International Journal of Science, Strategic Management and Technology
Volume **02** Issue **05** May-**2026** | ISSN: **3108-1762 (Online)** | Impact Factor: 3.8
An International, Peer-Reviewed, Open Access Scholarly Journal Indexed in recognized academic databases

Design and Simulation of a 300 MW Grid-Tied Solar Photovoltaic System using Four-Leg Inverter in Matlab/Simulink

Batch Number: 26EE10
Supervisor Name: **Mr.V.Yokeswaran**
M.Tech.
Department: Electrical and Electronics Engineering College Name: Egs Pillay Engineering College (Autonomous) - Nagapattinam, Tamilnadu,India.

Mohana Roubhan.M (8208E22EER031)

Sakthivel.S (8208E22EER042)

Velmurugan.S (8208E22EER054)

Ranjith.R (8208E22EEL306)

https://doi.org/10.55041/ijsmt.v2i5.138

Cite this Article: V.Yokeswaran, , Roubhan.M, M., Sakthivel.S, , Velmurugan.S, & Ranjith.R, (2026). Design and Simulation of a 300 MW Grid-Tied Solar Photovoltaic System using Four-Leg Inverter in Matlab/Simulink. International Journal of Science, Strategic Management and Technology, *02*(05). https://doi.org/10.55041/ijsmt.v2i5.138

Abstract

Solar energy has become one of the most promising renewable sources to meet growing power demands while reducing environmental impact. This paper presents the complete design and simulation of a large-scale 300 MW grid-tied solar photovoltaic (PV) system. The system uses a three- phase four-leg inverter, which offers better performance under unbalanced conditions compared to traditional three-leg inverters.

The PV array is modeled considering variations in solar irradiance and temperature. A DC-DC boost converter with Perturb and Observe (P&O) maximum power point tracking (MPPT) extracts maximum power from the panels. The four-leg inverter converts DC power to AC and synchronizes it with the utility grid using a phase-locked loop (PLL). The entire model is developed and tested in MATLAB/Simulink environment.

Simulation results show stable DC-link voltage, smooth active power injection into the grid, and low total harmonic distortion (THD) in the output currents. The four-leg topology helps manage neutral currents effectively during unbalanced loads or grid disturbances. This work highlights how the four- leg inverter can improve power quality and reliability in high-capacity solar plants. The proposed design can serve as a useful reference for practical implementation of utility-scale PV systems.

Keywords: Solar PV system, Grid-tied inverter, Four-leg inverter, MPPT, MATLAB/Simulink, Power quality, Renewable energy

1. Introduction

In recent years, the world has seen a rapid increase in the installation of solar photovoltaic systems due to falling panel costs and government support for clean energy. Large-scale grid-tied PV plants in the range of hundreds of megawatts are now common in many countries, including India. These systems not only generate clean electricity but also help in reducing dependence on fossil fuels.

However, integrating such high-power solar plants with the existing grid brings several challenges. Solar output varies with weather conditions, and the inverters must maintain good power quality, handle reactive power, and stay stable during grid disturbances. Traditional three-leg inverters often face difficulties when the load or grid becomes unbalanced, leading to neutral current flow, voltage distortions, and higher losses.

To address these issues, this project focuses on the use of a four-leg inverter topology for a 300 MW grid-tied solar PV system. The extra leg connected to the neutral point allows better control over zero-sequence components. The complete system was modeled and simulated using MATLAB/Simulink, which is a widely used tool for power electronics and renewable energy studies. This paper discusses the problem, objectives, system design, working principle, methodology, advantages, and key findings.

2. Problem Statement

Although solar PV technology has advanced significantly, large grid-tied systems still encounter problems related to power quality and stability. Conventional three-phase inverters can inject harmonics into the grid and struggle with unbalanced conditions commonly found in distribution networks or during partial shading/faults in PV arrays. Neutral currents in unbalanced situations can cause overheating of conductors, voltage imbalances, and even tripping of protection devices.

Moreover, achieving efficient maximum power extraction under varying irradiance and temperature while maintaining synchronized grid connection requires robust control strategies. For a high- capacity system like 300 MW, these issues get amplified, potentially affecting overall system efficiency and compliance with grid codes. The main problem addressed in this work is to design a reliable inverter topology and control scheme that can overcome these limitations in a utility-scale solar PV plant.

3. Objectives

The primary objectives of this project are:

To design a 300 MW solar PV array and model its characteristics under different environmental conditions in MATLAB/Simulink.

