ABSTRACT

Energy is one of the key factors supporting various human activities across multiple sectors. Among renewable energy sources, solar energy has gained increasing popularity due to its ability to be converted into electrical energy through photovoltaic (PV) systems. PV systems offer advantages such as ease of installation, flexibility in application, and low operational costs, making them an attractive option for promoting the transition towards clean energy. However, the output power of PV modules is highly influenced by environmental conditions such as solar irradiance and temperature, which necessitates a control system capable of maintaining the PV operating point at its Maximum Power Point (MPP).

This research aims to design and implement a solar charge controller based on the Extremum Seeking Control (ESC) algorithm, employing a non-inverting buck-boost converter topology that can either step up or step down the PV output voltage to match the requirements of the load and storage battery. The system adaptively adjusts the converter's duty cycle to ensure the PV voltage and current remain at optimal conditions. The control process involves signal conditioning through high-pass and low-pass filters, modulation, demodulation, and updating a reference voltage signal to control MOSFET switching.

Experimental results show that the ESC-based system achieves a power conversion efficiency of up to 78.77% with a maximum output power of 68.34 W. In comparison, the conventional constant PWM method only achieves an efficiency of 71.17% with an output power of approximately 31 W. These findings indicate that the ESC approach not only improves efficiency but also significantly enhances output power. With its ability to adapt to varying environmental conditions, the proposed system has the potential to be an effective solution for small to medium-scale PV applications, whether standalone or grid-connected.

Keywords: PWM, MPPT, ESC, buck-boost converter, solar charge controller[i]