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International Journal of Current Research

Vol. 16, Issue, 05, pp.28486-28493, May, 2024

DOI: https://doi.org/10.24941/ijcr.47129.05.2024

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

MPPT TECHNIQUES BASED DC-DC BOOST CONVERTER FOR GRID CONNECTED PHOTOVOLTAIC SYSTEM

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ARTICLE INFO

Article History:
Received 20th February, 2024
Received in revised form
25th March, 2024
Accepted 14th April, 2024
Published online 30th May, 2024

Key words:

Photovoltaic (PV), DC-DC Converter, Incremen-tal Conductance (INC), Maximum Power Point Tracking (MPPT), and Perturb and Observe (P&O).

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ABSTRACT

Solar photovoltaic systems play a pivotal role in renewable energy generation, offering a sustainable and envi- ronmentally friendly alternative to conventional power sources. Maximizing the power output of photovoltaic arrays is essential for unlocking their full potential as renewable energy sources. Maximum power point tracking methods continuously monitor and adjust the PV array's operating point to track the maximum power point on the voltage-current curve, thus boosting system efficiency. This paper explores the utilization of maximum power point tracking techniques to optimize the performance of solar photovoltaic systems. The integration of a DC-DC boost converter facilitates this process by dynamically adjusting the voltage in response to variations in temperature and irradiance levels, ensuring optimal power extraction from the solar array.In this paper, the two commonly employed algorithms such as incremen-tal conductance and perturbation and observation, are discussed for their effectiveness, adaptability and ease of implementation even under light and wind speed variations.

Citation: Rama Devi Neerukonda, Anunsha Kandi, Venkata Mallikarjun Reddy Kuppireddy, Sampath Komu, and Swathi Chunduru. 2024. *"MPPT Techniques Based DC-DC Boost Converter For Grid Connected Photovoltaic System". International Journal of Current Research, 16, (05), 28486-28493.*

INTRODUCTION

In the quest for sustainable energy solutions, photovoltaic (PV) systems have emerged as a promising avenue, harnessing the abundant and renewable energy from the sun. However, to fully leverage the potential of solar energy, efficient power conversion techniques are essential, especially in grid-connected setups. This introduction delves into the significance of Maximum Power Point Tracking (MPPT) techniques and the pivotal role of DC-DC Boost Converters in optimizing power extraction from PV arrays for grid integration. Maximum power point trackers are necessary for photovoltaic generating systems since the operational terminal voltage and current determine the PV array's output. The voltage and internal resistance of the array both fluctuate in response to variations in the amount of light falling. When exposed to homogeneous irradiance, a photovoltaic (PV) array displays a current-voltage characteristic with a distinct point known as the maximum power point (MPP), at which the array generates its maximum output power (Liu, 2002). In order to modify the internal resistance by altering the duty cycle using the MPPT algorithm, a dc-dc converter is integrated between the SPV array and the load (Rahul Suryavanshi, 2012). Maximum power point tracking (MPPT) can be implemented using a variety of techniques, including DSP-based algorithms, fuzzy logic, neural networks, P&O, PSO, incremental conductance (INC), and pilot cells. P&O and INC procedures are commonly employed, particularly because of their low cost. A drawback of MPPT technique is that the operating point oscillates around the MPP giving rise to the waste of some amount of available energy. Several improvements ofthe P&O algorithm have been proposed in order to reduce oscillation and improve the efficiency of the system (Batarseh, 2003). The foundation of the suggested incremental conductance approachis the idea that, at the highest power point, P = VI and dp/ dv = 0 yielding (Nafeh, 1998), (Harada, 1993). The drawback of this approach is thata more sophisticated control circuit means a higher systemcost (Eftichios Koutroulis, 2001). This paper focuses on exploring various MPPT techniques such as P&O and INC employed in conjunction with DC-DC Boost Converters for grid-connected PV systemsunder sun light variations. Subsequently, experimental results and simulations presented to evaluate the performance of selected MPPT algorithms integrated with boost converters as a point of efficiency, and suitability for real-world applications, considering factors such as cost-effectiveness, reliability and scalability.

