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MODELING OF SOLAR PHOTOVOLTAIC MAXIMUM POWER POINT TRACKING BATTERY CHARGE CONTROLLER FOR STANDALONE SYSTEM APPLICATIONS

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Abstract -The solar photovoltaic MPPT battery charge controller for lead acid and nickel-cadmium batteries used in standalone systems were presented in this paper. The MPPT battery charge controller is implemented using a buck converter. The purpose of the controller is to extend battery life and boost photovoltaic (PV) system efficiency. To achieve this, the three-stage charging strategy and the MPPT (Maximum power point Tracking) methodology were employed. The results shows that the lead acid battery controllers performance gives high efficiency than that of the nickel-cadmium battery controller performance. The proposed techniques were implemented in the MATLAB/SIMULINK environment.

Key Words: **PV System, Perturb and Observe algorithm, Buck converter, Battery Charge Controller, Three-stage charging method.**

1.INTRODUCTION

In the last ten years, solar photovoltaic energy has drawn a lot of interest. Up to 181 GW installed worldwide, it is one of the renewable energy sources with the quickest growth [1]. The PV module's power-voltage characteristics vary depending on the surrounding air conditions and have a distinct peak. Taking into account the PV system's initial cost, it is always necessary to run photovoltaic cells at maximum power point (MPP). Dc-dc converter interface is necessary for this purpose between battery and SPV. Additionally, to extend the battery's life, the controller for charging batteries is necessary [2]. PV cell properties (I-V or V-P) are also nonlinear and vary with temperature and insolation. The most expensive parts of standalone solar PV systems are the batteries and PV modules. The lifespan of the batteries is shortened when they are connected directly to the PV modules since there is no safeguard against overcharging [3]. Charge controllers can be used to prevent batteries from being overcharged, however they are less efficient than typical charge controllers since they do not operate PV modules at MPP. Running the PV module at its maximal power point will maximize power delivery to the batteries and enhance efficiency [4]. Additionally, a longer battery life requires the battery charging controller. Rechargeable batteries are often used by freestanding solar systems as a means of energy storage [5]. Optimizing power distribution to the batteries and improving efficiency can be achieved by operating the PV module at its maximum power point [6,7]. To charge the batteries a three-stage charging method is used which prevents the batteries from overcharging or deep discharging. This work also presents a battery charge controller, which is intended to extend the battery life. With MATLAB-SIMULINK, the entire system is simulated, and the outcomes are shown.

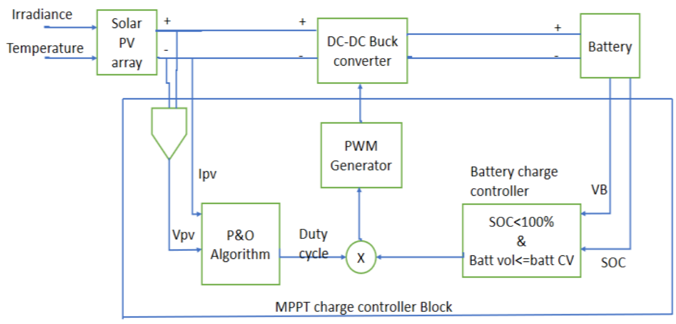

Fig 1. Block diagram of Solar PV MPPT battery charge controller

The above figure 1. Shows the block diagram of Solar PV MPPT battery charge controller. The solar irradiance and temperature are the input to the Solar PV array. The P&O technique takes the PV array current and voltage as the inputs and gives the duty cycle as output. The battery charge controller takes the battery voltage and initial state of charge as the inputs and follows the three-stage charging method conditions and produces the current, voltage and state of charge of battery. The duty cycle and outputs from battery charge controller are passed through multiply block to the PWM generator for the output of the buck converter switching device.

2.Maximum Power Point Tracking Battery charge controller

The MPPT battery charge controller block consists of Perturb and Observe technique and Battery charge controller.

