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# Simulation of Solar PV with Maximum Power Point Tracking Techniques in Composite Climate

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**ABSTRACT:** Solar photovoltaic (PV) systems are widely used for power generation however, their performance degrades under dynamic climatic conditions such as variations in solar irradiance and temperature. To address this issue, Maximum Power Point Tracking (MPPT) techniques are employed to ensure maximum power extraction. In this study, two MPPT methods are analysed a conventional Perturb and Observation (P&O) technique and an adaptive method based on Fuzzy Logic Control (FLC). While adaptive techniques such as FLC and Artificial Neural Networks (ANN) offer improved accuracy and faster convergence, they require higher computational resources. Since the output of a solar PV system is highly dependent on climatic conditions, climate analysis has been incorporated into the computational modelling to optimize input parameters and achieve desired performance. A building-level case study has been conducted to evaluate the feasibility of installing a solar PV plant. The study includes annual energy generation assessment, techno-feasibility analysis, and financial evaluation. Furthermore, a MATLAB-based model of a grid-connected solar PV system integrated with MPPT control strategies has been developed to analyse system performance under varying environmental conditions.

**KEYWORDS:** Maximum Power Point Tracking MPPT, Perturbation & Observation P&O, Fuzzy Logic Control, Artificial Neural Networks (ANN).

## I.INTRODUCTION

Energy not only plays an important role in our life but also in the overall economy of the country. The requirement for energy is increasing in our daily life due to the industrial revolution. In the most developing country like India, the large share of energy generation mainly depends upon non-renewable energy sources. The gradual depletion of these sources such as fossil fuels, oils, etc. leading the developing countries towards the un-sustainability of civilization. Along with that, the generation of energy through conventional sources is also a reason for greenhouse gases. It has become a global challenge to reduce the emission of greenhouse gasses like CO<sub>2</sub> and CO<sub>3</sub> to ensure secure, clean, and affordable energy. Whereas clean and sustainable energy is perfectly generated through renewable energy sources [1]. There are many renewable sources of energy such as solar energy, wind energy, Hydro energy, etc. The Photovoltaic (PV) system is the most efficient renewable source of energy which has taken the great attention of the researchers. As we know that as per the current energy scenario the lifestyle of the developing countries and developed countries as well facing the energy supply demand strain. The fulfilment of the power supply majorly depends upon the thermal based power plants and that is the main reason behind global warming. So many international organisations and government working hard to move towards the renewable source of energy for the fulfilment of the power supply that may be any form like solar energy, wind energy, hydropower and bio gas etc. Since all the renewable sources of energy has a shortcoming that it depends upon climatic conditions as well as locations like in coastal regions wind turbine based energy source has a better performance and in the mountain regions has better capacity for hydropower and likewise solar energy depends upon solar radiations upon climate and location where the sunny days will be more with better solar irradiance.

