HYBRID ENERGY STORAGE SOLUTION FOR STANDALONE PHOTOVOLTAIC SYSTEMS

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INTRODUCTION

Standalone PV (Photovoltaic) systems require an energy storage buffer to provide continuous power when solar irradiation is insufficient. The solar radiation goes below the required level during partial shading conditions and rainy or overcast conditions. In the above cases, more power must be supplied from the energy storage to the load. Usually the storage consists of batteries. Fluctuation in weather conditions causes batteries to discharge quite often. This may decrease the operational life of the batteries (Glavin, et. Al, 2008) (Yu Zhang, 2008). Also, when the load draws a burst of current such as in the case of motor startup, batteries may degrade more than during a normal run. an alternative way of supplying large bursts of current is to combine batteries and supercapacitors to form a hybrid storage system, where the battery can supply continuous power and the supercapacitor can provide instant power to the load.

The existing system using a bypass diode to protect partially shaded photovoltaic cells array inside solar panel from the normally operated photovoltaic array in the peak sunshine in the same PV panel. In multi-panel PV strings, the faulty panel or string has been bypassed by the diode which provides an alternative path to the flowing current from solar panels to the load (Electrical Technology, 2019) (Silvestre, 2007) (Aljafari, 2016). As a result, the PV system cannot respond to electrical loads as quickly as desired.

To overcome the power balancing problem, the battery combined supercapacitor HESS (Hybrid energy storage system) was proposed and thereby the battery can provide continuous power and the supercapacitor can provide instant power to the load as required (Kashif Javed, et. al, 2019). Thus, this was an effort to develop a prototype hybrid system to deliver more reliability. The HESS monitors and optimizes the flow of energy from the PV to the battery - supercapacitor considering the peak current load, the pulse current load, and the constant current load. Besides, the charge controller was designed and implemented to fulfill the above objective.

METHODOLOGY

Methodology of this research is as follows;

- Possible solar intermittencies were analysed.
- The availability of supercapacitors, methods of improving the different types of solar storage systems were observed.
- The required capacity of the battery and supercapacitor was calculated.
- An algorithm to integrate battery and supercapacitor power was developed and implemented in a MATLAB Simulink model.

The storage sizing has been calculated based on the function developed in research (Gunarathna. al, 2018). This function was developed considering the real-time solar irradiation data obtained from the Department of Meteorology, Sri Lanka. It was presented as a solution to maintain the stability of a power system by adding storage to a PV generating station.

Storage capacity (Z) = $\{[(I_{mpp} \times V_{mpp}) \times N_p \times \eta_{I(u)}] \times (2 - \eta_{I(s)}) \times (2 - \eta_s)\} \times H$

V_{mpp}	-	Voltage at P_{max} (V)	$\eta_{I(u)}$	-	Efficiency of the inverter near the PV panel
I_{mpp}	-	Current at P_{max} (A)	$\eta_{I(s)}$	-	Efficiency of the inverter near the storage
P_{max}	-	Maximum power (W)	η_s	-	Efficiency of storage
N_p	-	Number of panels	H	-	The inertia constant

Design of the prototype

Considering the power requirements and the properties of the storage devices a prototype simulation was designed. The main component configuration of the system is shown in figure 01.

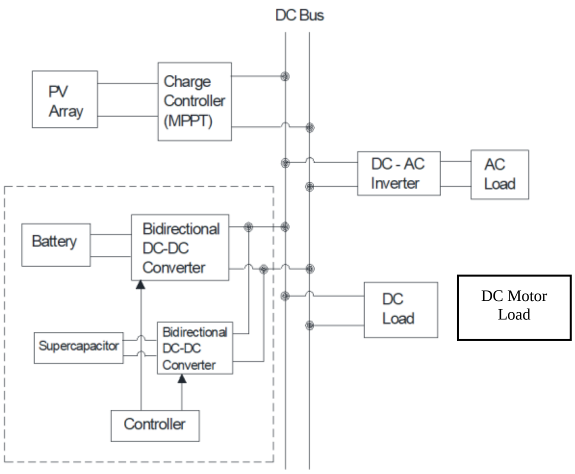

Figure 01 – Block Diagram of the proposed system

The prototype illustrates the configuration of both storage systems, the supercapacitor, and the battery. The DC motor is operated as the load and its power changes were observed using its RPM. Therefore, it simulates the instantaneous power demand thus the motor RPM dropping rate clearly gives an idea of the importance of HESS. Also switching from the supercapacitor to the battery depends on the capacities of them.

In this model, the controller consists of two feedback units to control the maximum power point tracking and the charge/discharge power flow controlling. The controller generates PWM signals.

1. Maximum Power Point Tracker (MPPT) controller for PV array

The MPPT controller supplies the DC-DC converter with the required PWM signal using the MPPT algorithm and takes the PV voltage as input. It implements the MPPT algorithm to increase the operating efficiency of the PV system and thus helps to extract the maximum available power. This controller controls the voltage of the PV array (Vishwakarma, July 2017). The inputs and outputs of the controller are as follows.

Input 1: DC voltage of the system. (V_DC).

Input 2: Battery State-of-charge (SoC). This is to check whether the SoC is greater than 98%.

Output: 5 kHz PWM signal by considering voltage and current generated from the PV array.

The block diagram of the simulation model of the controller is shown in figure 02.

