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Comparison of Incremental Conductance and Perturb and Observe Techniques of Maximum Power Point Tracking for PV Systems

Nigam Bam Malla[1*], Vision Parajuli[2]

[1,2]Department of Electrical Engineering, IOE, Paschimanchal Campus, Tribhuvan University, Nepal.*

Email: [2]pas074bel048@wrc.edu
Corresponding Email: [1]nigammalla@gmail.com*

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***Abstract:** The unceasing increase of the global energy call is linked with societies increasing awareness of the environmental effects of the extensive fossil fuels utilization. It has directed to the search for renewable energy sources, like as photovoltaic (PV) technology. The power from solar PV is connected directly to loads or fed to the grid. In general PV system is considered initially more expensive, however, it is the best suitable solution for standalone systems. With the developments in PV technologies, their applications increase rapidly, and grid-connected PV systems become popular. It indicates that PVs are more attractive to produce environmentally friendly electricity for various purposes. This research paper presents a comparison of incremental conductance (IC) and perturb and observe (P&O) in grid-connected PV. The study begins by providing a background on MPPT and the two specific techniques being evaluated. The P&O technique perturbs the voltage of PV array and notices the response in power output, while the IC method implements the slope of the power-voltage curve to incrementally adjust the operating point. At the end, it was observed that the INC MPPT technique accomplished maximum power point quickly. Similarly, there was less fluctuation in I&C method than in P&O method. The paper concludes that the IC method is a more appropriate choice for MPPT in grid-connected PV systems due to its superior performance and robustness.*

***Keywords:** IC, MPPT, P&O, PV.*

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1. INTRODUCTION

Photovoltaic (PV) systems are one of the most promising renewable energy sources that can help reduce greenhouse gas emissions and fossil fuel dependence. However, PV systems have some challenges, such as the high cost and low efficiency of PV modules, and the variability of solar irradiance and temperature that affect the output power of PV systems. Therefore, it is essential to optimize the performance of PV systems by using maximum power point tracking (MPPT) techniques that can adjust the operating point of the PV modules to match the maximum power point (MPP) under different environmental conditions (Elbarbary & Alranini, 2021). MPPT techniques are algorithms that control the duty cycle of a DC-DC converter connected between the PV modules and the load or grid. By changing the duty cycle, the MPPT techniques can regulate the input voltage or current of the converter to achieve the MPP of the PV modules. There are many MPPT techniques proposed in the literature, such as perturb and observe (P&O), incremental conductance (INC), fuzzy logic, neural network, etc. Each technique has its own advantages and disadvantages in terms of tracking speed, accuracy, complexity, and cost (Selman et al., 2016). Among the various MPPT techniques, P&O and INC are two of the most widely used methods due to their simplicity and effectiveness. P&O is a hill-climbing method that perturbs the PV voltage or current periodically and observes the change in power. If the power increases, it continues to perturb in the same direction; otherwise, it reverses the direction. INC is a method that calculates the incremental and instantaneous conductance of the PV module and compares them to find the MPP. Both methods have been extensively studied and implemented in different PV systems (Elzalik et al., 2013). However, there is still a need for a comprehensive comparison between P&O and INC methods under various operating conditions and scenarios. The main objective of this paper is to compare P&O and INC methods. The paper also presents a simulation model of a PV system with P&O and INC methods using MATLAB/Simulink software. The simulation results show the performance of both methods under different conditions.

2. MATERIALS AND METHODS

2.1 Matlab/Simulink

MATLAB is a high-level interactive environment for programming, numerical computation and visualization and programming language. SIMULINK is a block diagram-based simulation tool that is integrated with MATLAB, allowing for the modeling, simulation, and analysis of complex systems. Both are widely used in industries such as aerospace, automotive, communications, and finance for data analysis, algorithm development, and model-based design.

2.2 PV Array

The value of Irradiance and Temperature is fed to the Ir and T section of the Panel. The irradiance value fed is 1000 w/m^2. Similarly, the value of temperature is 50°C. The voltage-characteristic equation of solar cell is provided as (Tu and Su 2008; Salmi et al. 2012): Module photo-current I_{ph}:

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$$I_{ph} = [I_{sc} + K_i(T - 298)] * I_r/1000 \quad (1)$$

Where, I_{ph} = Photo-current (A); I_{sc}= short circuit current (A); K_i= short-circuit current; T= Operating temperature; I_r = Solar Irradiation in W/m^2.

