IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 1, July 2025
Impact Factor: 7.67

Design and Real-Time Simulation of Grid-Connected Solar PV System with Enhanced MPPT and Inverter Control in MATLAB/Simulink

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Abstract: *The global shift toward renewable energy sources has made photovoltaic (PV) systems increasingly important due to their clean, modular, and sustainable characteristics. This research paper presents the design and control of a grid-connected solar PV system implemented in MATLAB/Simulink. The proposed system includes four critical components: a Maximum Power Point Tracking (MPPT) controller to maximize energy harvesting from the solar panels, a closed-loop boost converter to elevate the panel voltage efficiently, a three-phase voltage source inverter (VSI) using six IGBT switches for DC to AC conversion, and an LCL filter to minimize harmonics and ensure quality power injection into the grid. The MPPT controller, based on the Perturb and Observe (P&O) method, continuously adjusts the duty cycle of the boost converter to extract the maximum power under varying irradiance and temperature conditions. A Proportional-Integral (PI) controller is employed for the closed-loop voltage control of the boost converter, ensuring a stable output voltage suitable for grid interfacing. The inverter is operated using Sinusoidal Pulse Width Modulation (SPWM) technique to generate a balanced three-phase output. The LCL filter is designed to attenuate high-frequency switching harmonics, maintaining the Total Harmonic Distortion (THD) within IEEE-519 standards. Simulation results validate the effectiveness of the proposed system under different solar irradiance conditions. The system not only ensures optimal energy harvesting but also delivers power to the grid with high efficiency and low distortion. This paper contributes toward enhancing the reliability and performance of solar PV systems in modern power grids.*

Keywords: Solar PV, MPPT, Boost Converter, PI Controller, Grid-Connected Inverter, LCL Filter, MATLAB Simulink, SPWM, Renewable Energy, Power Quality

DOI: 10.48175/568