To implement a DC-DC boost converter with P&O MPPT algorithm for maximum power extraction.

To develop a three-phase four-leg inverter with suitable modulation and control techniques for grid synchronization.

To simulate the complete grid-tied system and analyze its performance in terms of power quality, voltage regulation, and response to dynamic changes.

To evaluate the advantages of the four-leg inverter over conventional topologies, especially under unbalanced conditions.

4. Proposed System – Working Principle and Methodology

The proposed system consists of three main stages: the PV array with MPPT, the DC-DC converter, and the four-leg grid-tied inverter.

PV Array Modeling:

The 300 MW PV array was built by connecting multiple PV modules in series and parallel combinations. Each module is modeled using the single-diode equivalent circuit, with inputs for solar irradiance (G) and cell temperature (T). This allows realistic simulation of power output variations throughout the day.

DC-DC Boost Converter and MPPT:

International Journal of Science, Strategic Management and Technology
Volume **02** Issue **05** May-**2026** | ISSN: **3108-1762 (Online)** | Impact Factor: 3.8
An International, Peer-Reviewed, Open Access Scholarly Journal Indexed in recognized academic databases

A boost converter steps up the variable DC voltage from the PV array to a constant DC-link voltage suitable for the inverter. The Perturb and Observe (P&O) algorithm continuously adjusts the duty cycle of the converter by making small changes and observing the resulting power. This method is simple yet effective for tracking the maximum power point even when irradiance changes suddenly.

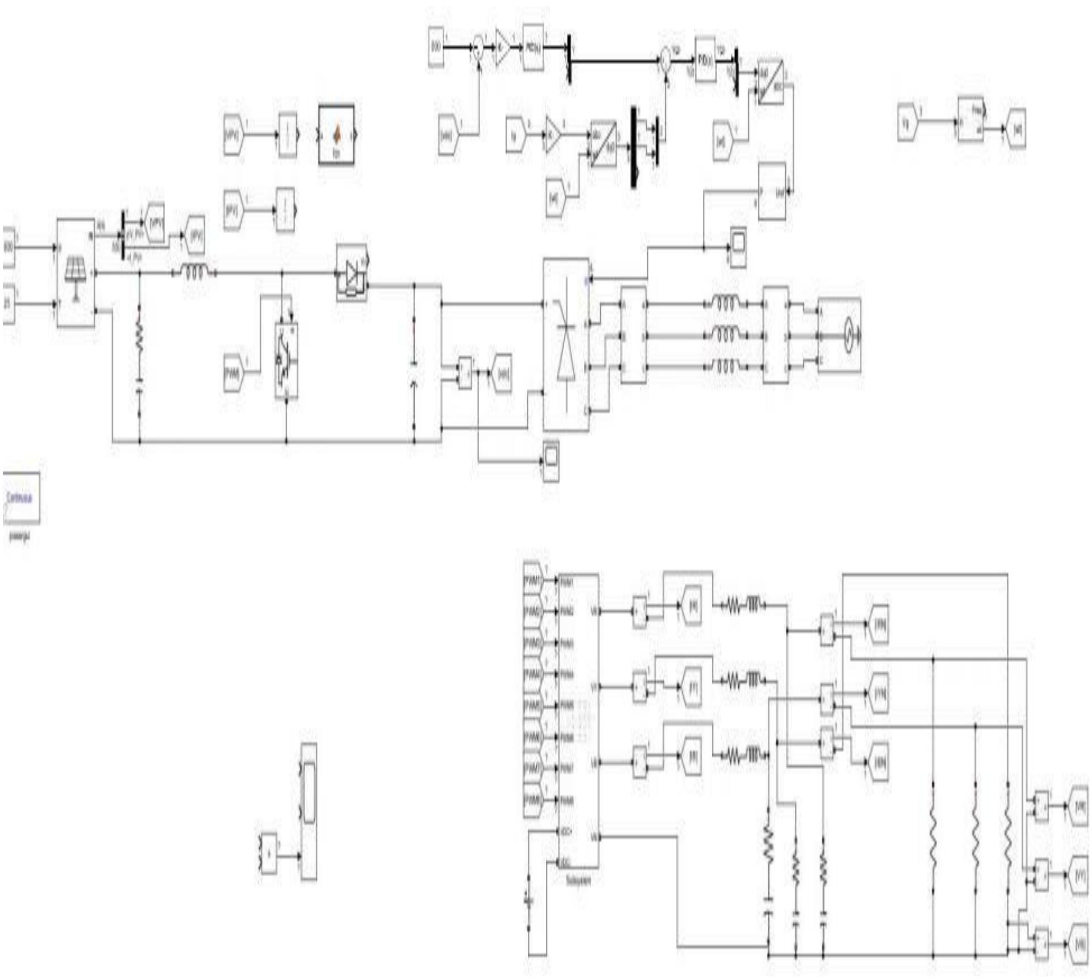
Four-Leg Inverter Topology and Control:

