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ANALYSIS AND COMPARISON OF MPPT TECHNIQUES IN PV SYSTEMS

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Abstract: This paper presents a comparative analysis of photovoltaic (PV) systems operating with and without maximum power point tracking (MPPT). The MPPT techniques considered are the Perturb and Observe (P&O) and Incremental Conductance (IC) algorithms. The objective is to evaluate and identify the algorithm that achieves higher efficiency in extracting maximum power from PV cells. A boost converter is employed to ensure impedance matching between the PV array and the load, thereby improving energy transfer. The systems—without MPPT, with P&O are modeled and simulated in MATLAB/Simulink, and their performance is analyzed under varying operating conditions.

***Index Terms* -** Photovoltaic system; maximum power point tracking (MPPT); Perturb and Observe; boost converter; MATLAB/Simulink.

I. INTRODUCTION

The increasing global energy demand driven by industrialization and population growth has led to significant investments in alternative energy solutions to address energy efficiency and power quality concerns. Among these, photovoltaic (PV) energy has emerged as a prominent resource, particularly in tropical and temperate regions where solar irradiance can reach up to 1000 W/m^2.

PV generation is gaining importance due to several advantages, including ease of deployment, high reliability, low maintenance requirements, operational flexibility, and the absence of moving parts, which minimizes noise and mechanical wear. Additionally, PV systems have applications such as desalination and distributed power generation. The conversion efficiency of PV cells typically ranges from approximately 18% for low-cost units to about 29% for high-efficiency modules. Furthermore, the declining cost of photovoltaic modules and modern power electronic systems is encouraging wider adoption and future large-scale installations.

However, PV generation is inherently intermittent and highly dependent on environmental conditions, which reduces its reliability as a standalone power source. To overcome these limitations, maximum power point tracking (MPPT) techniques are employed to ensure that the PV system operates at its optimal power point. This improves energy extraction efficiency and enhances both the steady-state and dynamic performance of the overall power generation system, enabling more stable and reliable power delivery to loads and the utility grid.

II. MPPT TECHNIQUES

Maximum power point tracking (MPPT) is a technique used to maximize energy extraction from renewable energy sources and is widely applied in photovoltaic (PV) systems.

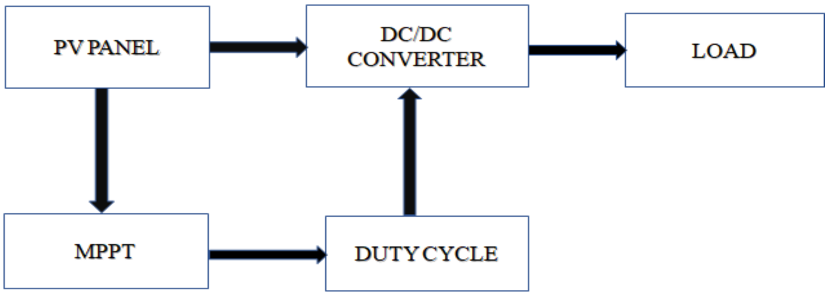

Fig1: Block Diagram of MPPT

In systems without MPPT, the PV panel output is directly connected to the load through a power converter, without any optimization of the operating point. Fig. 2 shows the Simulink model of the system without MPPT.

In contrast, in systems with MPPT, the PV panel output is first processed by an MPPT controller, which determines the optimal operating point. The controlled output is then supplied to the load through a power converter, enabling improved energy extraction and system performance.

Type of MPPT is:

- **Without MPPT**
- **Perturb & Observe (PO)**

A. Without MPPT.

To enhance the efficiency of photovoltaic (PV) systems, maximum power point tracking (MPPT) techniques are employed to ensure operation at the optimal power point under varying environmental conditions. The nonlinear characteristics of PV modules, influenced by solar irradiance and temperature, result in a unique maximum power point (MPP) on the power–voltage (P–V) curve. MPPT algorithms continuously track this operating point to maximize energy extraction and improve overall system performance.

B.Perturb & observe technique.

The Perturb and Observe (P&O) method is one of the most widely used MPPT algorithms in commercial photovoltaic (PV) systems due to its simplicity and ease of implementation. This method operates on a trial-and-error principle, where the PV controller perturbs the operating voltage or power reference and observes the resulting change in output power. If the output power increases, the controller continues to adjust the reference in the same direction. Conversely, if the output power decreases, the direction of perturbation is reversed to avoid operating away from the maximum power point (MPP). This iterative process enables the system to track the MPP under varying environmental conditions, although it may introduce small oscillations around the optimal point. Fig. 3 illustrates the Simulink model of the Perturb and Observe technique.