2.1. Perturb and Observe technique

Perturb and Observe technique is the most commonly used MPPT technique because of its easy implementation. This MPPT technique is used to improve the efficiency of solar panel. This algorithm alters the duty cycle of converter which changes the operating voltage of the PV Panel and observes the change in power output from PV Panel in response to perturbation. If the power increases the perturbation in same direction is continued, if the power decreases the perturbation direction is reversed. By ensuring adjustment of duty cycle based on the observed output, the P&O MPPT algorithm ensures that PV system operates at its maximum efficiency under solar irradiance and cell temperature. The Flowchart of Perturb and Observe technique is shown in figure 2.

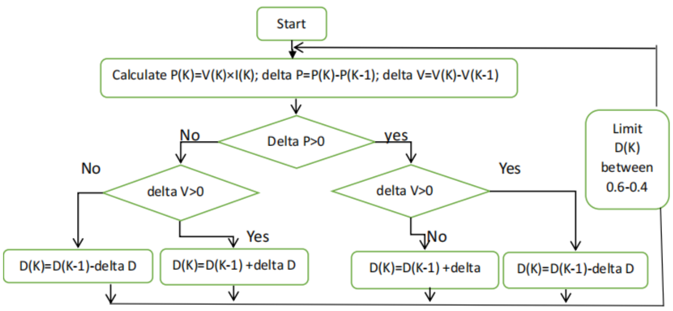

Fig 2. Perturb and Observe Algorithm Flow Chart

In Fig. 3, the PV array's voltage and current are input into the Perturb and Observe MPPT Simulation model. By using a multiply block and P(K), the current power is determined. The switch block uses the three-if-else criteria. Setting the duty cycle's perturbation step size is possible with the delta D block. Based on the three-if-else conditions, the duty cycle increase and decrement are determined. Next comes the adder with memory block D(K-1) and the duty cycle increment and decrement function. Battery charge controller block is coupled to duty cycle.

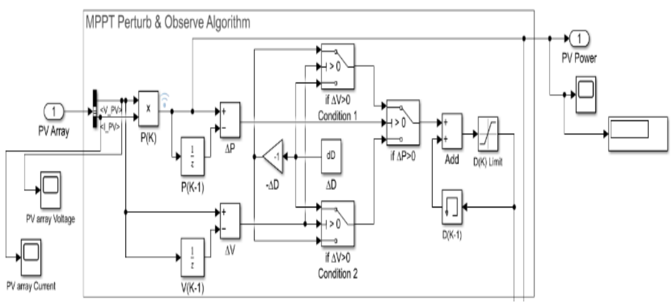

Fig 3. Perturb and Observe MPPT model

2.2. Battery Charge Controller

A battery charge controller maintains the parameters at the battery within the limits set out by the battery manufacturer by managing the current flow between the PV array, battery, and load. Three stages of charging are used to charge the battery utilizing the battery charge controller. Bulk charging, absorption charging, and float charging are the three phases of the battery charge controller's three-stage charging technique. Bulk charging raises the battery's voltage because the battery charge controller draws the highest current possible from the PV array. The battery charge controller gradually lowers the battery's current while maintaining a steady charging voltage during absorption charging. The battery obtains 100% state of charge during float charging. The flowchart of three stage charging method of battery charge controller is shown in figure 4.

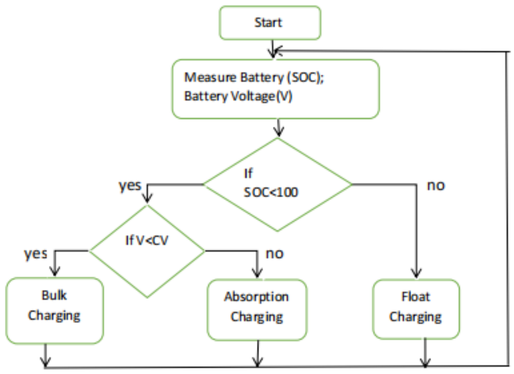

Fig 4. Three stage charging method Flowchart

The Simulation model of battery charge controller is presented in figure 5. The battery charge controller takes the state of charge and voltage from the battery. If the condition state of charge of battery less than 100% is true, it will disable the float stage and the duty cycle is allowed and passes through the multiply block so that the battery charge controller enters either in Bulk charging or Absorption charging. If the condition is false, so the battery state of charge is at 100% and enable the float charging without allowing the duty cycle. To know whether the charger enters in either Bulk charging or Absorption charging, there is a condition i.e. battery voltage less than battery constant voltage. If this condition is true, then enable Bulk charging and allow the duty cycle and pass through MPPT/CV charging multiply block and disable the float stage multiply block, then through the PWM generator block to the buck converter output. If this condition is false, then enable Absorption charging and allowing the duty cycle switching between MPPT and zero, and pass through the MPPT/CV charging multiply block and disable float stage multiply block, then through the PWM generator for the output of buck converter.