The heart of the system is the three-phase four-leg voltage source inverter (VSI). It uses eight switches (typically IGBTs with diodes). The fourth leg provides a neutral connection, which is the key difference from standard three-leg inverters. This extra leg helps independently control the zero- sequence currents.

Sinusoidal pulse width modulation (SPWM) or space vector modulation is used to generate switching pulses. A synchronous reference frame phase-locked loop (SRF-PLL) detects the grid phase angle for proper synchronization. PI controllers regulate the DC-link voltage and grid currents to achieve near- unity power factor and controlled active/reactive power flow. An LCL filter is placed at the output to reduce switching harmonics before connecting to the grid (modeled at 33 kV or 110 kV level, stepped up through a transformer).

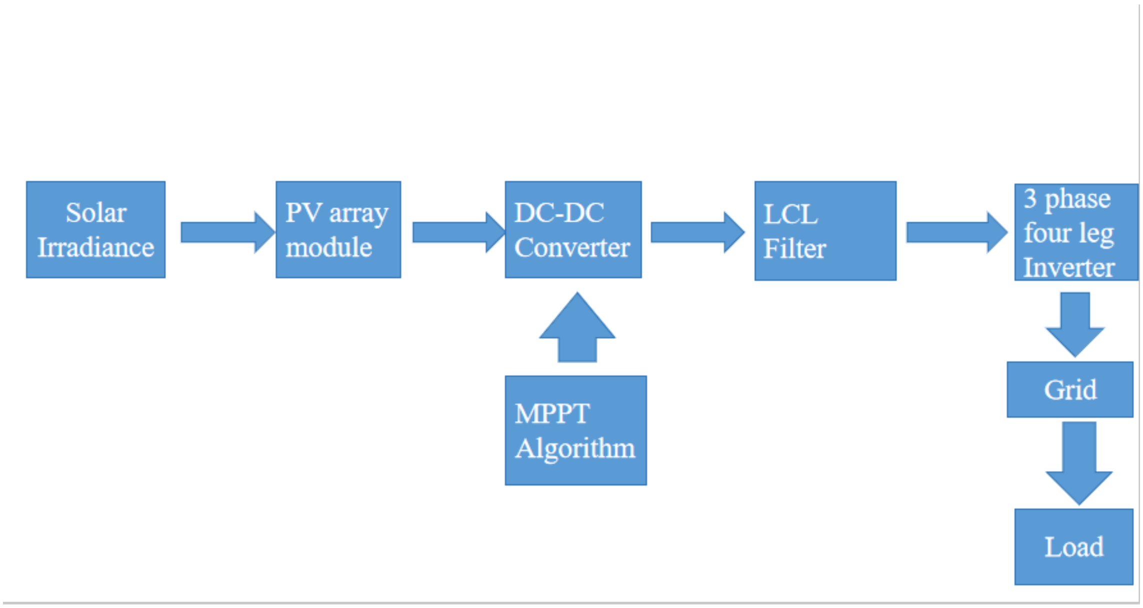
The entire system was assembled as a single Simulink model using SimPowerSystems toolbox. Discrete solver with small time steps was chosen for accurate power electronics simulation. Different test cases were run, including standard test conditions (1000 W/m², 25°C), step changes in irradiance, and unbalanced load scenarios.