MODELING OF SOLAR CELL: The solar cell's corresponding circuit diagram is displayed in Figure 1. A diode, a shunt resistance, and a continuous cur- rent source are all part of it. When considering recombination in the space charge area, the ideality factor of the diode is taken into consideration.

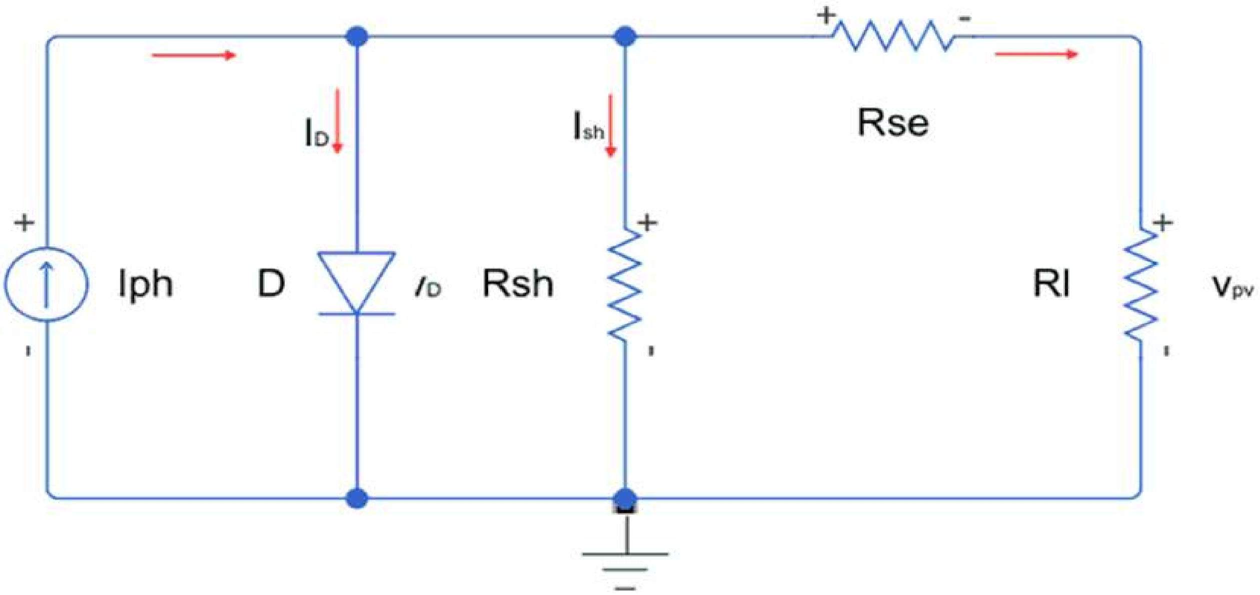

Fig. 1. Electrical equivalent circuit of a solar cell

The properties of a PV array are as follows, if the internalshunt resistance is disregarded (8), (9):

$$I_{pv} = I_g - I_{sat} * [\, \exp((q/AkT)(V + IRs)) - 1\,] \quad (1)$$

Where,
q Charge of an electron;
T Boltzmann's constant;
A Ideality factor of the p–n junction;
T PV array temperature (K);
I_g Light generated current Isat PV array saturation current;
R_s Intrinsic series resistance of the PV array;
Since it is possible to ignore the series resistance Rs, equation (2) can be reduced to:

$$I_{pv} = I_g - I_{sat} * [\, \exp(q/AkT) - 1\,] \quad (2)$$

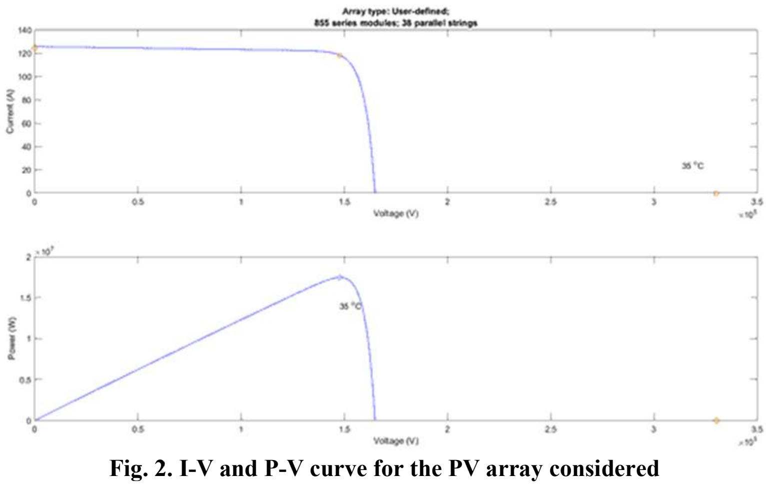

Fig. 2. I-V and P-V curve for the PV array considered

The output characteristics of a PV array under different air conditions are shown in Figure 2.

The PV array's output power can be stated as follows:

$$P = V\,I \tag{3}$$

The differentiation of P with regard to V can be stated as follows, based on (3) and (4):

$$dP/dV = I + (dI/dV)V \tag{4}$$

$$Ig - Isat\,[\,\exp(qV/AkT) - 1\,] - (qIsat/AkT)\exp(qV/AkT)\,V \tag{5}$$

$$dP/dV = I + (\Delta I/\Delta V)\,V \tag{6}$$

where the output voltage and current increases are denoted by delta V and delta I, respectively. The function of V that canbe used to model the properties of V versus dP/dV is equation (6). equation (7) indicates that I + $(\Delta I/\Delta V)V$ can be usedin place of the term dP/dv.

IMPLEMENTED MPPT ALGORITHM: Classical MPPT algorithms are available in the literatureto efficiently track the MPP and enhance the performance of photovoltaic systems. Nonetheless, the most popular MPPT algorithms are taken into account here, and they are

- Perturb and Observe (P&O)
- Incremental Conductance (INC)

Perturb and Observe (P&O) Method: P&O technique is the most often utilized MPPT algorithm. Little measured parameters and a straightforward feedback structure are used by this method. With this method, a periodic perturbation of the array voltage is applied, and the resulting output power is compared to that of the preceding perturbing cycle (10).In order to determine the momentary operating region, the perturbation and observation method measure Δp and ΔV. The reference voltage is then adjusted in accordance with the region to operate the system close to the Maximum power point. The implementation is straightforward because the method merely modifies the reference voltage. That being said, the approach struggles to keep up with suddenand drastic changes in the surroundings. Figure 3 illustrates a flow chart that makes understanding the method simple.

