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Rechargeable Battery with DC-DC Boost Converter Powered by Solar based on P&O MPPT

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Abstract: This paper focuses on the use of solar energy as a power source in a battery charging system. It becomes very difficult for us to find a source of power to charge the battery after running out of energy especially being outside. As a result, charging the battery with a solar-powered battery charger would be more practical. The system evaluates the control performance for the battery chargers in terms of voltage, current, and power output from solar power. A 24V 12W solar panel is used to power a battery that has a 15Ah 24V charging output. This project method uses the MPPT boost device charge controller. However, this project uses perturb and observe method to restore battery energy capacity to maximum capacity after recharging. Because it is used to charge a 24V, 15 Ah lead acid battery, it is designed for an input voltage of 24V and an output voltage of 26.4V. Based on the results of the battery charging system simulation, the output voltage of the DC-DC boost converter can be kept at around 26.4V. The charging time needed by a battery to be fully charging condition is 18000 seconds or 5 hours. For future work, the system can be achieved by performing MPPT using the Simulink model instead of putting code in the Embedded MATLAB function or solar radiation and temperature can be supplied as variable inputs in the Simulink model instead of constant values due to environmental changes.

Keywords: Battery Charger, Solar Power, P&O MPPT, Boost Converter

1. Introduction

The voltage and power characteristics of a star PV system are influenced by irradiation and temperature because of PV panels are costly, and most electrical outlet following (MPPT) is needed to trace most output power. A DC-to-DC device connects the PV panel and the battery [1]-[2]. As the solar irradiance increases, so do the voltage, current, and power of the PV module. Inversely, as the temperature rises, they fall. In this case, it is not appropriate to use it directly to charge a battery. A DC-DC boost converter is appropriate for installation between the PV module and the battery [3]. A boost converter is a dc-to-dc converter that is used to increase the magnitude of dc voltage. It is widely used in dc drives, dc power supplies, rectifier input power factor correction, and solar systems. One of the

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most common uses for this converter is to charge a battery with a higher voltage than the available voltage source. A lot of research has recently been done on boost converters to make them useful in solar systems, where battery charging is clearly noticeable [4]-[5]. Furthermore, battery charging in automobiles is accomplished through thermoelectric generation, which includes a boost converter. Regardless of the sources used, the converter requires a proper inductor to significantly increase the voltage [6]-[7].

The use of a DC-DC boost device in boosting up PV output voltage is important for charging up a 24-volts battery. Because the output from PV isn't constant because of the ambient temperature and environmental conditions, the modeling of such a device is crucial to confirm the regular charging of the battery. MPPT systems area units are used in the main systems wherever the supply of power is nonlinear like the solar PV modules. During this work, MPPT integrated boost device system is employed in solar PV applications with the battery charger connected to the complete PV system. The aim of charging the lead-acid battery is nothing except for the storage of power. This energy if it comes from the solar PV systems then fast charging of the battery has often finished with the assistance of the MPPT-boost device charge controller.

The main objectives of this simulation study of the simulation of solar battery charging system using MPPT and boost converter are to develop the rechargeable battery with dc-dc boost converter powered by solar based on P&O MPPT in MATLAB Simulink and evaluate the control performance for charging a battery in terms of voltage, current, and power from solar power.

2. Material and Methods

In this section, an explanation of the proposed solar battery charging system will be presented. Research from the previous relevant projects is helpful to prevent necessary mistakes and advance their project. The first subsection presents the design parameters used in the simulation. Then, is followed by the MPPT algorithm method and modeling circuit.

2.1 Materials

The first approach to improving photovoltaic solar panel performance is to employ a maximum power point tracker in quickly changing climatic circumstances and a DC-DC converter to optimize output power. When the solar panels are partially shaded, this system may function at the maximum power point MPP and provides the most electricity under diverse irradiance circumstances. With an output power of 20.06 watts, the design required just 20W, 17V solar size, which is adequate solar sizing to support the system's electrical supply. The battery charging system design, it was completed with the PWM modulator circuit to control the charging operation automatically. The charging time required by the battery to reach a fully charged state is 18000 seconds or 5 hours. This charging system uses the constant voltage method, which means that if the battery state of charge is less than 80%, the charging voltage will remain constant to avoid overcharging.

2.2 MPPT Algorithm Method

In this work, the P&O MPPT method is used and shown in Figure 1. The system starts by measuring the PV output voltage, V(k) and current, I(k) and calculating the value of power that is the product of voltage and current. After that, we measured the difference between old power and new power, and the difference between old voltage and new voltage. If the difference between initial power and previous power is equal to 0, it will return because it is already at the maximum power point. If the power difference is greater than 0, it checks if the difference in voltage is less than or greater than 0 and decides whether we want to increase or decrease the voltage. If the voltage increase, the battery is charging.