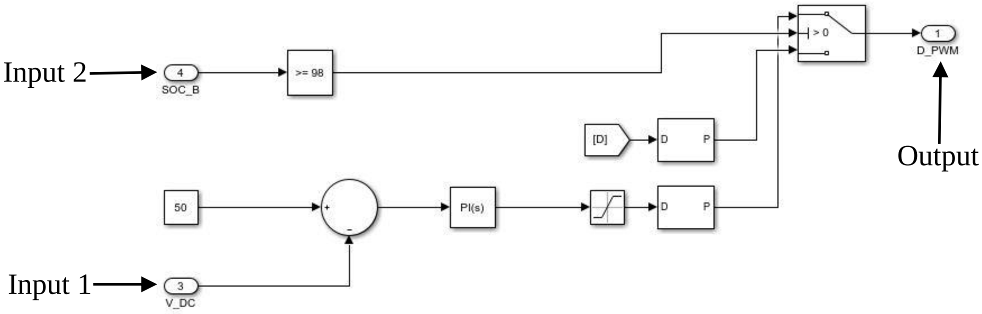

Figure 02 – Simulation block diagram of the MPPT controller

2. Charge/Discharge controller for battery and supercapacitor

This unit controls the energy balance between the battery and the supercapacitors. It generates four 16 kHz PWM signals to charge and discharge the supercapacitor and the battery separately. These parameters are passed to the bidirectional DC / DC converter to control the energy flow.

RESULTS AND DISCUSSION

Power was generated from PV array for different solar irradiation was delivered to a constant load supported by supercapacitor and battery hybrid system. According to provided data as showed in Figure 03, solar irradiation changed from 960W/m^2 to 500W/m^2, 960 W/m^2, 200 W/m^2 and back to 960 W/m^2 in 2 minutes and reference voltage was 50V. The power-sharing between Supercapacitor and Battery is shown in Figure 04.

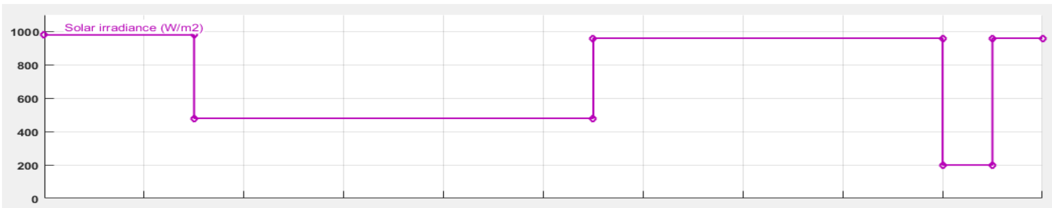

Figure 03 - Solar irradiance variation

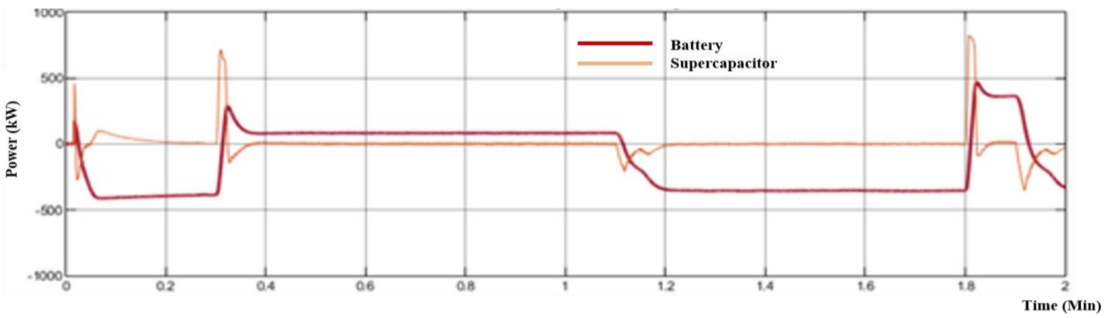

Figure 04 – Power sharing between supercapacitor and battery

As shown in the results when the irradiation drops from 960 W/m^2 to 500 W/m^2, the supercapacitor injects more power than the battery and drops down as the battery takes-up the load. When the solar irradiation goes up to 960 W/m^2, the battery gets charged. During the irradiation drop from 960 W/m^2 to 200 W/m^2 the supercapacitor injects more power and the battery is loaded slowly. In each irradiation drops, the battery power injection is smoothly increased without the burst current.

When the system consists of only a lead-acid battery the motor RPM was dropped considerably when solar irradiation drops. With the inclusion of hybrid storage system, the motor RPM variation was insignificant.

CONCLUSIONS/RECOMMENDATIONS

Based on results, it can be stated that the proposed stand-alone PV array with battery-supercapacitor shared storage system is well suited as an industrial sector application. Also, the HESS can withstand solar intermittency problems caused by partial shading. Because the irregular irradiation patterns disrupt the conventional methods for planning the daily operation of the power management. Their power fluctuates over multiple time horizons, forcing the Power operator to adjust its day-ahead, hour-ahead, and real-time operating procedures.

Further Works

This method also has optimum energy capacity, In the present problem of this HES System is supercapacitor price was very higher than LAB, but in future it will be solved by decreasing the price and increasing the capacity of Supercapacitors. This HESS can be used in Electric Vehicle motor starting and it will enhance Battery lifetime. Also, this system can be developed for change over switches for uninterrupted power sources to transfer without any sense of interchanging, as it can be applied in smart grids where wind power is integrated.

As improvements, this system can be developed to cater to more than two energy sources and modify the algorithm to select the optimized power delivery. This can be done by introducing relevant constraints to the algorithm.

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