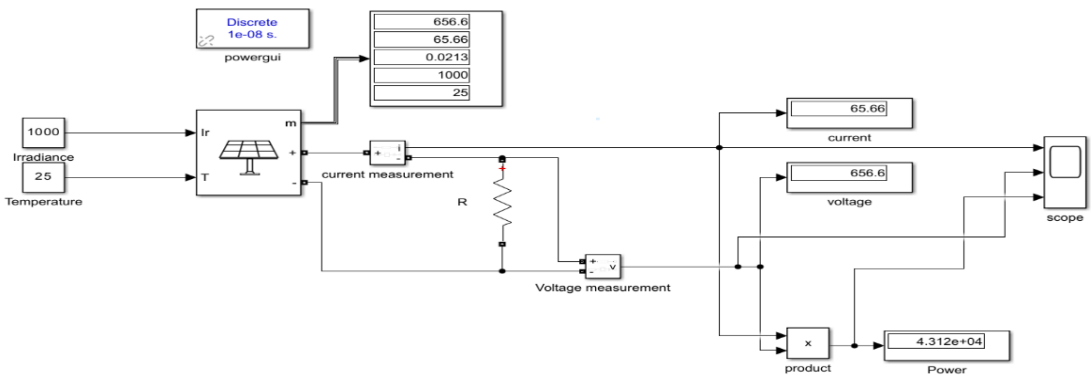

Fig.2. Shows the Without MPPT technique PV system.

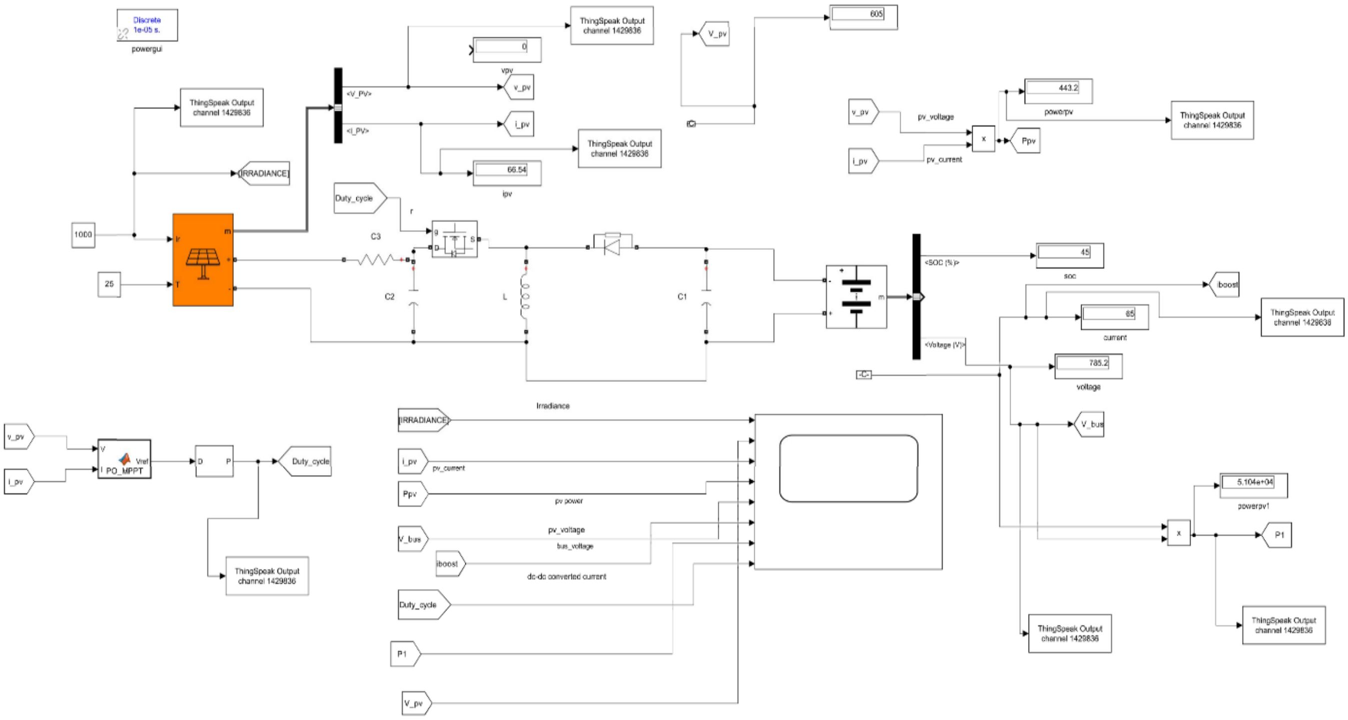

Fig.3. Shows the Perturb and Observe technique applied in PV system.