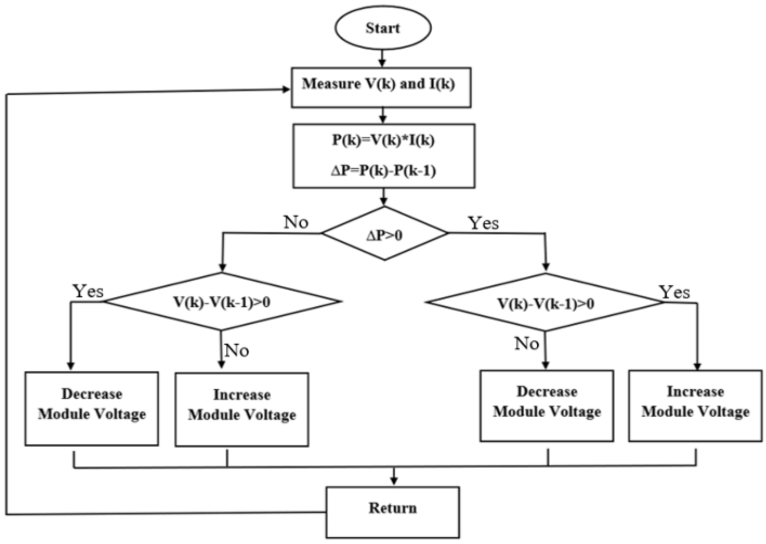

Figure 1: Flowchart of P&O MPPT Method

2.3 Flowchart of Rechargeable Battery with DC-DC Boost Converter Powered by Solar based on P&O MPPT system.

Initially, the solar source will direct energy directly to the developed photovoltaic arrays. When the solar arrays receive solar energy, the solar will be the main power supply in the system, and the energy received from the source will recharge the system's lead acid battery by stepping up the voltage to ensure that the input voltage is greater than the battery's voltage to recharge the battery. However, this charging system employs a constant voltage method, which means that if the battery state of charge is less than 80%, the charging voltage will remain constant to prevent overcharging even if the irradiance levels vary, with the only difference being that a negative value of the battery current indicates that the battery is charging. As a result, the charging time required by the battery to reach a fully charged state is 18000 seconds or 5 hours. When the battery is fully charged, the energy from the source will be cut off. As an alternative, a lead acid rechargeable battery can be used as a backup or primary power supply for the system. The battery will last 8-12 hours as the main power supply, allowing the load to continue working properly as shown in Figure 2.

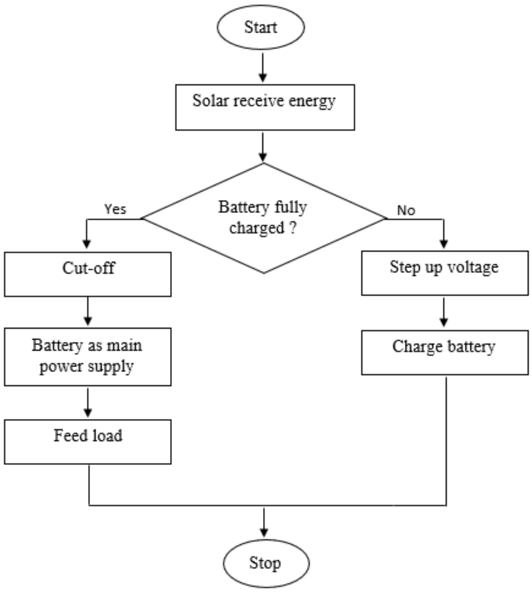

Figure 2: Flowchart of the system

3. Results and Discussion

The battery charge controller's performance is demonstrated by charging the battery through the constant voltage absorption charging stages to demonstrate the charger's one-stage charging capability in this section.

3.1 Performance of PV module for battery charging system

A 20W, 17V PV modules are modelled, simulated, and validated in accordance with its specification. In the validation, an error percentage is used as a signal that the PV module modelling may be used as the DC voltage source of the DC-DC boost converter. Figures 3, 4 and 5 illustrate the voltage-time, current-time, and power-time curves under the standard test conditions (STC) of 1000 W/m² and 25ºC, respectively. Moreover, the values of voltage, current and power between 0.01 seconds and 0.02 seconds in figures 3,4, and 5 show the solar system reaching its maximum power point before changing consistently according to changes in radiation and temperature. Table 1 shows the validation of the PV module simulation results and data sheet for the voltage at maximum power point, Vmpp, current at maximum power point, Impp, and maximum power, Pmax.