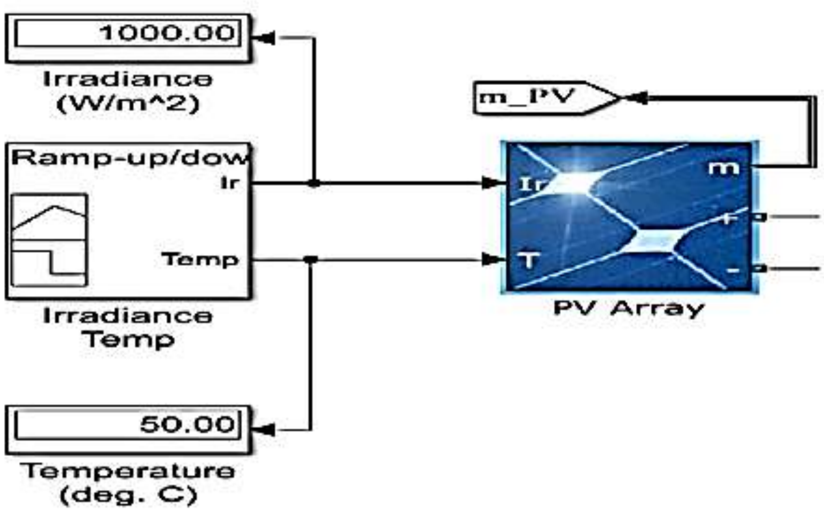

Figure 1. PV Array Design

The value of parameters fed to the solar panel and model of solar panel is tabulated below in the table 1.

Table 1. PV Parameters (De Brito et al., 2011)

Module	**Sun Power SPR-305E-WHT-D**
Power (Maximum)	305.226 watt
Voc (Temperature Coefficient) in(%/°C)	-0.27269
Open circuit Voltage (Voc)	64.2
Cells per module (Ncell)	96
Voltage at Peak power point	54.7
Temperature Coefficient of Isc (%/°C)	0.061745
Current at Peak Power point Imp(A)	5.58
Short Circuit Current Isc(A)	5.96

2.3 Boost Converter

The modeling is done based on the boost converter circuit diagram. In the modeling, the boost converter boosts DC voltage from 270 to 500. This converter implements an MPPT system which mechanically alters the duty cycle to yield the required voltage to calculate peak power.

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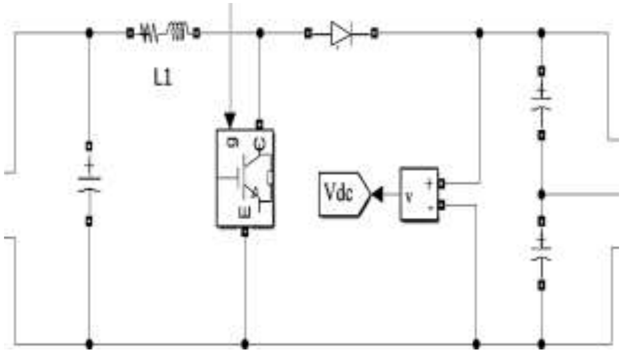