III. SIMULATION RESULTS

The simulation results of all two methods—without mppt, perturb & observe (P&O) and MPPT—are compared in this section. And the output waveforms are shown in figures.4, 5, 6, and 7. The output waveform of the 53kV grid-connected system's output is used as the foundation for comparison of the results. The findings of the study using Without MPPT and With MPPT approaches are compared in Table 1.

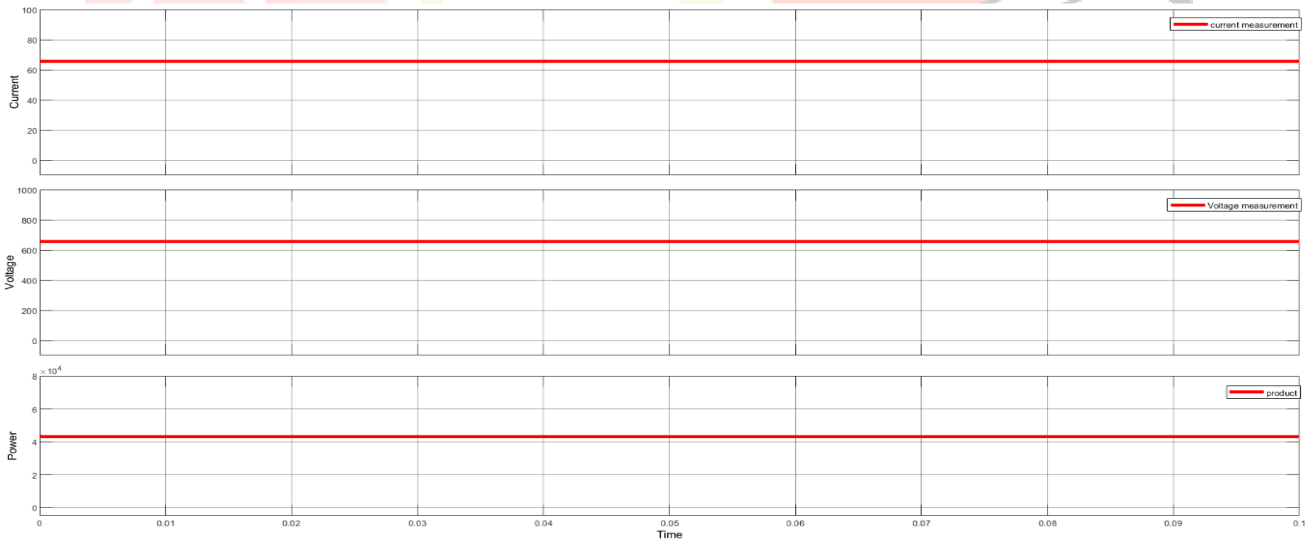

Fig.4. Output of PV model array without MPPT

In Fig.4. X axis consists of Time and Y axis consists of Power, Voltage and Current.

