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Development of Battery Monitoring System and Estimating SOC of Li-ion Battery for Off-Grid Application

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Abstract – *Renewable energy sources (RES) can be regarded as the key input for development because of its' unique properties such as cleanliness, noiselessness, eco-friendly nature, etc. Due to the intermittent nature of renewable energy especially solar photovoltaic storage technology such as batteries need to be deployed. This paper presents a battery monitoring system to estimate the accurate state of charge of the battery used for a solar-powered off-grid system. In addition to this, there is also described battery management system for Li-ion batteries to optimize the battery performance. The balance of system is described however further improvements are needed as power output from the solar module is non-uniform.*

Key Words: Li-ion Battery, Battery monitoring, BMS (Battery Management System), SOC estimation, off-grid system.

1. INTRODUCTION

Nowadays the renewable energy is too much important in the whole world. Solar energy can be considered as a clean and green resource of energy [1]. The irradiances, we got from the sun is non-uniform in nature, that's why storage device like battery is needed to be deployed. The Battery monitoring system inspects the health of the individual cell and helps us to estimate the state of charge of the battery and inform the end-user about the present condition of the battery bank. There are some parameters for monitoring a rechargeable battery. The parameters are each cell voltage, temperature, charging/discharging current, and load current. State of Charge (SOC) measures the total amount of charge stored in a battery at a specific time. SOC provides information about how much time it can use before recharging. For Li-ion battery its' challenging to find the SOC via OCV method as SOC in Li-ion Battery is a non-linear function of open-circuit voltage [2][3]. So, in this paper coulomb counting method is used for having high accuracy over the OCV method.

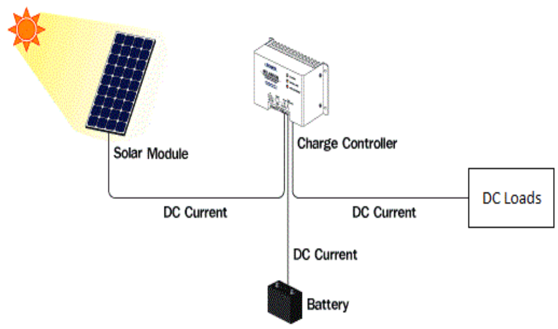

Fig -1: Basic PV off-grid system

Fig-1 represents the basic building blocks of a stand-alone PV system for DC-DC transmission

1.1 Battery monitoring and parameters

It is a feature that monitors the voltage and current of the battery and indicates to the end-user if the battery is low in the form of percentage or duration. It also needs to include charging, safety monitor, temperature measurement features at battery monitoring. The parameters for health monitoring of a rechargeable battery are: each cell voltage, temperature, battery charging/discharging current, and load current. The importance of health monitoring of battery is improved battery life and bank performance, supplying continuous power without interrupt, reduce battery maintenance cost.

1.2 Battery Management System

A Battery management system is an embedded system that monitors battery voltage, load current, state of charge (SOC), state of health (SOH) [8], temperature, and the other parameters of the battery [5]. BMS also controls the charging and discharging of the battery. The tasks of BMS are given here: It can detect the unsafe operation condition of battery, protect the cells of the battery from damage and enhance the life of a battery.

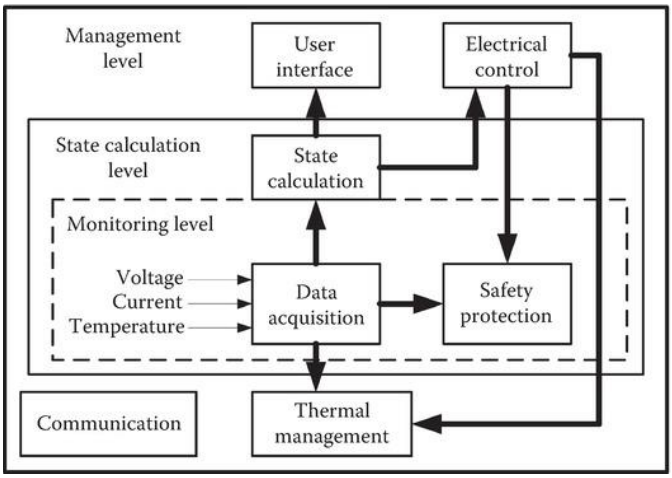

Fig -2: General diagram of BMS

2. STATE OF CHARGE (SOC) ESTIMATION

State of charge of a battery plays a key role in charging a battery efficiently. It accounts the total amount of charge contained in a battery at any particular time or instance.

There are several SOC estimation techniques like Open Circuit Voltage (OCV) method, Coulomb Counting, Least Mean Square (LMS), etc. As we know open circuit voltage is directly proportional to its SOC in a Lead-acid battery. But for Li-ion battery, SOC is a non-linear function of OCV. Due to high accuracy coulomb counting method is applied while calculating the State of Charge of the Li-ion battery.