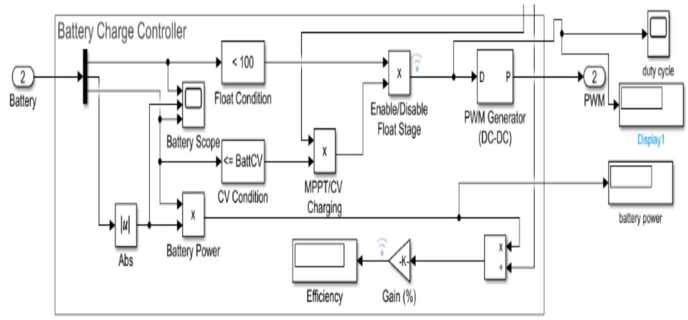

Fig 5. Simulation model of battery charge controller.

3.DC/DC Converter

A buck converter is used for the implementation of MPPT battery charge controller. The buck converter steps down the input PV array and maintains the power flow to charge the battery. The buck converter consists of MOSFET device, inductor, diode, an input and output capacitor. Diode D1 is used in order to prevent the flow of power back from battery to PV array. Table 1. Shows the specifications which are used for buck converter topology.

Table -1: Buck converter parameters

Input Voltage of PV array	146.4V
Input capacitance C1	0.001F
Output capacitance C2	0.001F
Inductance L	0.01H
MOSFET R_{on}	0.02ohms
Diode forward Voltage D_2	0.5V
PWM switching Frequency f_{SW}	1000HZ

Table -2: Solar panel specifications at 1000W/m² and cell temperature 25°C

PARAMETERS	SPECIFICATIONS
Peak power (Pmax)	2000W
Open circuit Voltage /Voc	36.6V
Short circuit Current/Isc	8.75A
Max power voltage/Vmp	30.9V
Max power current /Imp	8.1A

Two modules are considered in parallel with four modules in series for the given specific PV array with the following specifications as mentioned in table 2.

4.Simulation Model

The Simulation model of Solar PV MPPT battery charge controller is shown in figure 6. It consists of Solar PV array, DC-DC buck converter, battery and MPPT battery charge controller. The MPPT battery charge controller consists of Perturb &Observe MPPT algorithm and battery charge controller. Figure 7 Shows the subsystem of MPPT battery charge controller model. The PWM generator is connected to the MPPT battery charge controller output in order to turn on the buck converter's switching mechanism.

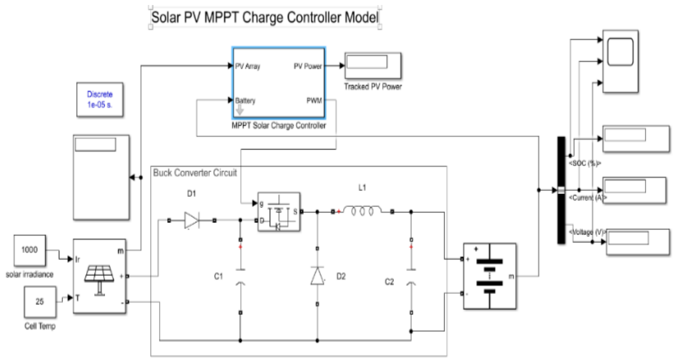

Fig 6. Simulation model of Solar PV MPPT battery charge controller.