Figure 2. DC to DC Boost Converter

Table 2. Boost Converters Parameters

Resistance	0.005Ω
Inductance	5e-3 H
Capacitance	100e-6

2.4 Flowchart of P&O Method

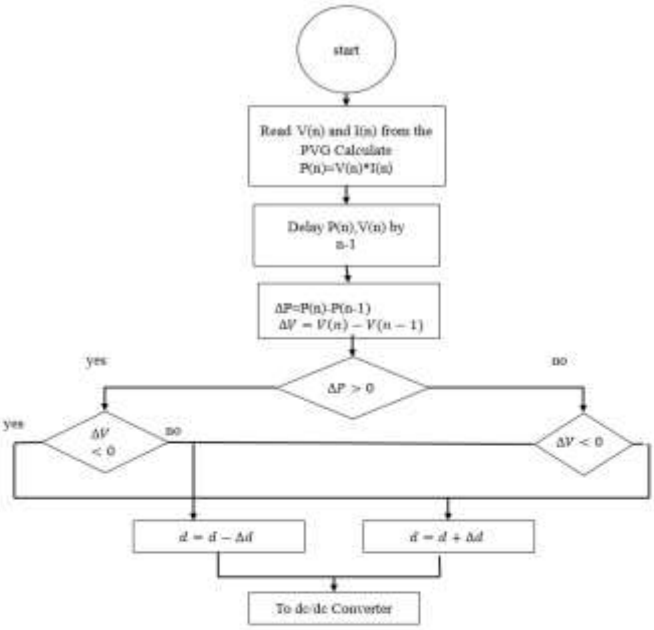

Figure 3. P&O Method Flowchart (Rana et al. (2016))

The P&O algorithm flowchart is demonstrated in Figure 3; initially, the current and voltage from the PV array are calculated. Then, the current and voltage product gives power of PV module. After that status of power will be investigated to look if P equals 0 or not. If this criterion is met, the MPP converts the operating point. If it isn't sufficient, it begins the search for next state where P > 0. If this condition is met, it will examine to look if V > 0.

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If it is satisfied, it meant that the operational point is on the MPP left side. If V > 0 criterion is not fulfilled, the condition is reversed.

2.5 Flowchart of IC Method

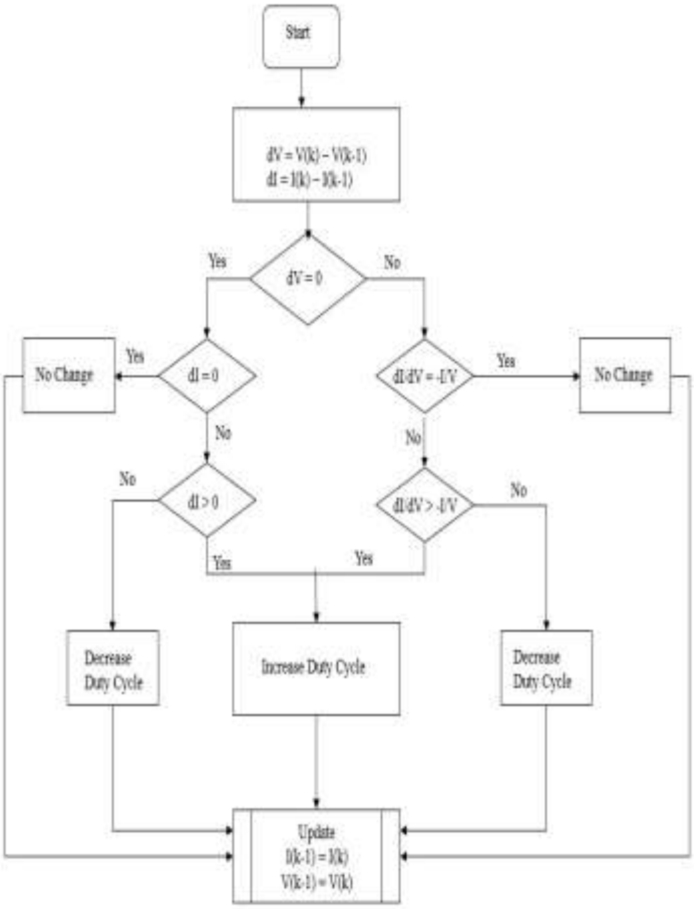

Figure 4. Flowchart of IC Method (Rana et al. (2016))

The P&O algorithm flowchart is depicted in Figure 4. This technique implements the incremental conductance (ΔI/ ΔV) of PV array to determine the power variation sign regarding voltage (ΔP/ ΔV). By contrasting the array conductance (I/V) with the incremental conductance (ΔI/ ΔV), the INC method finds the highest point of power. The affair voltage is the MPP voltage when these two are identical (ΔI/ ΔV = I/ V). This voltage remains constant by the regulator until the irradiation shifts and the process begins again. The INC algorithm is relevant on the assumption that P/V = 0 and P = VI at the maximum power point.

2.6 Integration of PV with Converter and MPPT

The MPPT implementation in MATLAB is done following the flowchart of IC and P&O methods as shown in Figures 3 and 4.

