Adaptive Variable Step-Size MPPT Strategy for Enhanced Efficiency in Photovoltaic Systems under Dynamic Environmental Conditions

Abstract

The growing demand for sustainable and clean energy will drive the continued development of solar photovoltaic (PV) systems as a leading renewable energy technology. Due to their pollution-free operation, ease of installation, and scalability, PV systems will increasingly be adopted for both rural and urban electrification. However, their efficiency will remain highly sensitive to environmental variations such as solar irradiance and temperature, which introduce nonlinear behavior in the power–voltage characteristics of solar panels. To ensure maximum energy extraction, PV systems must operate consistently at their Maximum Power Point (MPP), a condition that will be achieved through Maximum Power Point Tracking (MPPT) algorithms.

This proposed research will focus on developing a modified adaptive variable step-size MPPT algorithm designed to dynamically regulate the duty cycle of a DC–DC converter for optimal power tracking. The algorithm will intelligently adjust its step size in response to real-time variations in solar irradiance, thereby enabling faster convergence to the MPP and reducing power losses caused by steady-state oscillations. The performance of the proposed algorithm will be validated using MATLAB/Simulink simulations on a Shell SP75 PV module. The simulated results for voltage, current, and output power will be compared against those obtained from conventional MPPT techniques. The proposed method is expected to demonstrate superior tracking accuracy, enhanced power conversion efficiency, and improved adaptability to rapidly changing atmospheric conditions.

In the extended phase of the research, the developed control strategy will be adapted and applied to grid-connected three-phase PV systems, aiming to achieve stable synchronization and efficient energy integration into the power grid. This work will thus contribute a novel and intelligent MPPT solution that enhances the operational reliability and energy yield of modern solar PV systems.

Keywords: *Photovoltaic (PV) System, Maximum Power Point Tracking (MPPT), Adaptive Control, Variable Step-Size Algorithm, DC–DC Converter, Renewable Energy Optimization*