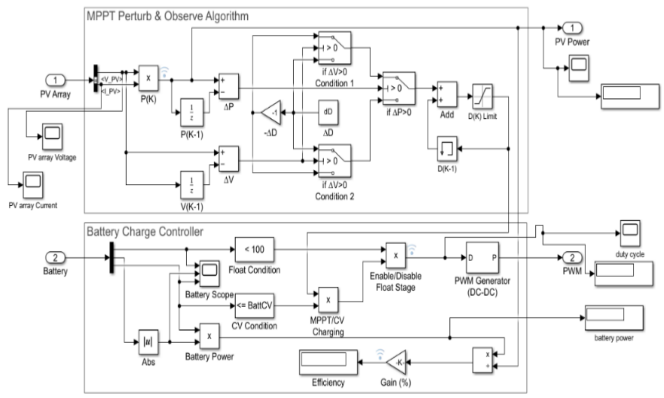

Fig 7. Subsystem of MPPT battery charge controller block.

5. Simulation Results

5.1 MPPT battery charge controller performance with lead acid battery

The battery block is set to a lead acid battery,24V,100AH capacity and initial state of charge 99.7% and simulation duration of 60sec, battery charging constant voltage of 28.8V. The PV array solar irradiance is set to 1000w/m² and temperature is set to 25°C.The performance of the MPPT battery charge controller with lead acid battery is shown in figure 8.

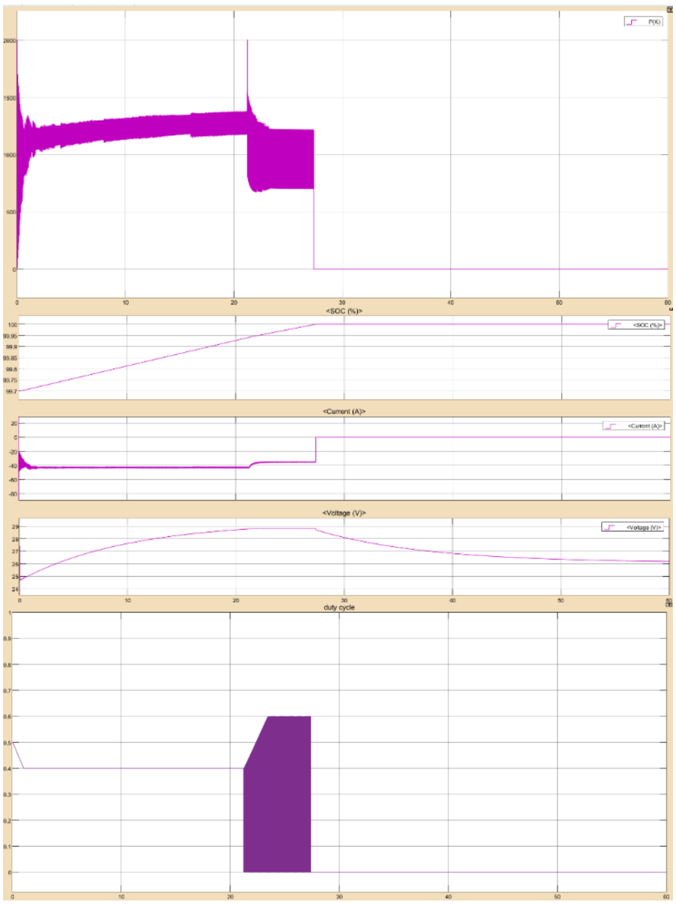

Fig 8. MPPT battery charge controller with lead acid battery

According to the results, when the battery voltage and state of charge are less than 100% and 28.8V, respectively, the battery charge controller starts charging the battery at MPPT bulk charging. The battery voltage remains constant at 28.8V for 22 sec after it enters the absorption stage. The duty cycle is switched between MPPT and zero during the absorption stage in order to maintain a steady charging voltage of 28.8V, which is visible from 22 to 28 secs. The battery charge controller switches to the float stage, which has a zero duty cycle and a floating voltage of 26.19V, when the state of charge reaches 100% in 28 sec. The overall efficiency of the Solar PV MPPT battery charge controller with lead acid battery obtained is 18.04%.

5.2 MPPT battery charge controller performance with Nickel cadmium battery

The battery block is set to a Nickel cadmium battery,28.8V,100AH capacity and initial state of charge 99.7%, simulation duration of 80sec and battery charging constant voltage of 33.6V. The performance of MPPT battery charge controller with Nickel cadmium battery is shown in figure 9.