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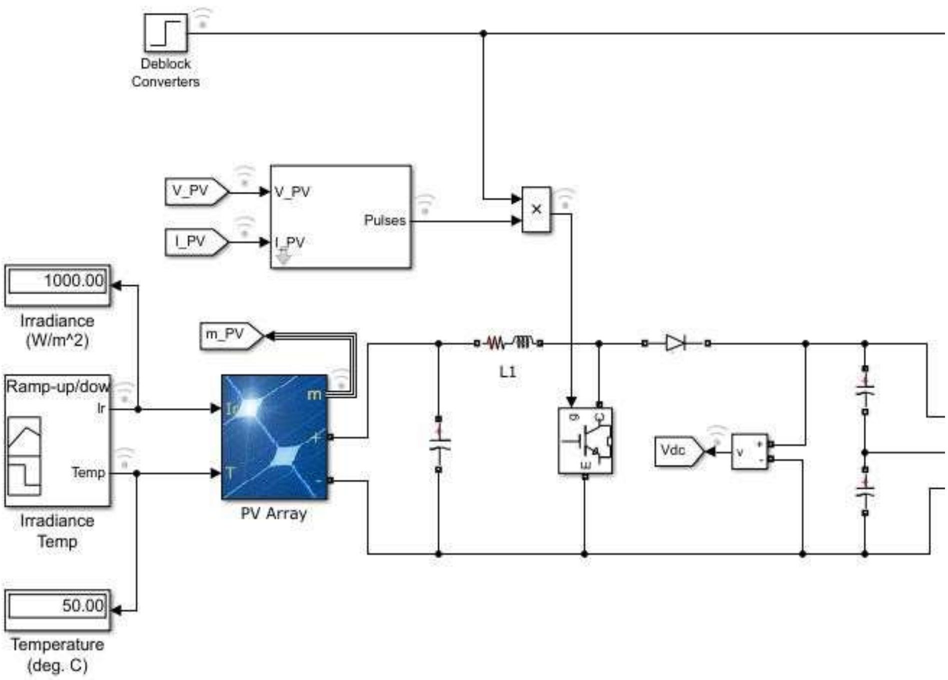

Figure 5. Integration of MPPT with PV Panel and Boost Converter

2.7 VSC Controller

The three-level VSC converter, whose Simulink implementation is shown in Figure below, maintains a unity power factor while regulating dc bus voltage at 500V.

