

Design of Battery Charging from Solar Using Buck Converter with MPPT Algorithm

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ABSTRACT

Solar photovoltaic (PV) energy provides a clean and sustainable source for battery-charging applications. However, the nonlinear characteristics of PV modules and variations in solar irradiation and temperature cause continuous changes in the available output power. Therefore, an effective maximum power point tracking technique is necessary to extract the maximum available energy from the PV array. This paper presents the design and simulation of a solar-powered battery charging system employing a DC–DC buck converter and a Perturb and Observe (P&O) Maximum Power Point Tracking (MPPT) algorithm. The voltage and current of the PV array are continuously monitored, and the P&O algorithm adjusts the duty cycle of the buck converter to operate the PV array close to its maximum power point. The converter steps down the PV voltage to a level suitable for charging a 12-V battery. The complete system is modeled and simulated using MATLAB/Simulink. Simulation results reported in the project demonstrate maximum power extraction of approximately 210 W under an irradiance of 1000 W/m² and a cell temperature of 25°C. The proposed approach provides regulated battery charging while improving utilization of the available photovoltaic energy.

Keywords— Photovoltaic system, Maximum Power Point Tracking, MPPT, Perturb and Observe, Buck Converter, Battery Charging, MATLAB/Simulink, Solar Energy.

INTRODUCTION

The increasing demand for electrical energy and growing environmental concerns associated with conventional energy sources have encouraged the utilization of renewable energy. Among the available renewable resources, solar photovoltaic energy has gained significant attention because of its availability, clean operation, modularity, and suitability for standalone applications. A photovoltaic panel converts incident solar radiation directly into electrical energy. Nevertheless, the electrical characteristics of PV systems are nonlinear and their output varies considerably with changes in solar irradiance and temperature. Hence, operating a PV system at its maximum power point is important for obtaining better utilization of the installed solar capacity.

Battery storage is commonly incorporated in standalone PV systems to store excess energy and provide power when solar energy is unavailable. Proper control of the charging process is essential because inappropriate charging and discharging conditions can adversely affect battery performance and lifetime. A DC–DC converter placed between the PV source and battery can regulate energy transfer and establish the required charging voltage. In the proposed system, a buck converter is employed because the PV array voltage is higher than the required battery voltage. The converter performs the required step-down operation while an MPPT controller determines its appropriate operating duty cycle.

The proposed work employs the Perturb and Observe (P&O) algorithm for maximum power point tracking. The algorithm measures PV voltage and current, evaluates the resulting power, and changes the operating point according to the variation in power. By continuously adjusting the buck-converter duty cycle, the system attempts to maintain operation around the maximum power point despite variations in environmental conditions. The complete PV array, MPPT controller, buck converter and battery charging system is modeled using MATLAB/Simulink.

LITERATURE SURVEY

Several researchers have investigated MPPT-controlled solar charging systems and DC–DC converter configurations. Rashid *et al.* [1] discussed an efficient solar charging system incorporating maximum power point tracking and a buck converter, emphasizing MPPT control and converter design. Varghese *et al.* [2] presented an MPPT algorithm for solar charging stations and evaluated its performance. Hasan and Islam [3] concentrated on the design and simulation of a buck converter for solar energy systems, including converter control strategies and simulation considerations. Hassan *et al.* [4] investigated a buck-converter-based MPPT configuration for photovoltaic systems and considered both system design and experimental operation.

Esram and Chapman [5] presented a comparative study of different MPPT methods, including P&O and Incremental Conductance techniques. Dhawan and Arora [6] considered the implementation of MPPT for PV battery charging through a buck converter, while Badri *et al.* [7] studied the simulation of a solar battery charger incorporating maximum power point tracking. Lekshmi *et al.* [8] addressed an MPPT-based solar battery charging system using a buck converter. Hossain *et al.* [9] investigated an MPPT-based battery charging system for photovoltaic applications, and Kumar *et al.* [10] studied the simulation of a photovoltaic battery charging system with MPPT. Collectively, these studies demonstrate the importance of coordinating the MPPT algorithm with the DC–DC converter to achieve improved photovoltaic energy extraction and controlled battery charging.

PROBLEM STATEMENT

The output voltage and power of a photovoltaic panel continuously vary with solar irradiation, temperature, and operating conditions. Direct connection of a solar panel to a battery therefore cannot guarantee maximum energy extraction or regulated charging. The system must efficiently extract the available maximum PV power, step down the solar-panel voltage to the required battery level, and regulate the charging voltage and current. Furthermore, the battery must be protected against undesirable operating conditions such as overcharging, excessive discharge and overheating. Hence, an MPPT-controlled buck converter is required to provide an efficient interface between the photovoltaic source and battery.