MATLAB SIMULATION DIAGRAM:



International Journal of Science, Strategic Management and Technology
Volume **02** Issue **05** May-**2026** | ISSN: **3108-1762 (Online)** | Impact Factor: 3.8
An International, Peer-Reviewed, Open Access Scholarly Journal Indexed in recognized academic databases

BLOCK DIAGRAM:

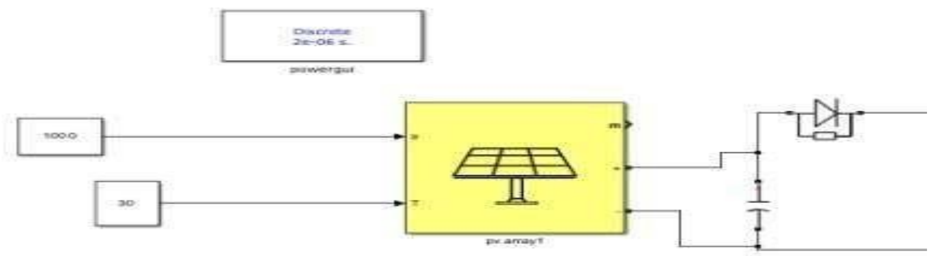


PV Array:

The solar PV system converts solar irradiation into electrical energy. In the simulation, the PV array receives irradiation and temperature inputs which influence the generated voltage and current.

The PV output is connected to a DC-DC converter, which regulates the voltage before supplying it to the DC link.

Solar PV System Model in MATLAB/Simulink



DC TO DC Converter:

In a panel system the voltage produced is not always the same. It changes with how much sunlight hits the panels and the temperature. To make sure the inverter works correctly and the DC link voltage stays steady a special converter is used.This converter helps to increase and control the voltage from the panels.A boost converter is used in this project to do that it steps up and regulates the voltage, from the solar panels.

Boost Converter Structure:

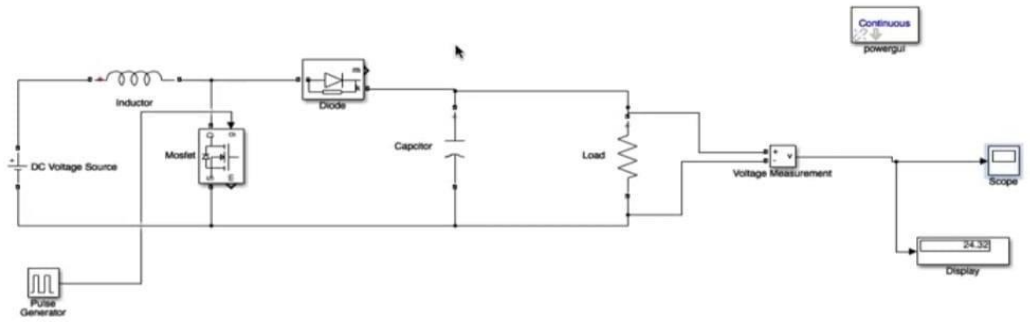
The boost converter consists of:

- Inductor (L)
- Switch (MOSFET/IGBT)
- Diode (D)

International Journal of Science, Strategic Management and Technology
Volume 02 Issue 05 May-2026 | ISSN: 3108-1762 (Online) | Impact Factor: 3.8
An International, Peer-Reviewed, Open Access Scholarly Journal Indexed in recognized academic databases

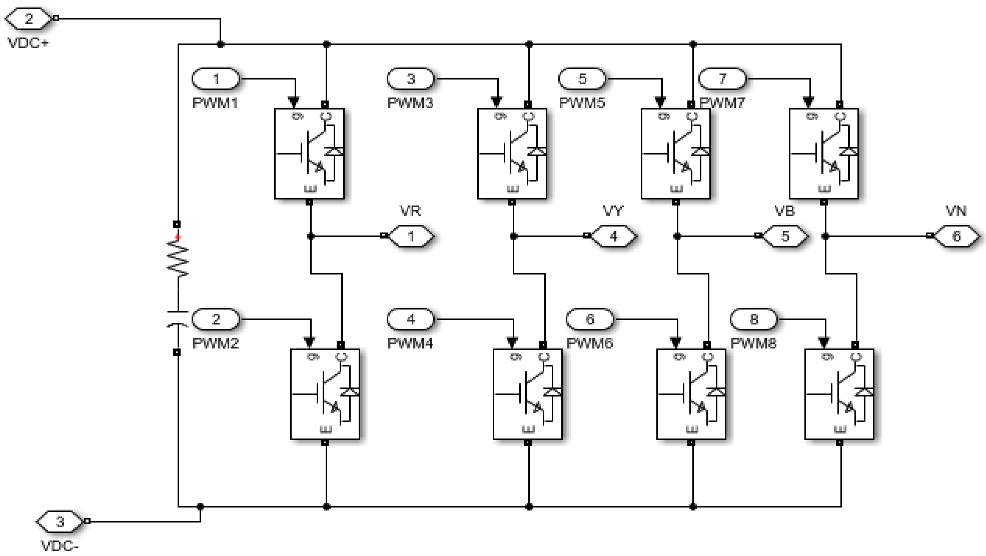
- Output Capacitor (C)

These components work together to step up the input voltage.