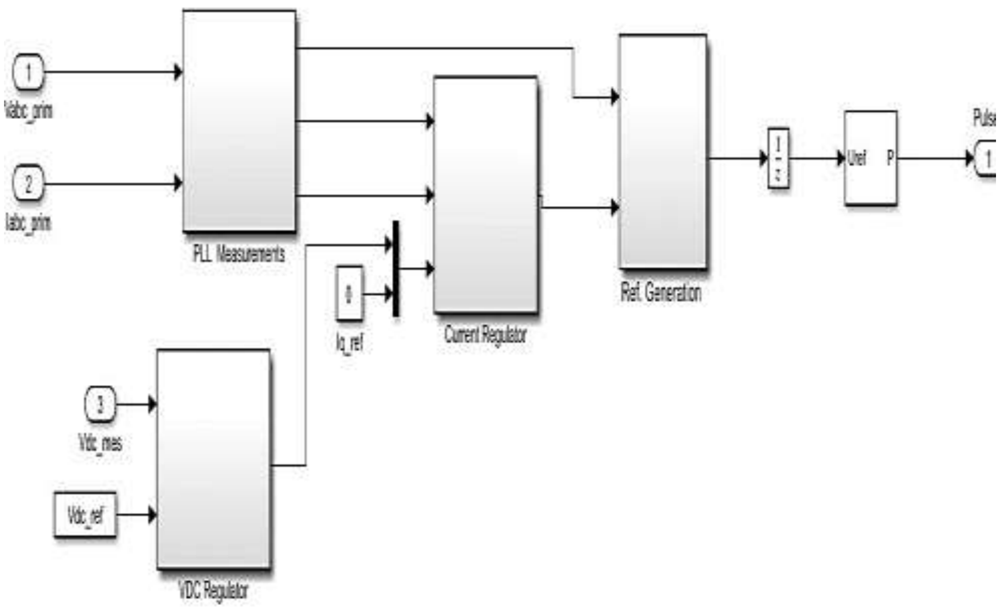

Figure 6. VSC Main Controller

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3. RESULT AND DISCUSSION

3.1 Power Comparison

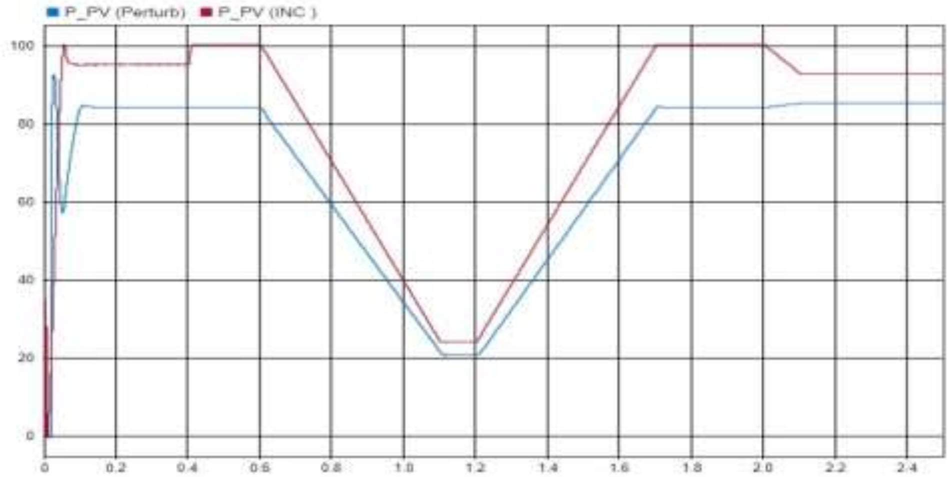

Figure 7. Comparison of PV Power

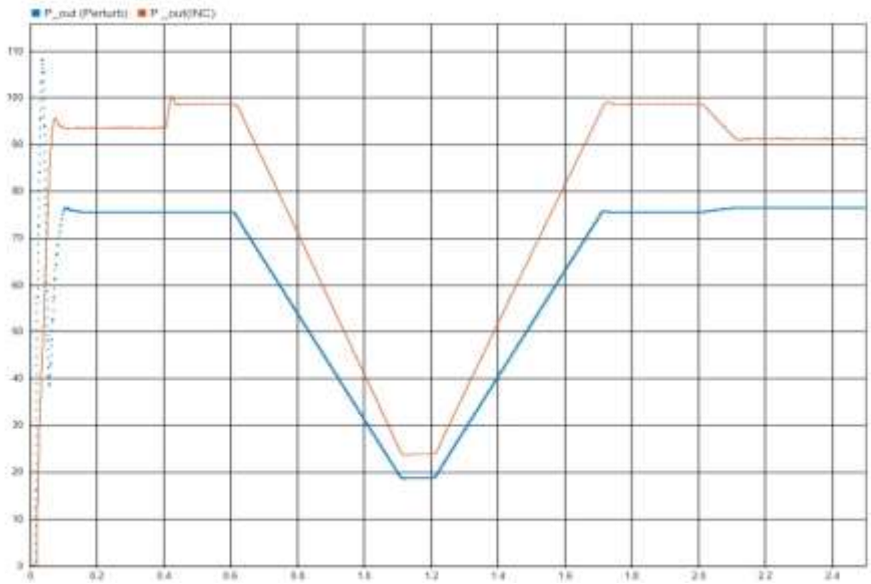

Figure 8. Comparison of Output Power

In Figure 7, the power extracted from the PV module is converted. Similarly, in Figure 8 the output power is compared. From the simulation graph of the I&C Method, it is evident that it attains maximum power that is 100 W at t= 0.072 seconds which is comparatively faster. Similarly, the variation of Power is proportional to Irradiance. In P&O Method the output power is not proportional to irradiance. Similarly, it attains maximum power slower than that of the I&C Method which is at t= 0.394 seconds. Hence, it can be concluded that the incremental conductivity method is more efficient at locating the maximum power point.