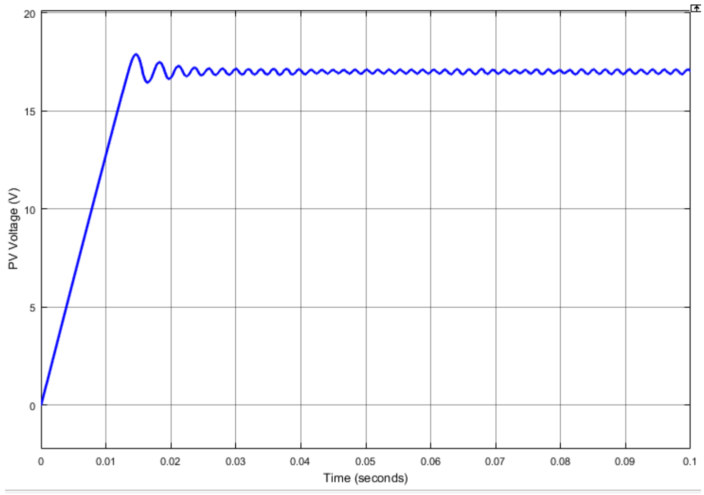

Figure 3: Curve of 20W, 17V PV module voltage

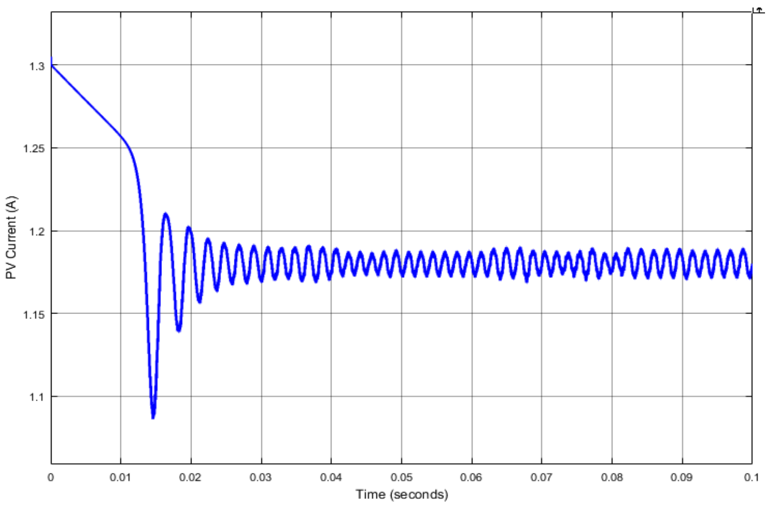

Figure 4: Curve of 20W, 17V PV module current

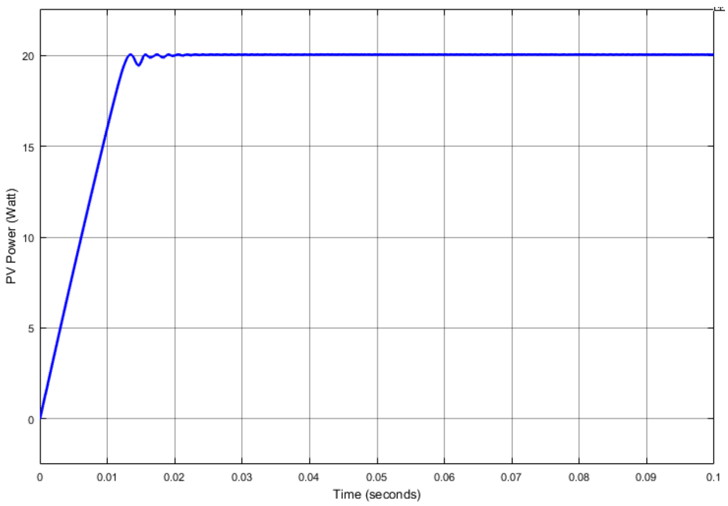

Figure 5: Curve of 20W, 17V PV module power

Table 1 shows that the datasheet and simulation result of maximum power is 20W, and 20.06W means that the PV module does not has an error percentage of maximum power. The voltage and current at maximum power point of 12W, 24V PV module for simulation are 17.01V and 1.179A. It shows that the error percentage of voltage and current at maximum power point for 20W, 17V and PV modules are 0.06% and 0.08%. It can be analyzed that all error percentages are in the range ± 0.1%. It shows that the PV module modeling is suitable for use in the DC-DC boost converter.