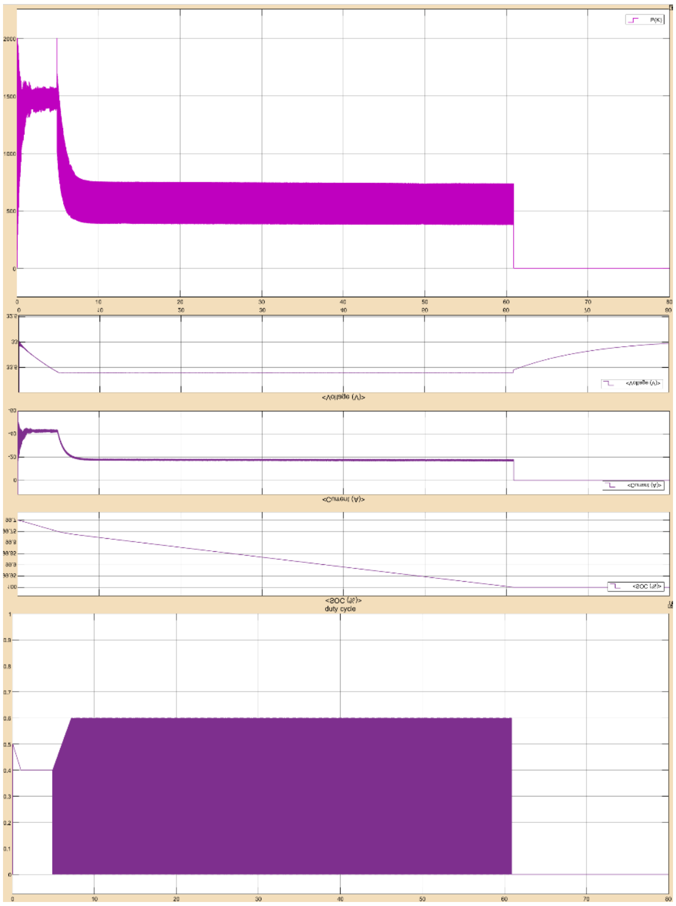

Fig 9. MPPT` battery charge controller with Nickel cadmium battery

According to the preceding plots, when the battery voltage and state of charge are less than 33.6V and less than 100%, the battery charge controller starts charging the battery at MPPT bulk charging.The battery voltage remains steady steady at 33.6V for 4.7sec after it enters the absorption stage.The duty cycle is switched between MPPT and zero during the absorption stage in order to maintain a steady charging voltage of 33.6V, which is visible from 4.7 sec to 60.8 sec. The battery charge controller switches to the float stage, which has a zero-duty cycle and a floating voltage of 33.02V, when the state of charge reaches 100% in 60.8 sec.

The overall efficiency of the solar PV MPPT battery charge controller with Nickel cadmium battery obtained is 22.74%.

Table 3:Parameter variation of Lead acid battery and Nickel cadmium battery

Battery	Input voltage	Input current	PV power	MPPT Occurred	Battery power	Efficiency
Lead acid battery	146.4 V	1.194mA	0.1748 W	7.8msec	0.03153 W	18.04 %
Nickel cadmium battery	146.4 V	1.194mA	0.1748 W	5.6msec	0.03748 W	22.74 %

6. Conclusion

With the use of a 2000W PV array source, the MPPT battery charge controller can track the maximum power and use a three-stage charging mechanism to charge a 24V lead acid battery. Similar to that, this model can control the charging of a 28.8V nickel-cadmium battery by monitoring the maximum power from a 2000W photovoltaic array and applying a three-stage charging process. The MPP appears at 0.0078 seconds for lead acid batteries and at 0.0056 seconds for nickel cadmium batteries, according to a comparative analysis of the MPPT battery charge controller performance for lead acid and nickel cadmium batteries. This means that the controller can reach the MPP using P&O technique faster for the nickel cadmium battery than the lead acid battery. Hence, Choosing the Nickel cadmium battery which gives higher efficiency than the lead acid battery can be beneficial for standalone system operations, as it can lead to improved reliability.

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