OBJECTIVES

The main objectives of the proposed system are:

1. To maximize the power extracted from the photovoltaic panel using the Perturb and Observe MPPT algorithm under variations in solar irradiation and temperature.
2. To design and simulate a DC–DC buck-converter-based charging system capable of providing controlled and regulated charging to a 12-V battery.

The objectives presented in the project additionally emphasize improved solar-system efficiency, optimized charging, stable output voltage and protection of the battery against undesirable charging conditions.

PROPOSED SYSTEM

The proposed solar battery charging system consists mainly of a photovoltaic array, MPPT controller, DC–DC buck converter and battery. The PV array acts as the primary energy source and converts solar radiation into electrical energy. The voltage and current generated by the array are measured and supplied to the MPPT controller. Based on

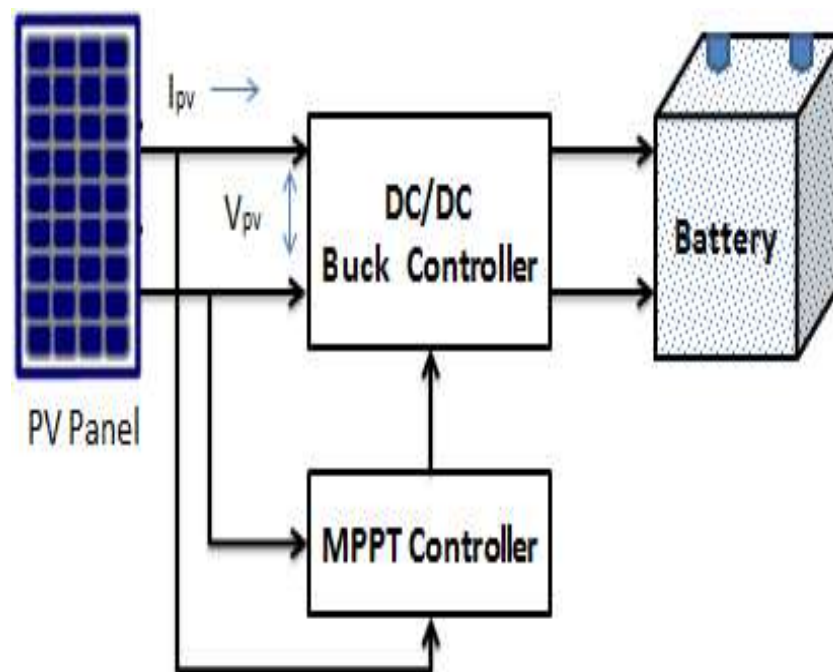
these quantities, the controller determines the instantaneous PV power and uses the P&O algorithm to identify the direction in which the operating point should be changed.

The MPPT controller generates the required duty-cycle command for the buck converter. The buck converter reduces the comparatively higher PV voltage to a suitable charging voltage for the battery. The converter therefore serves both as the power-processing stage and as the mechanism through which the operating point of the PV array is controlled. The overall configuration allows the MPPT algorithm to optimize energy extraction while the converter delivers regulated electrical energy to the battery. The block diagram in the source report illustrates this energy flow from the PV panel through the DC/DC buck controller to the battery, with the MPPT controller providing feedback control.

BLOCK DIAGRAM

Fig. 1 shows the block diagram of the solar battery charging system, where the PV panel supplies voltage and current to the DC–DC buck controller. The MPPT controller continuously tracks the maximum available solar power and adjusts the buck converter operation to provide efficient and regulated charging of the battery.

Fig .1:Block diagram of the system



SIMULATION DIAGRAM

Fig. 2 shows the MATLAB/Simulink model of the proposed solar battery charging system, consisting of a PV array, P&O-based MPPT controller, DC–DC buck converter, and battery. The MPPT controller regulates the converter switching to extract maximum power from the PV array and provide controlled charging to the battery.