Boost Converter used in our project

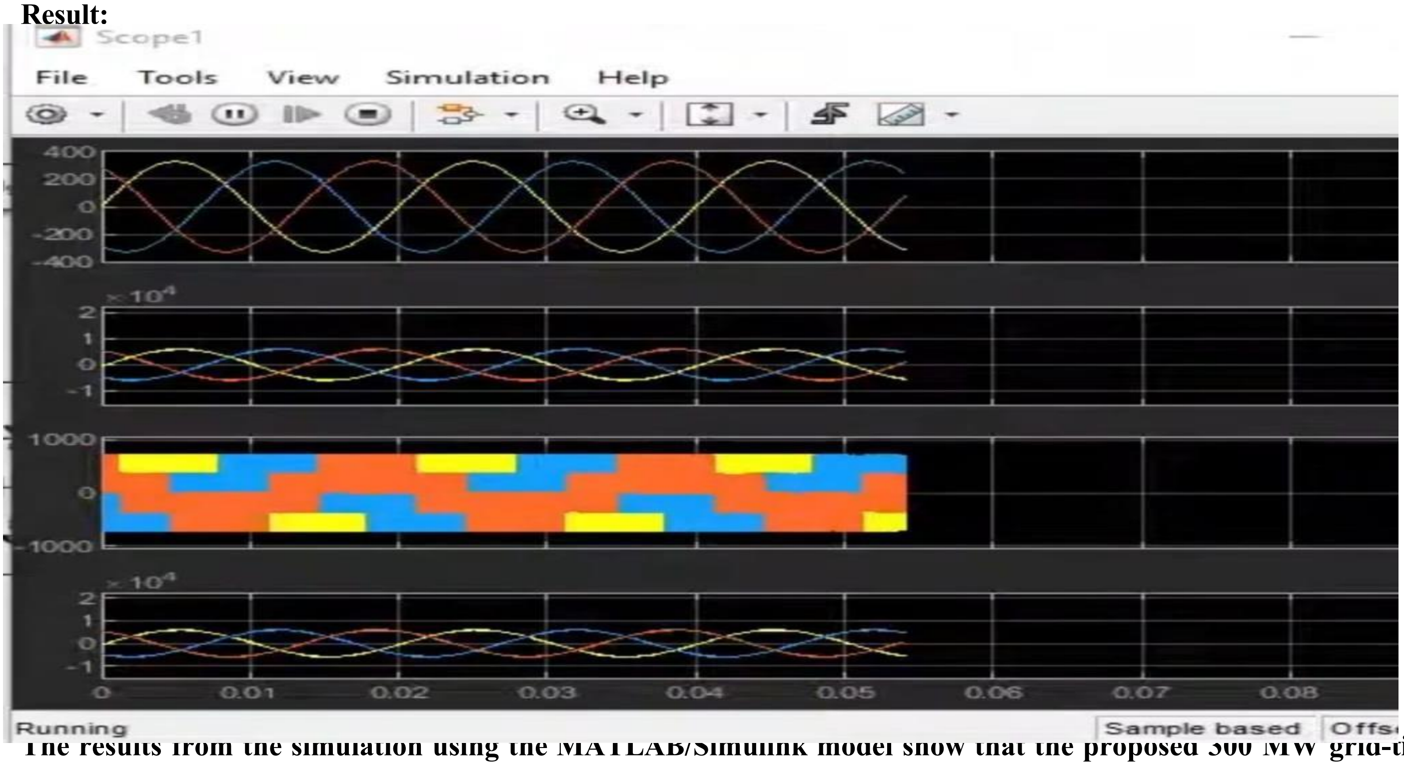
Four leg inverter:



In grid-connected systems the inverter is really important. It converts DC power from panels into AC power that can be used by the grid. Most grid-tied systems use three-leg inverters, which work fine when the load is balanced.In real-life distribution systems the load is often imbalanced. This means that one phase might have load than the others. When this happens current flows through the wire causing voltage distortion and reducing power quality. A standard three-leg inverter can't handle this imbalance well.To solve this problem we're using a four-leg inverter. This type of inverter has a leg that just for handling the neutral current. This makes the system work better especially in real-world grid applications. The four-leg inverter helps to improve power quality and makes the system more reliable.