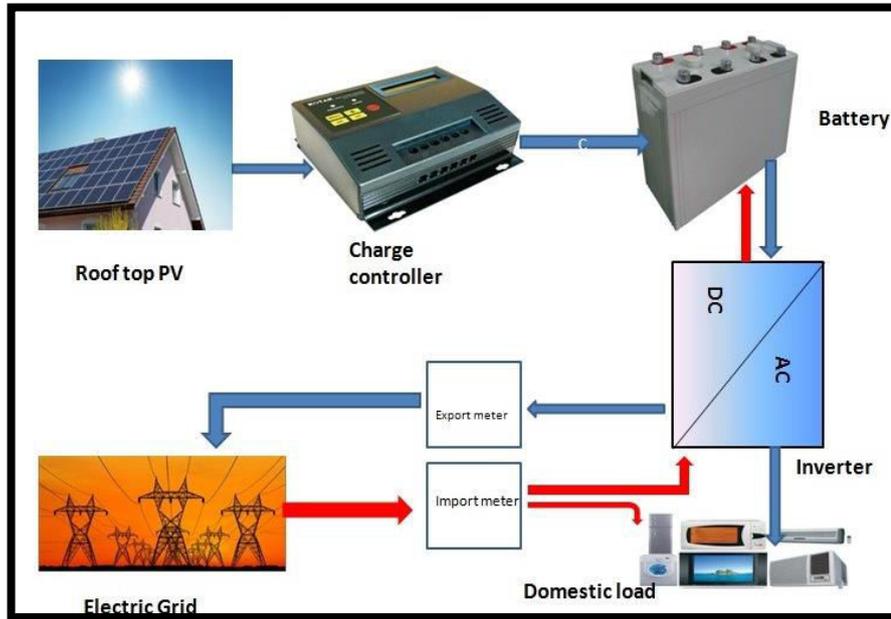


Fig -1: Solar PV with hybrid battery and inverter

## II. MAXIMUM POWER POINT TRACKING SYSTEM

Many researchers have done a lot of work in improving array configuration, parameter evaluation and also in the field of improvement of MPPT. Due to non-linearity of radiations the maximum power point tracking is the only method to improve the desired output. Depending upon the environmental conditions the location of MPPT changes. The purpose of role of various algorithm is to control the duty cycle. The major aim is to extract the maximum power from the solar PV array.

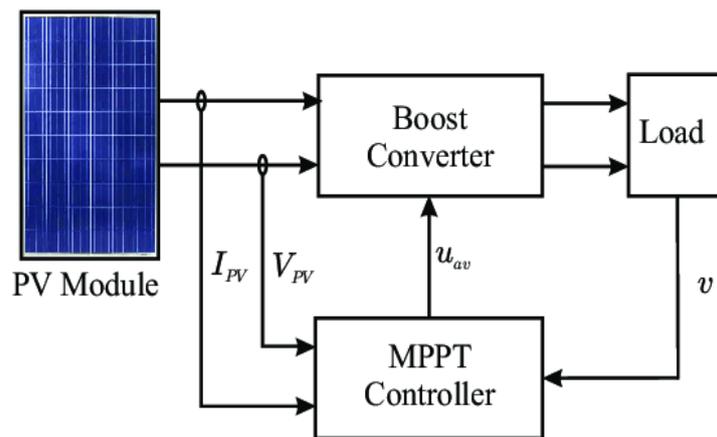


Fig. 2 Maximum Power Point Tracking

The **P–V (Power–Voltage) characteristic curve** of a PV panel has a unique point called the **Maximum Power Point (MPP)** where the product of voltage and current is maximum.

Without MPPT:

- The PV system may not operate at its optimal point.
- Power losses of 10–30% can occur.

With MPPT:

- The operating point is continuously adjusted.
- Maximum available power is delivered to the load or grid.