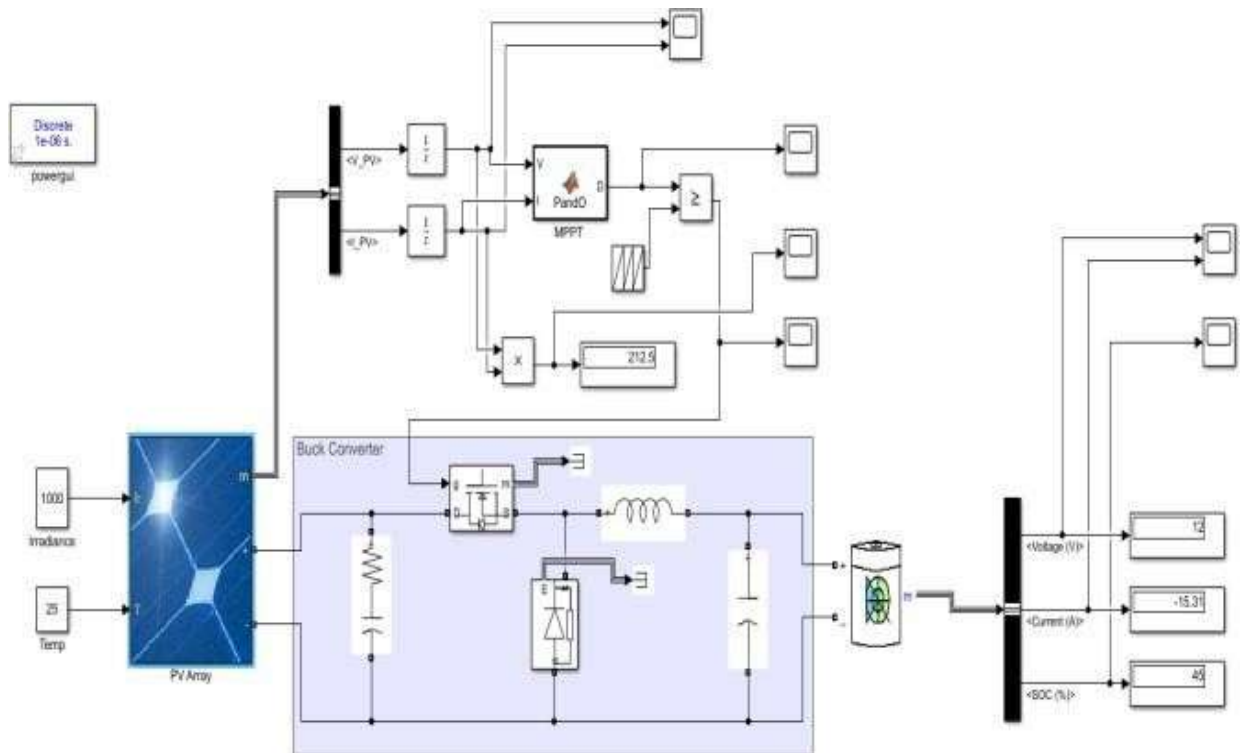


Fig 2:Simulink Model

RESULTS AND DISCUSSION

The MATLAB/Simulink analysis demonstrates the operation of the photovoltaic charging system under MPPT control. The simulation outputs presented in the report include the MPPT-controller response, converter gate pulse, PV power, battery charging voltage and current, PV-array voltage and current, and battery state of charge. These quantities are used to assess the ability of the controller to extract solar power and regulate energy transfer to the battery.

At a cell temperature of **25°C** and solar irradiance of **1000 W/m²**, the simulated PV system is reported to deliver approximately **210 W**, corresponding to its rated output, while maintaining MPPT operation and charging the 12-V battery. When solar irradiance decreases, PV-array power and battery charging current decrease. Similarly, an increase in cell temperature reduces PV power and consequently lowers the charging current. Increasing the number of parallel PV strings increases both the available power and charging current.

The battery State of Charge (SOC) provides further evidence of charging operation. According to the simulation results, the SOC increases from approximately **45% to 45.004% during a one-second simulation interval**. Although the change is small because of the short simulation period, its increasing trend indicates that energy is being transferred to the battery.

Overall, the simulation indicates that coordination between the P&O MPPT controller and the buck converter enables the PV array to operate near its maximum power point while providing an appropriate charging interface for the battery. The system therefore responds to environmental changes by modifying the converter duty cycle and corresponding charging current.