International Journal of Science, Strategic Management and Technology
Volume 02 Issue 05 May-2026 | ISSN: 3108-1762 (Online) | Impact Factor: 3.8
An International, Peer-Reviewed, Open Access Scholarly Journal Indexed in recognized academic databases

Result:



The results from the simulation using the MATLAB/Simulink model show that the proposed 300 MW grid-tied solar photovoltaic system works well. This system uses a four-leg inverter topology. The waveforms shown in Fig demonstrate how the inverter performs when it is connected to the grid.The first waveform shows the three-phase output voltages from the inverter. These voltages are balanced and sinusoidal. They are also synchronized with the utility grid with each phase shifted by 120°. The voltages produced are stable. Have very little distortion. This shows that the control strategy used for the inverter is effective.

The second waveform shows the three-phase currents that the inverter sends to the grid. These currents are balanced and sinusoidal which means the inverter can deliver power efficiently while maintaining power quality. The harmonic content in the current is very low because the system uses pulse width modulation control and filtering. This makes sure the system meets the standards for connecting to the grid and makes it more reliable.The third waveform shows the pulses that control the switching of the switches. These pulses regulate how the switches work and control the conversion of DC power from the panels into AC power that can be used by the grid. The sequence of these pulses shows that the inverter is working stably and the signals that control the switches are being generated correctly.

The last waveform shows how the current on the grid side changes after it has been filtered. This current stays smooth and sinusoidal when the system is running steadily. The results show that the proposed four-leg inverter can balance out any unevenness in the system and make the grid- connected solar photovoltaic system more stable.Overall the simulation shows that the system designed can convert power efficiently reduce distortion improve the quality of the voltage and connect to the grid reliably. This makes it a good choice for generating power on a large scale. The 300 MW grid-tied solar photovoltaic system using a four-leg inverter topology is an option, for this. The solar photovoltaic system works with the four-leg inverter topology.

5. Advantages of the Proposed System

Using the four-leg inverter brings several practical benefits for large-scale grid-tied solar applications:

Better handling of unbalanced loads and neutral currents, which reduces voltage distortion and improves overall power quality.

Improved stability during grid faults or partial shading in the PV array.
Lower total harmonic distortion (THD) in grid currents, helping the system meet standards like IEEE 519.

Enhanced capability to support reactive power and voltage regulation at the point of common coupling.

Simpler control of zero-sequence components compared to three-leg designs, leading to more reliable operation in real-world weak grids.

In addition, the complete MATLAB-based simulation allows easy testing of different scenarios without building expensive hardware prototypes at this stage. The grid-tied configuration itself offers advantages like no need for large battery storage and the possibility of exporting excess power through net metering.

6. Conclusion

This project successfully demonstrates the design and simulation of a 300 MW grid-tied solar PV system incorporating a four-leg inverter. The results obtained from MATLAB/Simulink validate that the system maintains stable operation, achieves effective MPPT, and delivers good power quality

even under varying conditions. The four-leg topology proves particularly useful for managing unbalanced situations, which is a common challenge in high-power renewable integration.

The proposed can be scaled or modified for real plant implementation after hardware validation. Future work may include real-time controller testing using hardware-in-the-loop (HIL) setups, advanced control methods like model predictive control, and detailed economic analysis. Overall, this work contributes toward reliable and efficient large-scale solar power generation.

Key References

[1] The North African Journal of Scientific Publishing (NAJSP) Design and Implementation of Grid-Tied Solar PV Systems with Enhanced Efficiency Using MPPT Controllers Author-Abdullah Ghayth,Ziyodulla Yusupov E-ISSN: 2959-4820 Volume 3, Issue 2, 2025 Page No: 137-150

[2] Simulation of 4-Leg Inverter based APF for PV based System with Effective Controller Author- G.Divya, M. Lakshmi Swarupa, S. Sunanda, B. Sabitha E3S Web of Conferences 472, 03005(2024)

[3] A. K. Sharma and R. S. Yadav, "A review on the performance of boost converters for solar energy applications," Renewable Energy Reviews, vol. 45, pp. 482-494, 2023.

[4] Design, Modelling, and Analysis of Novel Solar PV System using MATLAB.
Ayan Banik , Anurag Shrivastava , Ravindra Manohar Potdar , Sanjiv Kumar Jain , Santosh Gopal Nagpure , Mukesh Soni Vol 51 part 1,2022,pages 756-763