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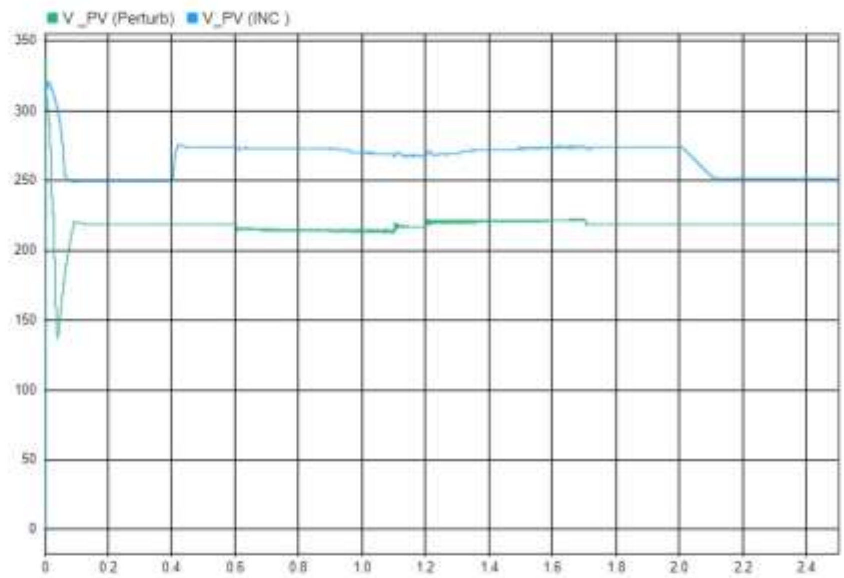

Figure 9. PV Voltage Comparison

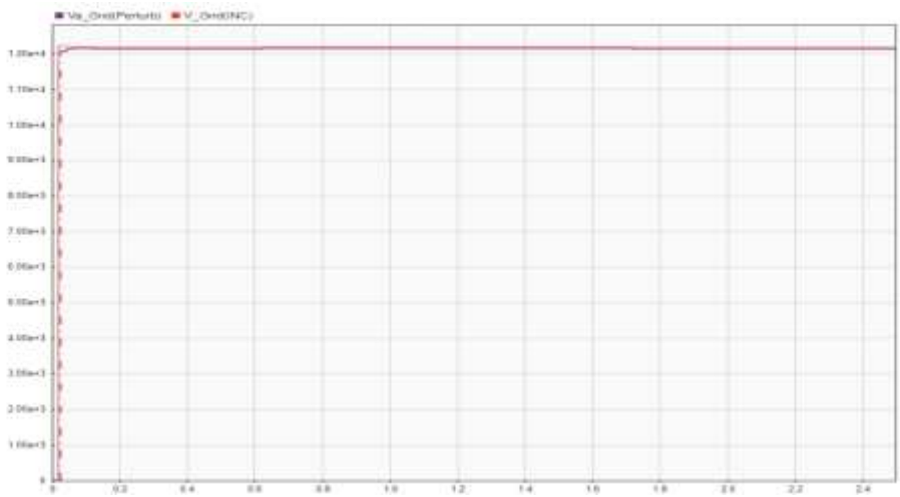

Figure 10. Voltage to Grid Comparison

From figures 9 and 10, it is evident that the voltage in the I&C method doesn`t oscillate about a maximum power point but the voltage in the P&O technique oscillates near the peak power point. Therefore, the voltage in the I&C method doesn`t fluctuate whereas the voltage fluctuates in the P&O method. Therefore, I&C is preferable to the P&O method.

Table 3. Comparison between INC and P&O

MPPT Techniques	Voltage from PV (V)	Power from PV (kW)	Power Output (KW)
INC Method	251.54	92.89	91.25
P&O Method	218.84	85.31	76.5

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The INC method wring out the most power possible from the solar panel than the P&O technique. This is because the P&O method is affected by the varying atmospheric conditions. From the output obtained from our project, it is evident that the INC Method excels in every aspect. In P&O Method, step size control is difficult. There is a slow reach to MPP in the P&O method.

4. CONCLUSION

The simulation outcomes proved that the IC method had a quicker tracking speed and lower power loss related to the P&O technique. The IC method efficiency was also slightly greater than that of the P&O method. In conclusion, the IC method is a more efficient and effective technique for grid-connected PV systems MPPT equated to the P&O method. The IC method has quicker tracking speed, lower power loss, and higher efficiency than the P&O approach.

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