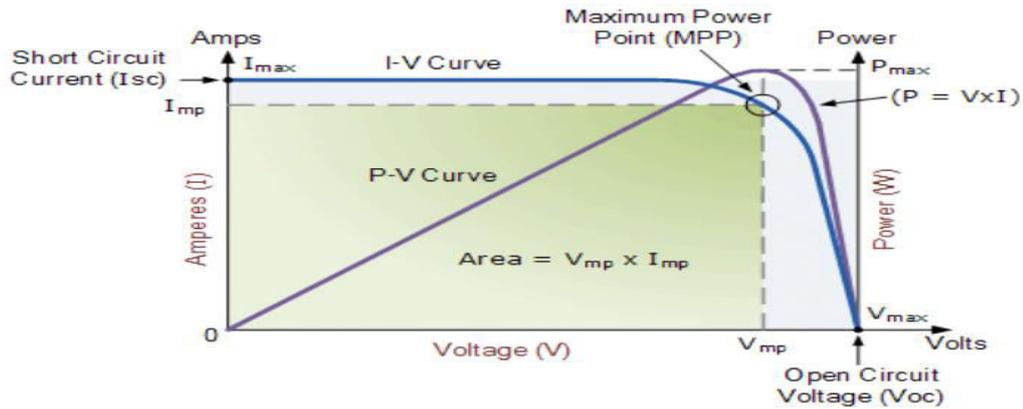


Fig. 3 PV Characteristics of Solar PV

### III. PERTURBATION & OBSERVATION METHOD

The Perturbation and Observation (P&O) method, also called the Hill-Climbing algorithm, is one of the most widely used techniques for Maximum Power Point Tracking (MPPT) in solar photovoltaic systems. In this method, the controller periodically perturbs (slightly increases or decreases) the operating voltage of the PV array and observes the resulting change in output power. If the perturbation causes the power to increase, the controller continues perturbing in the same direction. If the power decreases, the direction of perturbation is reversed. By continuously comparing the change in power ( $\Delta P$ ) with the change in voltage ( $\Delta V$ ), the system gradually moves toward the Maximum Power Point (MPP). At the MPP, any small perturbation results in a reduction in power, causing the operating point to oscillate slightly around the maximum power. The P&O method is simple, easy to implement, and requires low computational resources, making it suitable for low-cost applications. However, its main drawback is steady-state oscillation around the MPP and reduced accuracy under rapidly changing irradiance conditions.

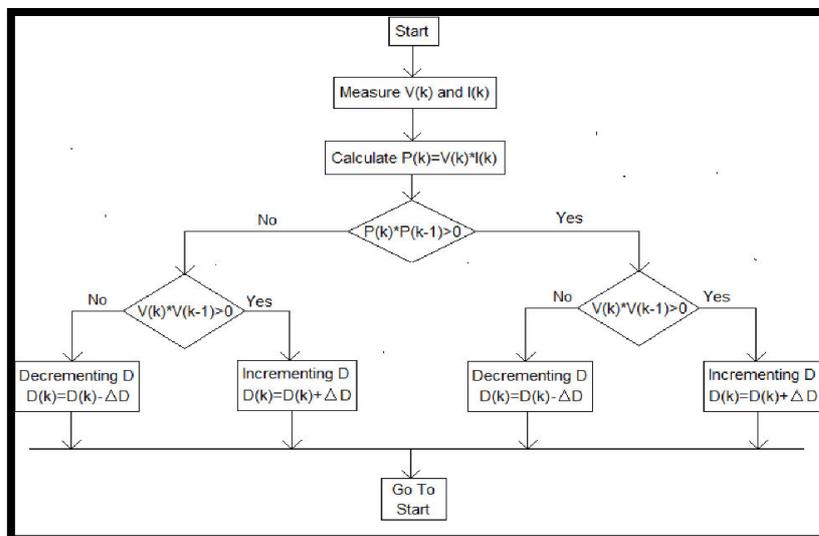


Fig. 4 Flowchart of P&O Method

#### IV. FUZZY LOGIC CONTROL

A Fuzzy Logic Control (FLC) system is a smart control approach that mimics human decision-making instead of relying strictly on mathematical equations. It is especially useful in systems where operating conditions change frequently, such as solar photovoltaic (PV) systems. In Maximum Power Point Tracking (MPPT), fuzzy logic helps adjust the operating point of the PV panel so that maximum power can be extracted under varying sunlight and temperature conditions. Rather than working with exact numerical thresholds, fuzzy logic uses descriptive terms like low, medium, or high to evaluate system behaviour. The controller generally uses two input signals: the error (which indicates how far the system is from the maximum power point) and the change in error (which shows the trend of movement). These inputs are first converted into fuzzy values through membership functions. Then, a set of predefined IF-THEN rules determines the appropriate control action. Finally, the fuzzy result is converted back into a precise output signal that adjusts the duty cycle of the DC-DC converter. Fuzzy logic controllers respond quickly to environmental changes and significantly reduce steady-state oscillations near the maximum power point. Although they require careful design of rules and membership functions and involve slightly higher computational effort, they provide better accuracy and stability compared to traditional MPPT techniques.