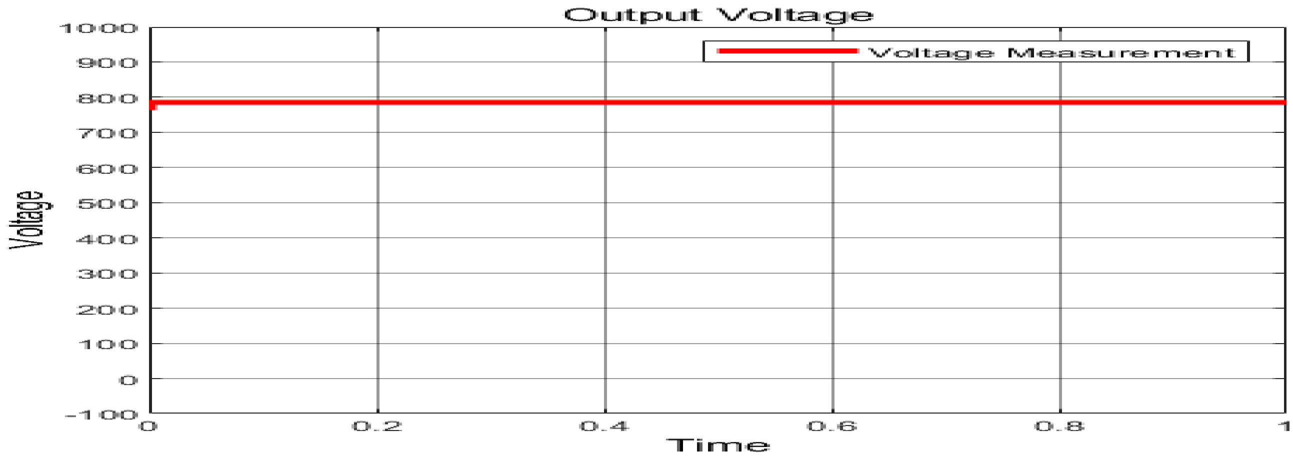

Fig 5: P&O output voltage

In Fig. 5. X axis consists of Time and Y axis consists of Voltage.

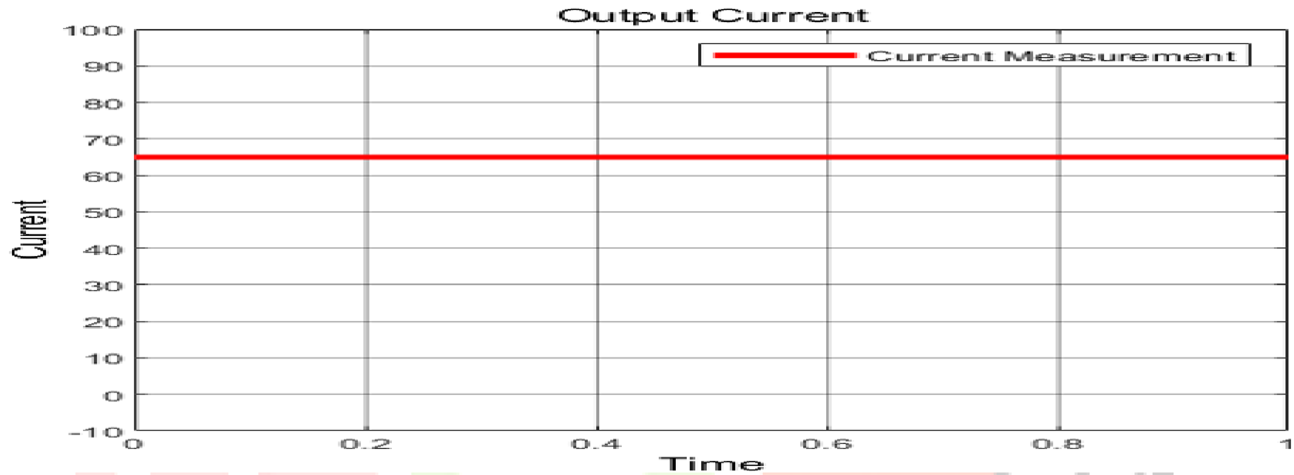

Fig.6. P&O Output current

In Fig. 6. X axis consists of Time and Y axis consists of Current.

Fig 7: P&O Output power

In Fig. 8. X axis consists of Time and Y axis consists of Power

TABLE: 1 COMPARING WITH AND WITHOUT MPPT TECHNIQUES.

Parameter	Without MPPT	P&O Technique
Current	65.66A	65A
Voltage	656.5V	785.02V
Power	43.11kW	51.04kW

IV. CONCLUSION

This work presents a comprehensive analysis of maximum power point tracking (MPPT) techniques in photovoltaic (PV) systems. The methods considered include Perturb and Observe (P&O) and operation without MPPT. The simulation results of the PV array are evaluated based on the load power at the converter output, and the system performance is analysed under grid-connected conditions using a boost converter.

The results indicate that the load power obtained using MPPT techniques is significantly higher than that obtained without MPPT. Among the evaluated methods, the P&O algorithm demonstrates superior performance compared to the system without MPPT. This is attributed to its faster convergence, low computational complexity, effective tracking capability, and satisfactory operating voltage adjustment, which collectively contribute to improved overall system efficiency.

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