The mathematical form of the CC method can be expressed as:

$$SOC(t) = SOC(t_o) - \frac{1}{Q}\int_{to}^{t}(\eta . i_{bat}(t) - S_d)dt$$

where $SOC(t_o)$ and $SOC(t)$ are the SOCs at initial time and sampling time t respectively; η is the Columbic efficiency; $i_{bat}(t)$ is the instantaneous charging or discharging current (+ve for discharging and -ve for charging); S_d is the self-discharge rate, and Q is the nominal capacity. The implementation of this method is quite simple with very low computational complexity. The initial unknown SOC is the main concern in the CC. Moreover, the sensor error also has a negative effect on the accuracy of the SOC estimation. Therefore, this method works more efficiently, where the SOC needs to be estimated for the short period and the initial SOC is known.

3. CIRCUIT DIAGRAM AND MATLAB SIMULATION

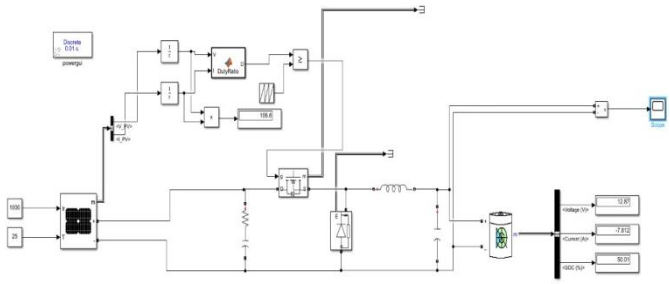

Fig -3: Simulation program implemented in MATLAB

The simulation was made for 1.3 KWh average energy consumption per day. In general, the standalone PV system voltage is 12, 24, 48 or 96 VDC as per the requirements of the system [4]. The operating voltage may be kept higher to minimize voltage drop in the cable when the battery bank is located far away from the PV array. Therefore, the system voltage should be chosen as per the load demand. As per the case study general condition is recommended according to the Table-1.

Table -1: Recommended SV as per Energy Demand

	Energy Demand	SV (V)
Case 1	$E_{required\_daily}$<1kWh	12
Case 2	1kWh<=$E_{required\_daily}$<=4kWh	24
Case 3	4kWh<$E_{required\_daily}$<=8kWh	48
Case 4	$E_{required\_daily}$>8kWh	96

It is important while calculating the load current with suitable SV, the maximum current being drawn from the battery should not be greater than 120A [4][6].

$$I_{total\_load} = \frac{1}{SV} \times [\sum DCpower + \sum ACpower]$$

The battery bank capacity required, is calculated based on the load demand where battery acts as a source and also based on critical load of the entire system. Here 0.5KWh energy consumption on daily basis is required to be supplied by the battery bank [9]. It is calculated that battery capacity of 42Ah should be needed as per system requirements. The total capacity required daily is determined by dividing the energy required daily with respect to standard system voltage.

$C_{required\_daily} = E_{required\_daily}/SV$

.Fig 3.1: Simulation of Battery Charging Circuit

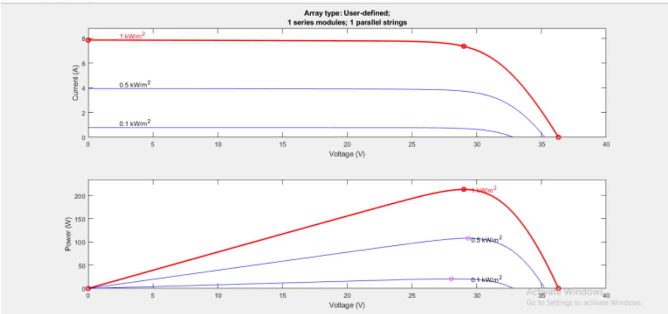

Fig 3.2: Output Characteristics of PV Array

Fig 3.2 shows an output characteristic of the PV array where at 1000 W/m² and 25⁰ C temperature PV array is producing 218 Watt. Voltage at maximum generation PV array is drawing a 7.84 short circuit current.

4. CONCLUSIONS

Simulink provides an environment for battery charge analysis on Li-ion Battery. Based on battery charging parameters output data is analyzed it is shown that for calculating the state of charge for lithium-ion battery using coulomb counting method the initial state of charge is required. Therefore this method is very efficient for a short period of SOC estimation. For longer time period, error gradually builds up and CC method becomes inefficient. In this paper standard irradiance and temperature is taken for this simulation, dynamic solar irradiance and temperature are not considered. The crucial parameters of PV array, as well as battery such as voltage, current, state of charge, state of health is monitor and control throughout the simulation. In future this circuit will be connected to a DC micro-grid and load to source profile will be analyzed.

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