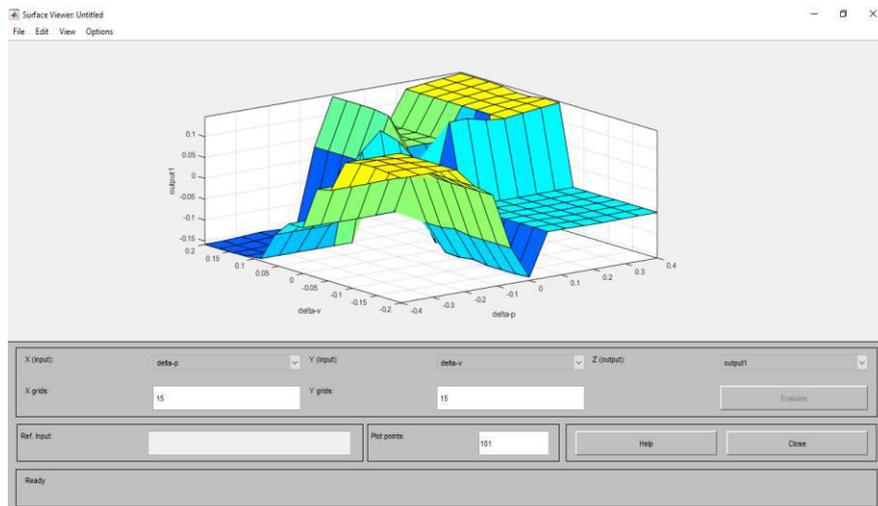


Fig. 5 Surface View

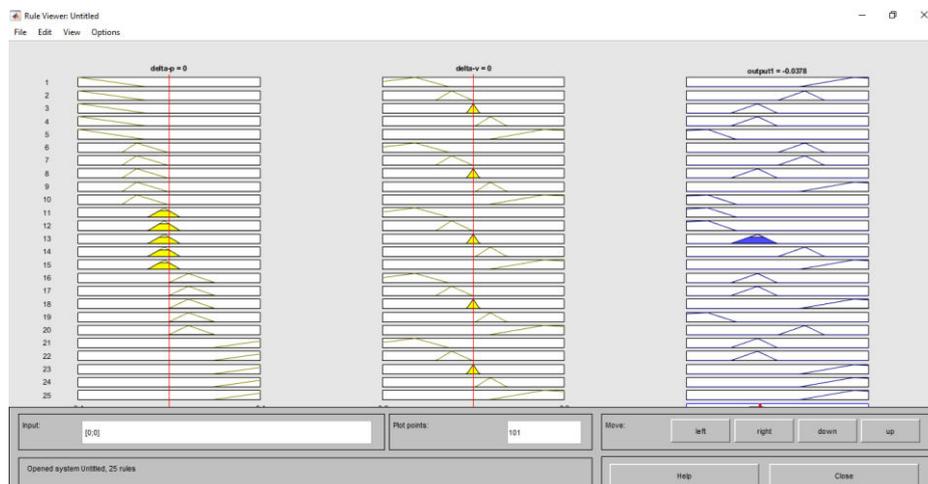
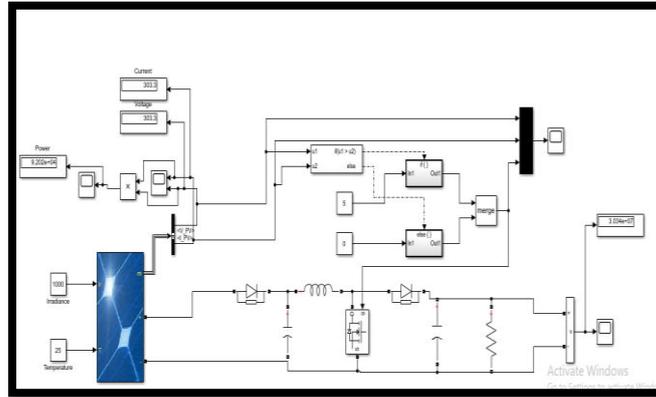
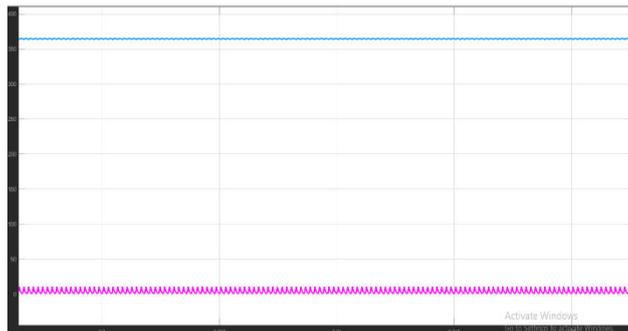