Table 1: Validation of 20W, 17V PV module

Parameters	**Data sheet**	**Simulation**	**Error percentage**
Maximum power, Pmax	20W	20.06W	0 %
Voltage at maximum power point, Vmpp	17V	17.01V	0.06 %
Current at maximum power point, Impp	1.18A	1.179A	0.08 %

3.2 Performance of DC-DC Boost Converter and MPPT for battery charging system

The 24V to 26.25V DC-DC boost converter is designed for the efficiency of 100% and the output power of 100W. It means that the output power equals the input power. The inductance of the inductor is 20µH and the capacitance of the capacitor of 500µF is achieved for the current ripple 5% of the inductor current, the capacitance-voltage ripple is 0.5% of the capacitor voltage and the duty ratio is 0.3.

By eliminating the resistance load of 5.76, a 24V, 15Ah lead acid battery is attached to the output terminal of the DC-DC boost converter. The modeling of a PV-powered DC-DC boost converter based on an MPPT solar controller is run for 0.1 seconds while the battery is charging to observe and analyze the voltage of the PV module as shown in Figure 3, the battery power as shown in Figure 7, the battery voltage and battery current as shown in Figure 8, and the battery state of charge as shown in Figure 9.

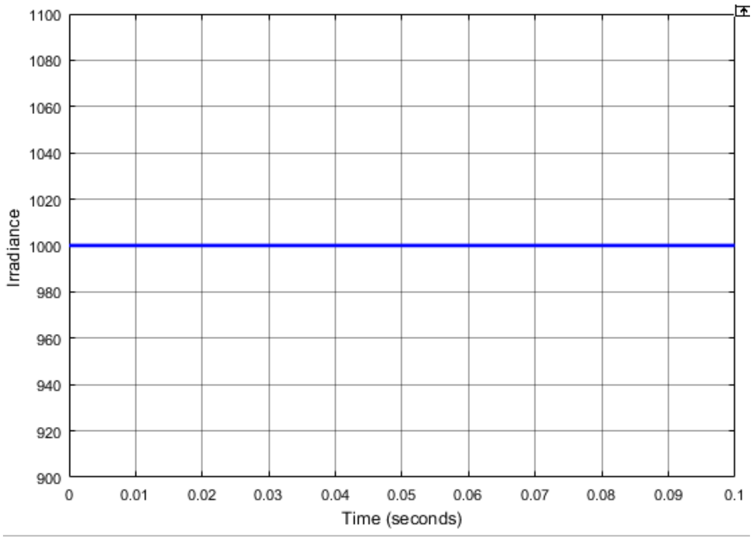

Figure 6: The 1000W/m² irradiance level at the PV module

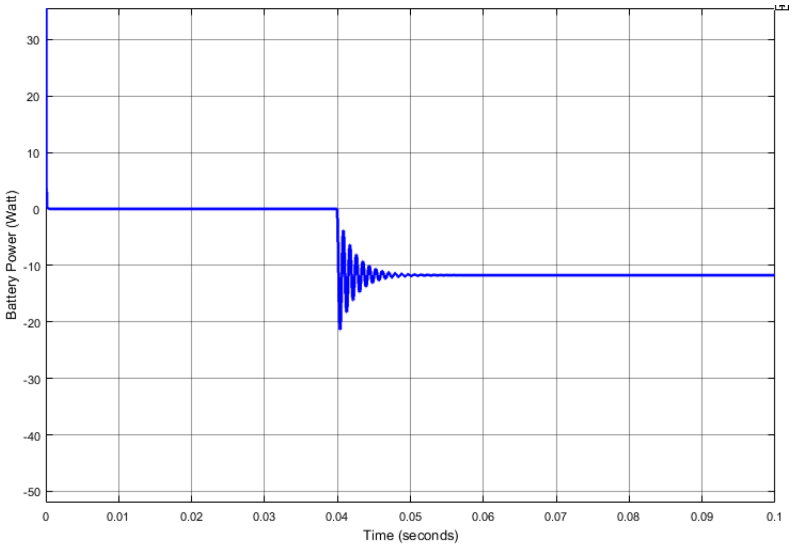

Figure 7: Battery power curve at 1000W/m² irradiance level

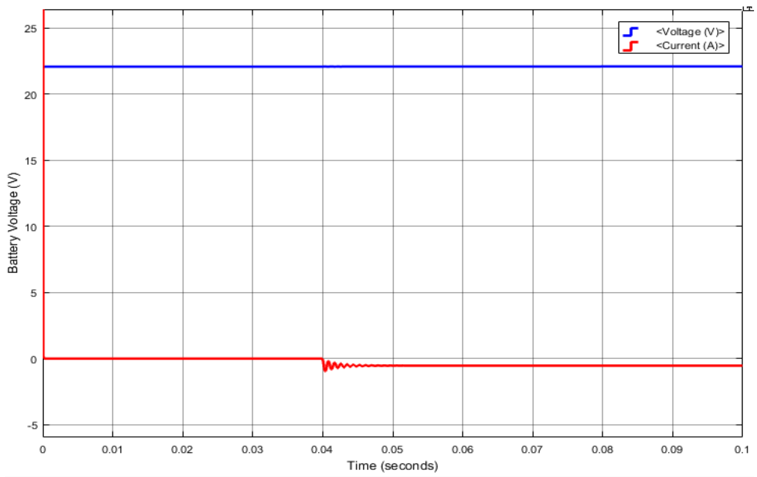

Figure 8: Battery Voltage & Current curve at 1000W/m² irradiance level

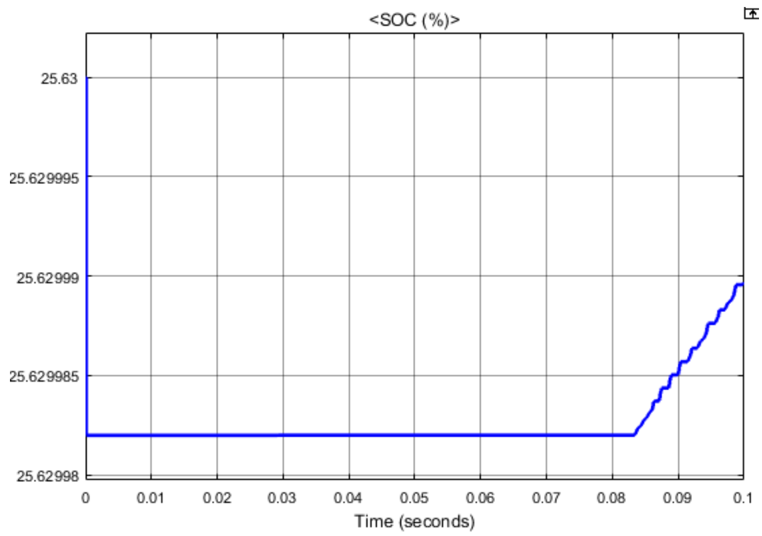

Figure 9: Battery State of Charge (SOC) curve at 1000W/m² irradiance level

The P&O algorithm monitors the maximum power point and keeps the average voltage at the peak point constant. Table 2 shows the battery charging system according to different levels of irradiance at a 25% initial state of charge for a charged battery. Table 3 shows that the battery charging system according to different levels of irradiance at a 100% state of charge for a fully charged