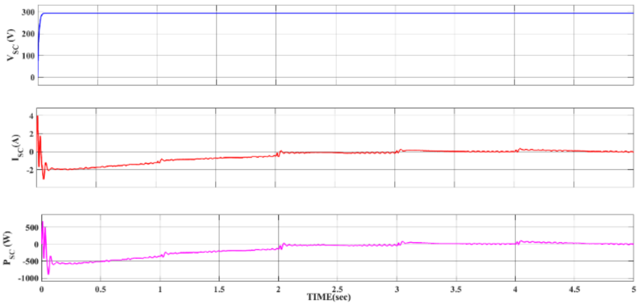

Fig.9. Super Capacitor (SC) waveform, (a) SC voltage, (b) SC current, (c) SC power

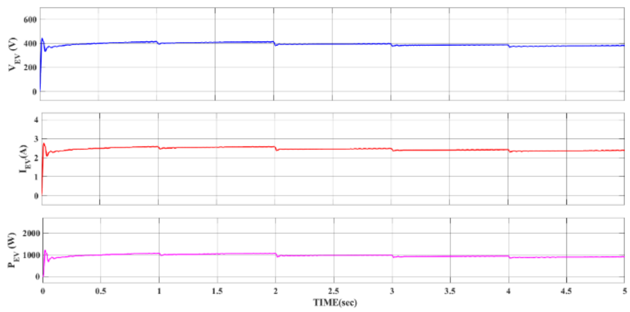

Fig.10. Charging station (a)voltage (b) current (c) power waveform

V. CONCLUSION

The suggested PMS manages the power fluctuation efficiency of solar PV systems. SC compensates for very short-term power oscillations, while storage batteries compensate for long-term power variations and help to meet EV load requirements. The simulation results confirmed the proposed system as well. The proposed work could be expanded by integrating the grid with the solar system.

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