Fig. 6 Rule View

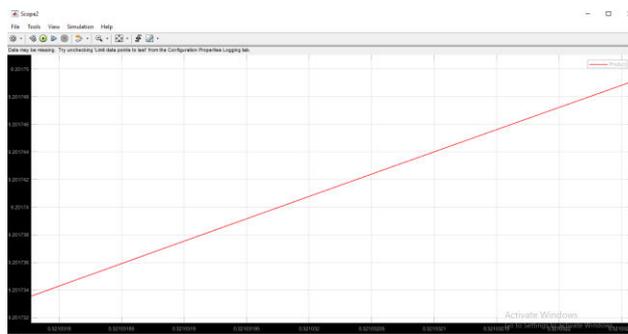
**V. RESULT AND DISCUSSION**



**Fig. 7 Solar PV with P&O Method**



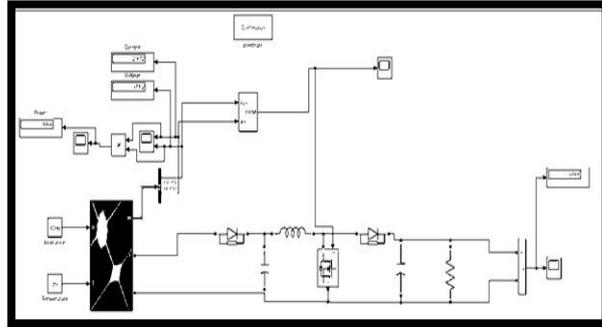
**Fig. 8 Voltage and current**



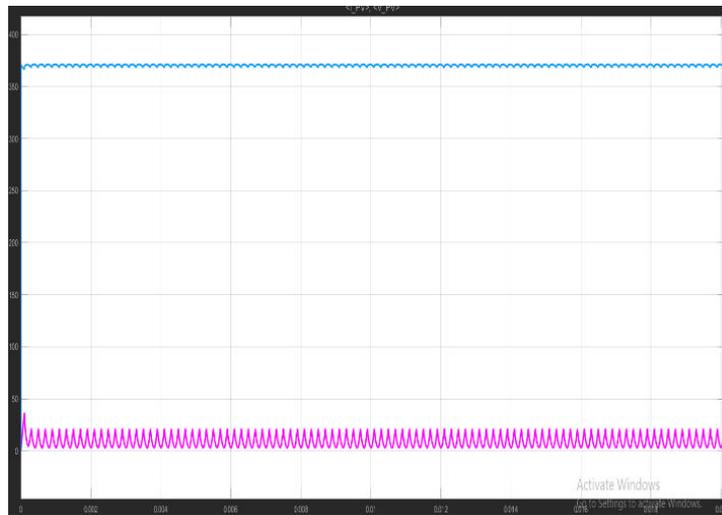
**Fig. 9 Output Power**

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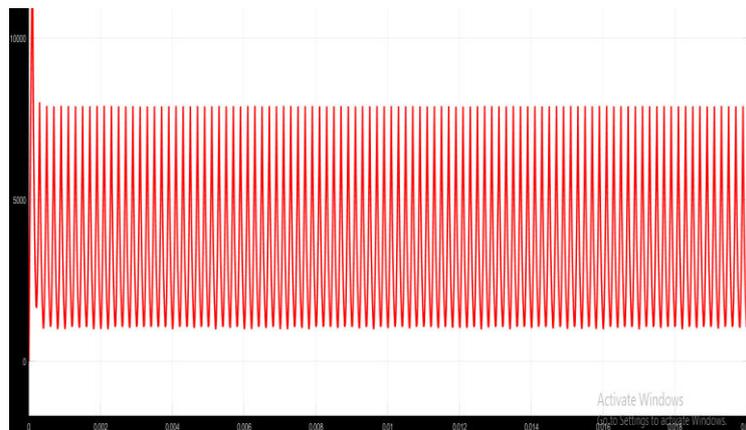
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**Fig. 9 Solar PV with Fuzzy**



**Fig. 10 Voltage and Current output**



**Fig. 11 Output Power**

### SYSTEM INFO

Modify the inputs below to run the simulation.

DC System Size (kW):	<input type="text" value="150"/>	
Module Type:	<input type="text" value="Standard"/>	
Array Type:	<input type="text" value="Fixed (open rack)"/>	
System Losses (%):	<input type="text" value="14.08"/>	
Tilt (deg):	<input type="text" value="20"/>	
Azimuth (deg):	<input type="text" value="180"/>	

Fig. 12 System Info

### RESULTS

Print Results

**224,348 kWh/Year\***

Month	Solar Radiation (kWh / m <sup>2</sup> / day)	AC Energy (kWh)
January	5.90	20,656
February	6.45	20,120
March	6.87	22,953
April	6.84	21,791
May	6.43	21,238
June	4.74	15,426
July	4.01	13,666
August	3.79	13,071
September	4.78	15,855
October	5.72	19,724
November	5.84	19,882
December	5.66	19,965
<b>Annual</b>	<b>5.59</b>	<b>224,349</b>

Fig. 13 Annual generation from 150 KW

In this work, a solar photovoltaic (PV) system integrated with Maximum Power Point Tracking (MPPT) techniques has been designed and analysed. Both conventional and adaptive MPPT methods were considered. The conventional techniques include the Perturb and Observe (P&O) method and the Incremental Conductance (INC) method. The system model was developed in