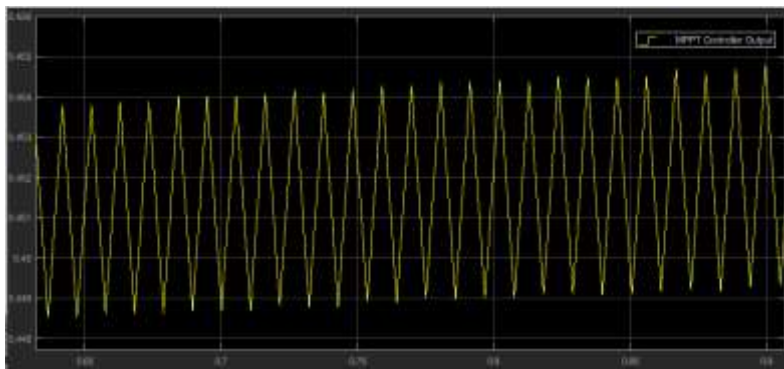


Fig 3:MPPT Controller output

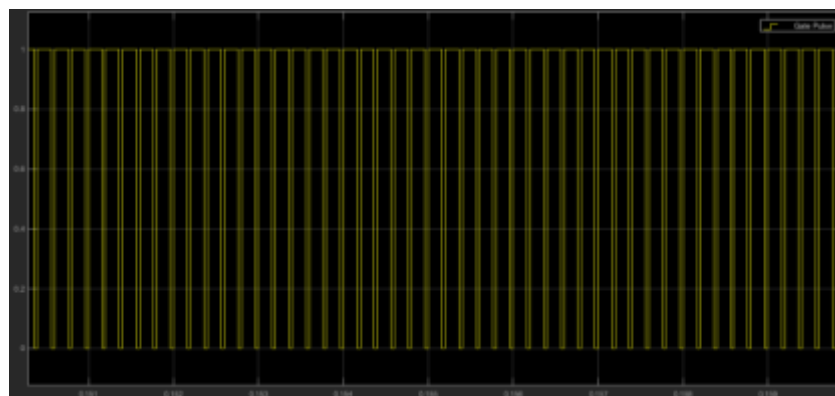


Fig 4:Gate Pulse

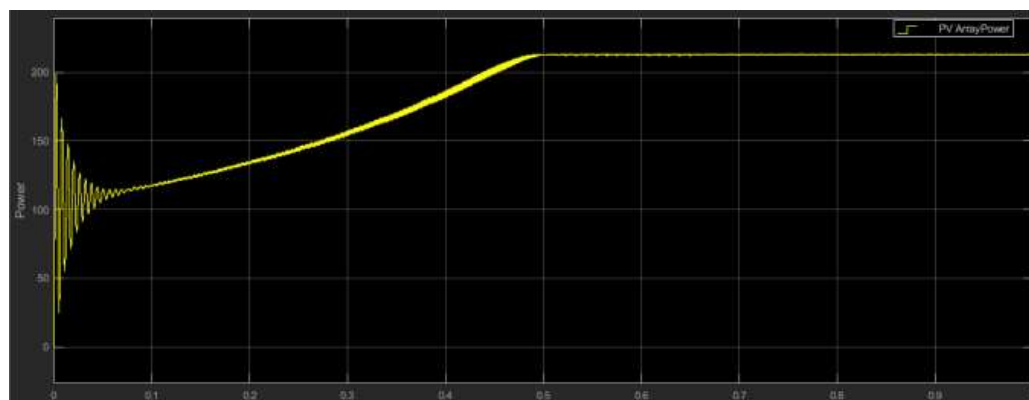


Fig 5:PVPower

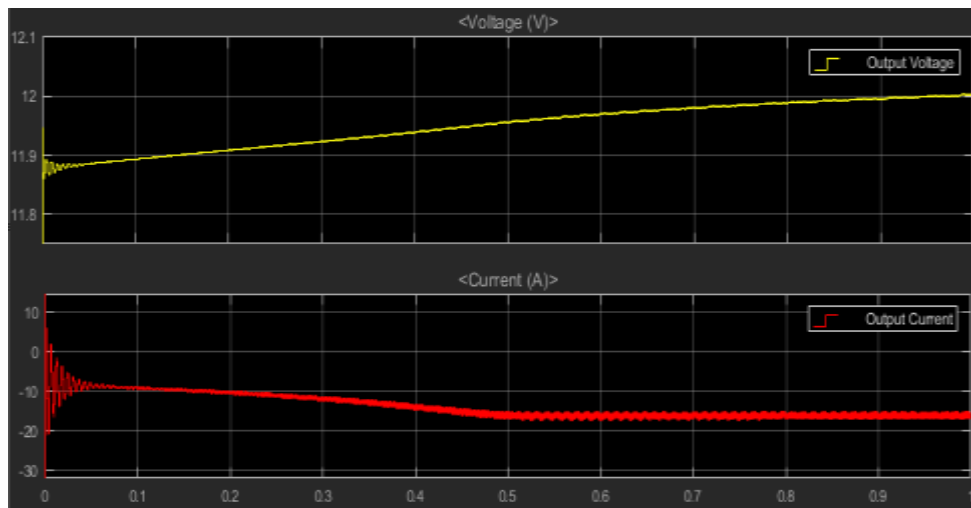


Fig 6:OutputChargingVoltage&CurrentOfbattery

CONCLUSION

A solar photovoltaic battery charging system based on a buck converter and Perturb and Observe MPPT algorithm has been presented and simulated using MATLAB/Simulink. The P&O algorithm determines the maximum power operating region by monitoring variations in PV voltage, current and power and subsequently modifies the converter duty cycle. The buck converter performs the required voltage step-down operation and controls the charging current supplied to the 12-V battery.

The simulation reported in the project demonstrates that the PV array can produce approximately 210 W under an irradiance of 1000 W/m² and cell temperature of 25°C while maintaining MPPT operation. Variations in solar irradiation and temperature cause corresponding changes in PV power and battery charging current, and the controller responds by adjusting the buck-converter operation.

Thus, the proposed configuration provides an effective approach for extracting photovoltaic energy and supplying regulated charging power to a battery. The system can contribute to cleaner standalone power applications and can be extended to supply loads directly or through an inverter.

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