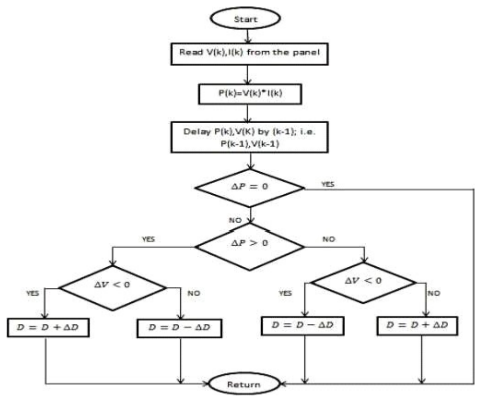

Fig. 3. Flowchart of Perturb and Observe (P&O) method algorithm

Incremental Conductance (INC) Method

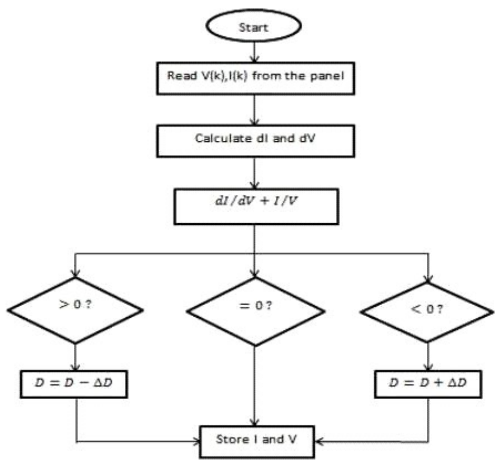

Fig. 4. Flowchart of incremental conductance (INC) method algorithm

The Incremental Conductance (INC) method solves the issue with P&O methods in rapidly changing air conditions. When the MPPT reaches the MPP, the incrementalconductance approach can detect it and cease influencing the operating point. In the event that this need is not satisfied, the relationship between dI/dV and –I/V can be used to determine which way the MPPT operating point has to be perturbed.The fact that dP/dV is negative when the MPPTis to the right side curve of the MPP and positive when itis to the left side curve of the MPP is the basis for thisrelationship. While P&O oscillates about the MPP, this algorithm establishes when the MPPT has reached the MPP. There is no denying this advantage over P&O.By comparinga PV array's incremental conductance and instantaneous conductance, the incremental conductance approach preciselylocates the highest power point (11).Compared to the perturb and observe method, the incremental conductance method canfollow quickly increasing and declining irradiance conditions with higher precision (12). This algorithm's drawback is that, in comparison to P&O, it is more sophisticated. Theflow chart presented in Figure 4 makes the method clearly understandable.

SIMULATION AND RESULTS

A grid-connected photovoltaic system used for experimentalmeasurements is shown in Figure 5. The inverter for gridconnections at 220 V/50 Hz is provided by the boost MPPT converter. Figure 5 displays the Simulink model of a photo- voltaic array with a dc-dc boost converter using the perturb and observe (P&O) MPPT method and figure 6 displays the associated outcome.

Figure 7 shows the Simulink model of a PV array with a dc-dc boost converter that uses the INC MPPT method. Figure8 illustrate the simulation results of the INC MPPT algorithm. The output voltage of fluctuates between 145V to 150V, the output power fluctuates between 2.6kW to 2.7kW ., accordingto the data.the grid side volotage is 25kv, the current between the grid and load is 63.4A, the load side current is 65A. TableI shows the rating of the components.

Table I.

0	Capacitor across the solar panel	1100uF
L1	Inductor for the boost converter	70uF
C2	Capacitor across the dc-link	6500uF
L2	filtering inductor for the inverter	75uF
R2	Equivalent resistance of the inverter	25ohm
C2	Filtering capacitor for the inverter	7uF
L3	Inductor for the battery converter	2.5mH
R3	Resistance of L3	0.2ohm
F	Frequency of AC grid	50Hz
fs	Switching frequency of power converter	10kHz
Vd	Rated DC bus voltage	400V
Vrms	Rated AC bus line voltage (rms value)	400V
n1/n2	Ratio of transformer	2:1