battery. When the irradiance level of 1000W/m², the battery is in 22.08V at 25% initial state of charge and fully charged to a voltage of 26.25V at 100% state of charge. This charging system employs a constant voltage method, which means that if the battery state of charge is less than 80%, the charging voltage will remain constant to prevent overcharging even if the irradiance levels vary, with the only difference being that a negative value of the battery current indicates that the battery is charging. Thus, the charging time needed by a battery to be fully charging condition is 18000 seconds or 5 hours.

Table 2: The battery charging system according to different irradiance levels at 25% battery state of charge (SOC)

Irradiance Level (W/m²)	PV Voltage (V)	PV Current (A)	PV Power (W)	Battery Power (W)	Battery Voltage (V)	Charging Current (A)
100	12.82	0.1260	1.616	-0.0005	22.06	-0.000024
500	12.92	0.5966	10.100	-0.1526	22.07	-0.006913
1000	16.90	1.1870	20.050	-2.1670	22.08	-0.098120

Table 3: The battery charging system according to different irradiance levels at 100% battery state of charge (SOC)

Irradiance Level (W/m²)	PV Voltage (V)	PV Current (A)	PV Power (W)	Battery Power (W)	Battery Voltage (V)	Charging Current (A)
100	1.616	0.1260	12.83	-0.0008	26.18	-0.00003
500	10.100	0.5959	16.94	-2.0220	26.20	-0.0772
1000	17.010	1.179	20.06	-5.6010	26.25	-0.2134

4. Conclusion

Overall, in this project, the solar battery charging system design is successfully developed with the help of the MPPT-boost device charge controller. Based on the result analysis, the higher the level of solar irradiation, the greater the output of the PV array, and the less the output of the battery with the only difference being that a negative value of the battery current reading indicates that the battery is being charged. Therefore, further research with MPPT using Simulink models by supplying solar irradiation and temperature variable inputs can be done to improve the level of accuracy of data.

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