MATLAB/Simulink, where the P&O algorithm was implemented for MPPT control. In addition, the same PV system was integrated with a Fuzzy Logic Control (FLC)-based MPPT approach, representing an adaptive method. In the fuzzy controller, the rule base can be customized according to specific climatic conditions, improving adaptability and performance. For practical validation, an educational-category building located in Bhilai, Chhattisgarh (a composite climate region) was selected as the study site. The simulation results successfully generated output waveforms of voltage, current, and power, demonstrating proper operation of the PV system under different conditions. Following simulation, practical implementation was carried out at the selected institutional building. The results indicate that the fuzzy logic controller provides faster dynamic response and better tracking performance compared to the conventional P&O method. However, the implementation cost and computational complexity of the fuzzy system are higher than those of the P&O technique.

Calculation for 150Kwp Solar Roof Top Savings		Units
Total kWp potential	150	Kw
Solar PV Panel Efficiency	16%	
Annual Energy Generation	2,24,348	Kw
Cost per kWp	50,000	Cr
Total capital cost for proposed Solar PV plant	75,00,000	Cr
Electricity cost per kWh	7.00	Cr
Total cost saving	15,70,436	Years
Payback period	4.77	%

Fig. 14 Overall calculation for 150 KW Roof top solar

## VI. CONCLUSION

Table 1 – Comparison of MPPT methods

Method	Complexity	Accuracy	Speed	Cost
P&O	Low	Moderate	Medium	Low
INC	Medium	High	High	Medium
FLC	High	Very High	Fast	High
ANN	Very High	Very High	Very Fast	High

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