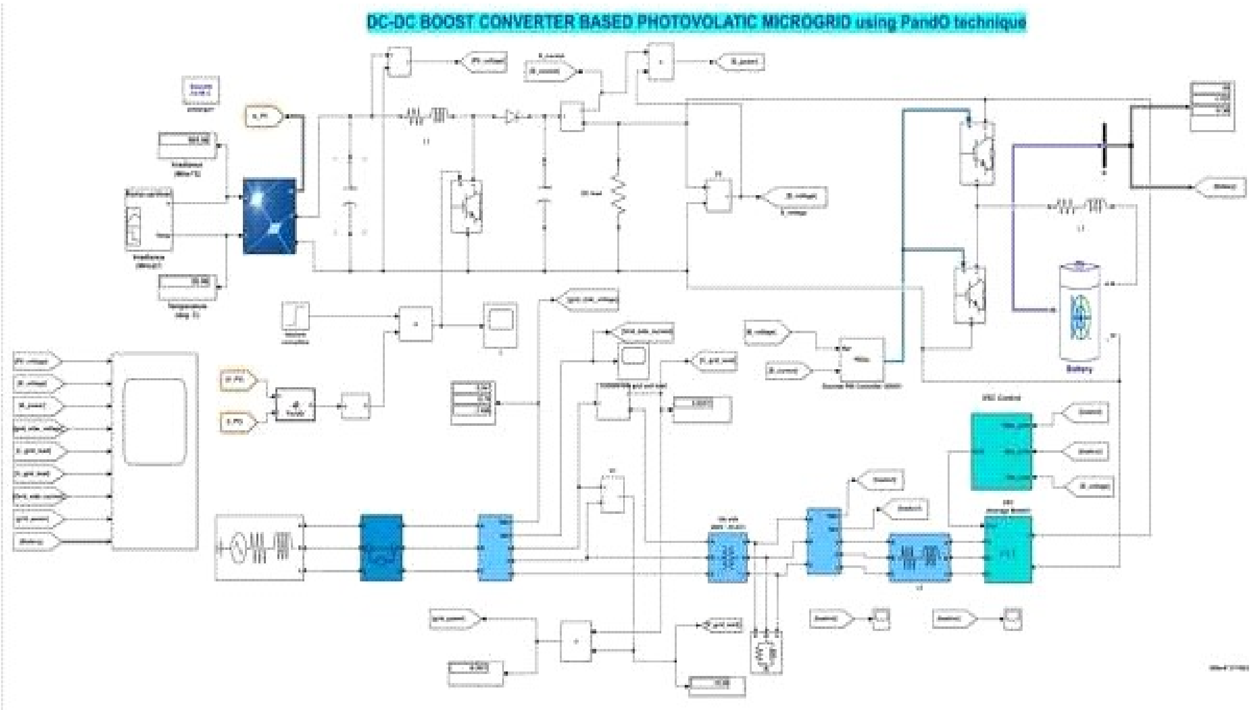

Fig. 5. Simulink Model of P&O MPPT with dc-dc converter

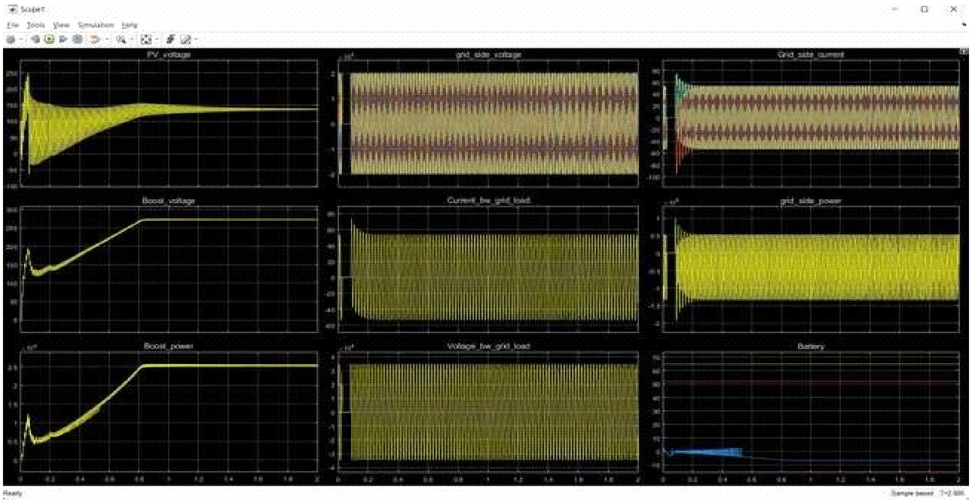

Fig. 6. Simulation results of P&O MPPT algorithm

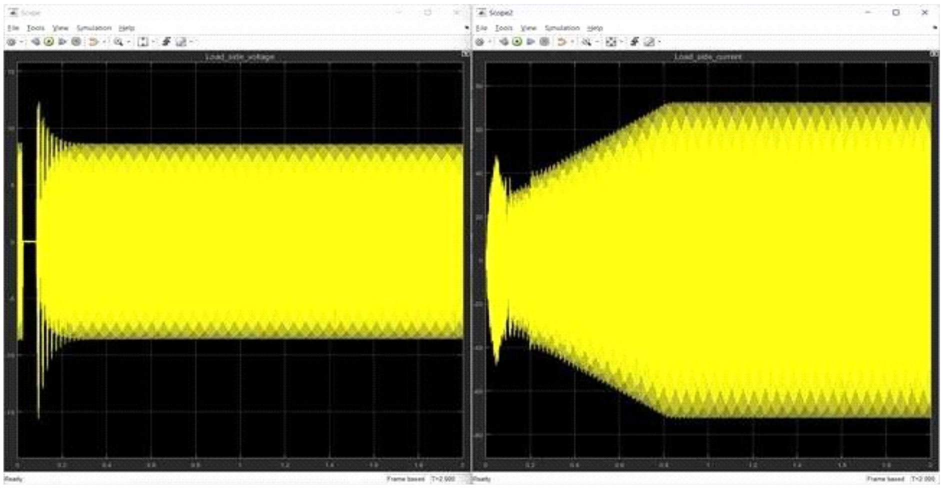

Fig. 7. Simulation results at load side current and voltage of P&O MPPTalgorithm

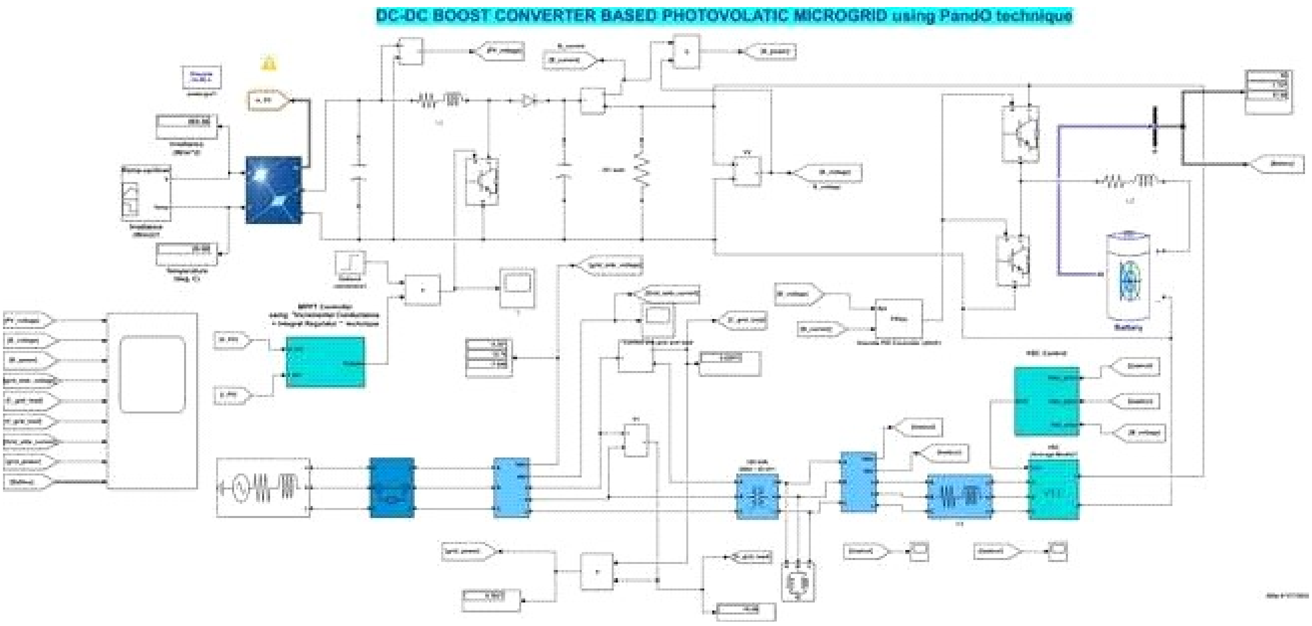

Fig. 8. Simulink Model of INC MPPT with dc-dc converter

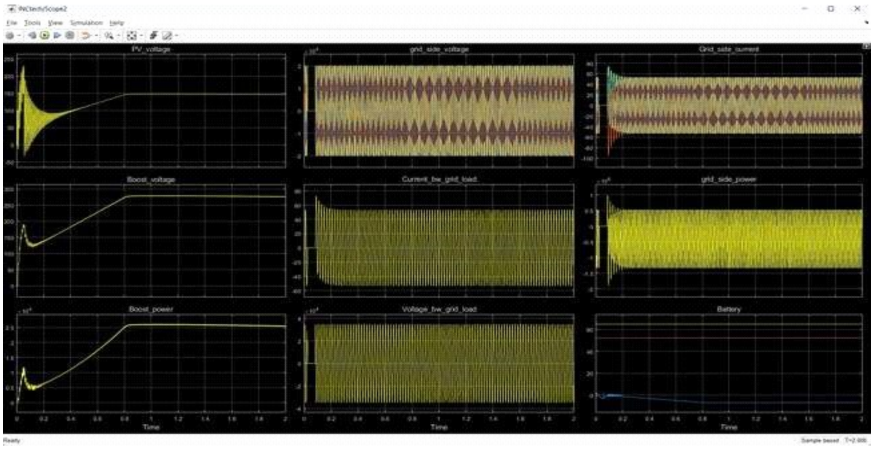

Fig. 9. Simulation results of INC MPPT algorithm

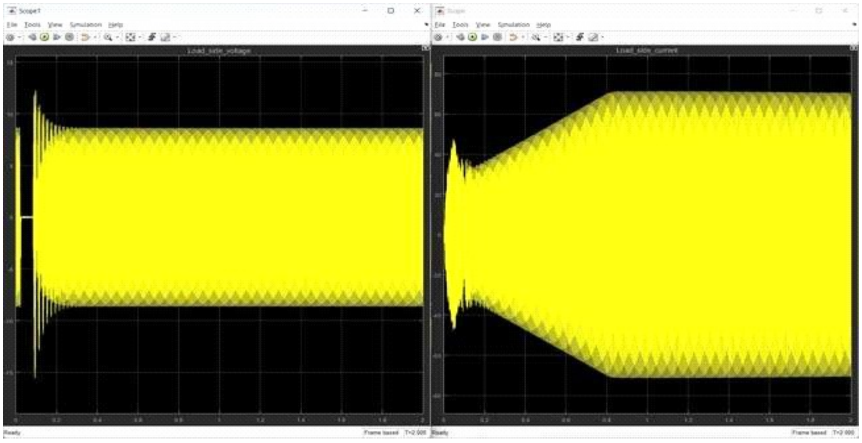

Fig. 10. Simulation results at load side current and voltage of INC MPPTalgorithm

Comparison between P&O and INC MPPT Algorithms: Comparing of THD values of P&O and INC Techniquesare shown in the Tables II, Table III and Table IV. The THD values are drawn at the while the current and voltagesare stable. The corresponding values of THD are taken at different atmospheric conditions. Table II shows the harmonicdistortion of current and voltages in the irradiance at 500and temperature at 35deg C for both P&O and INC MPPT techniques. Table III shows the harmonic distortion of current and voltages in the irradiance at 1000 and temperature at35deg C for both P&O and INC MPPT techniques. Simillary, Table IV shows the harmonic distortion of current and voltages in the irradiance at 1500 and temperature at 35deg. C. Figure 11 and 12 are the FFT analysis of both the INC Technique and P&O Technique .The P&O MPPT method oscillates close to MPP when atmospheric circumstances are constant or change slowly. nonetheless, when atmosphericconditions fluctuate quickly, the P&O MPPT method is ineffective; nonetheless, the INC MPPT method also findsthe MPP accurately in these situations. the table II to TableIV and figuer 11 & 12 provide comparisons of two techniques for a range of parameters. As per the results, THD difference between both techniques are compared and results depicted that the P&O has the more harmonic distorction as compared to the INC Tech.

Table II. THD values at the irradiance 500W/m^2

Pulse signal(Irr=500)	INC Tech		P&O Tech	
Start time	Magnitude	THD	Magnitude	THD
0.2	25.11	1.05%	23.02	3.30%

Table III. THD values at the irradiance 1000W/m^2

Pulse signal(Irr=1000)	INC Tech		P&O Tech	
Start time	Magnitude	THD	Magnitude	THD
0.2	48.28	0.52%	45.98	0.81%

Table IV. THD values at the irradiance 1 500W/m^2

Pulse signal(Irr=1500)	INC Tech		P&O Tech	
Start time	Magnitude	THD	Magnitude	THD
0.2	52	0.96%	97.98	1.22%

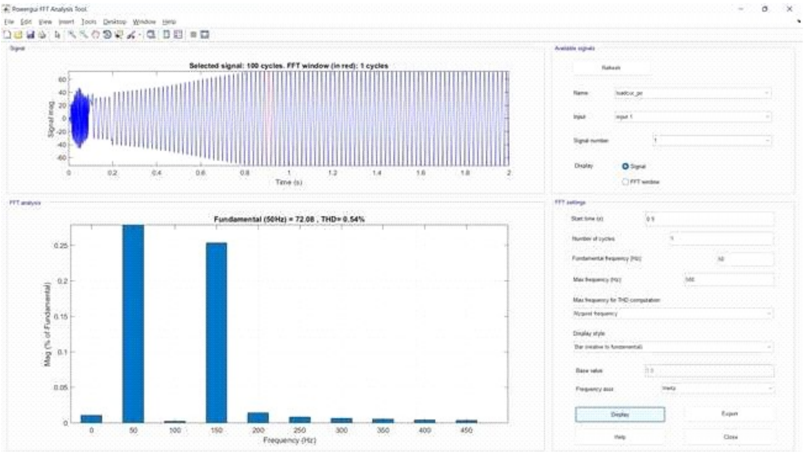

Fig. 11. Total Harmonic Distortion(THD) in the P&O Technique

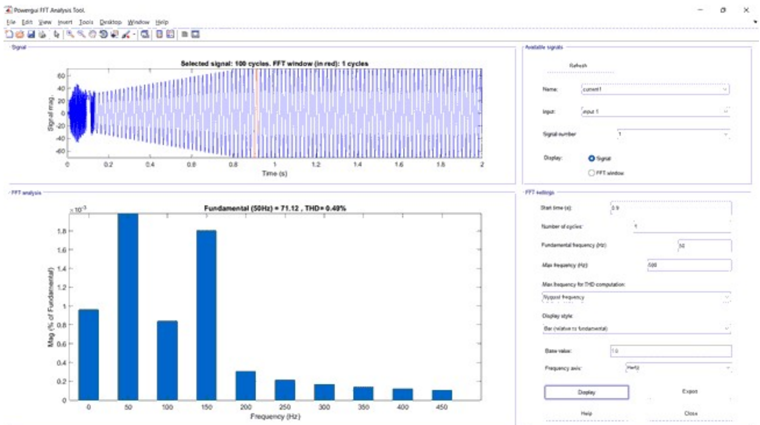

Fig. 12. Total Harmonic Distortion(THD) in the INC Technique

CONCLUSION

The simulation results comparing the Incremental Conduc-tance (INC) and Perturb and Observe (P&O) MPPT methods for a solar PV array reveal compelling insights into their performance across diverse atmospheric conditions. Across various atmospheric conditions, the INC method consistently exhibits superior performance compared to the P&O technique. This superiority is evident in terms of both power tracking efficiency and the smoothness of the output voltage profile. This smoother output translates into more stable and consistent power delivery, minimizing fluctuations and enhancing system reliability. The INC method also demonstrates lower Total Harmonic Distortion (THD) compared to the P&O method. This indicates reduced distortion in the output waveform and better compatibility with grid-connected systems, ensuring compliance with stringent power quality standards. The results of INC method through simulation lays a strong foundation for its adoption in real-world solar PV systems. By leveraging the INC algorithm, system integrators and developers can enhance the efficiency, reliability, and overall performance of grid connected PV installations, contributing to the wider adoption of solar energy

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