Maximum Power Extraction in Low Power PV FED High Voltage Gain Boost Converter using Optimization Algorithm (PO & INC) by Limiting the Oscillations

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Abstract

Aim - *The aim of this work is to efficiently extract the maximum power in low power PV based high voltage gain boost converters for green energy environment by considering two different innovative MPPT algorithms by limiting the oscillation.* ***Materials and Methods -*** *Perturb and Observe(P&O) and Incremental conductance (INC) Maximum power point tracking (MPPT) Algorithms are implemented and investigated so as to identify the point where the maximum power is available with reduced oscillations.* ***Results -*** *Based on the findings obtained it is inferred that the P&O algorithm extracts maximum output power with minimum ripple voltage magnitude (1.5v) while in INC extracts (1.75v).* ***Conclusion -*** *P&O MPPT algorithm gives superior output power in contrast with INC algorithm for the selected data.*

Key-words: Photovoltaic (PV) System, Innovative Maximum Power Point Tracking (MPPT), Perturb and Observe (P&O) Algorithm, Incremental Conductance (INC) Algorithm, Green Energy, Environmental Engineering.

1. Introduction

In present days, the demand on electricity is increasing which leads to the development of renewable energy sources. Especially stand alone PV based energy systems are preferred over others to satisfy the ever increasing demand on electricity. The research is about extricating maximum power using the MPPT that helps in enhancing the efficiency by varying PV panel parameters. The main areas of applications are for inverters (Rubavathy, Jaanaa Rubavathy, and Murugesan 2018) , building-

related needs,battery based power systems, communications applications (Villalva, Gazoli, and Filho 2009); (Otmane, Malika, and Ihssane 2017).

As far as Renewable Energy is concerned, the literature on the area is growing. One crucial problem with any PV system is that the amount of maximum power generated is constantly changing with environmental conditions, chiefly with solar irradiance. If the solar irradiance is varied, the operating point of the PV array will move away from its maximum power point. To overcome this problem, a Maximum Power Point Tracking (MPPT) algorithm with DC-DC Boost converter discussed to increase the efficiency of the PV array. The clear idea of extracting maximum solar power (Islam et al. 2018) based on different MPPT is presented. Efficiency of solar cells has been increased by using the MPPT Algorithm as discussed (Han et al. 2019). The use of the diode model for PV modules using a combined analytical and numerical approach is presented by tracking maximum power using MPPT (Yahya-Khotbehsara and Shahhoseini 2018). Self predictive P&O based floating step size P&O method for PV systems is discussed (Kumar et al. 2018). so as to reduce the steady state terminal voltage oscillations. From the overall literature on PV based converter module, P&O MPPT algorithm tracks the maximum power efficiently.

Previously our team has a rich experience in working on various research projects across multiple disciplines (Sathish and Karthick 2020; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Sureshbabu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020). Now the growing trend in this area motivated us to pursue this project.

Extracting of Maximum power from the PV system is a demanding factor. The most commonly used MPPT algorithms for PV systems are Perturbation and Observation (P&O), Incremental conductance(INC) and Fuzzy logic based MPPT methods. In this paper P&O and INC MPPT algorithms are considered for analyzing the performance of PV fed high voltage gain boost converters to extract maximum power with minimum oscillations. In general P&O method is introduced to give power variation in PV modules by periodically measuring the PV output power and then it is compared with the previous power to track the maximum power efficiently. Whereas in INC the instantaneous and the incremental conductance of the PV array is compared to track the MPP with uniform step size. Hence the P&O and INC algorithms are studied and implemented because of their simplicity and require less time to track the maximum power.

2. Materials And Methods

This study was conducted in a Power Electronics Lab at Saveetha school of Engineering. Sample size was calculated using previous literature (Yıldırım 2020). In this work there are no human or animal samples used so no ethical approval is required. Two algorithms are considered & its sample size is calculated using GPower Software. Based on this, it is determined that 7 samples for each group so total samples taken are 14. GPower setting parameters: Statistical test - difference between two independent means, $\alpha - 0.05$, G Power - 0.8016, effect size-1.41, mean INC- 0.9127, mean PO- 0.8745, sd-0.2701147. The system is simulated using the MATLAB simulink model.

Solar photovoltaic (PV) energy is one of the most feasible environmentally friendly power sources, considered less contaminated than fossil energy. The PV model is designed using a single diode model with shunt and series resistance as shown in Fig. 1 (Yıldırım 2020; Gules et al. 2008; Pakkiraiah and Durga Sukumar 2017; Siouane, Jovanović, and Poure 2018; Eltamaly and Abdelaziz 2019). The Current -Voltage (I-V) characteristics of a single diode PV model can be described by the following Equations (1-3). The PV cell output current is calculated by equation [1], where I_{PH} is photo-generated controlled circuit, I_D is the current in the diode equation, R_S is the shunt resistance, R_{SH} is the shunt resistance can be expressed with the following equations:

$$I_{PV} = I_{PH} - I_D - I_{SH} \qquad [1]$$

$$I_D = I_O \left(e^{\frac{q(V+I_{PV}R_S)}{\alpha \gamma T}} - 1 \right) \qquad [2]$$

$$I_{SH} = \frac{V + I_{PV}R_S}{R_{SH}} \qquad [3]$$

Fig. 1 - Equivalent circuit for a single - diode PV Model
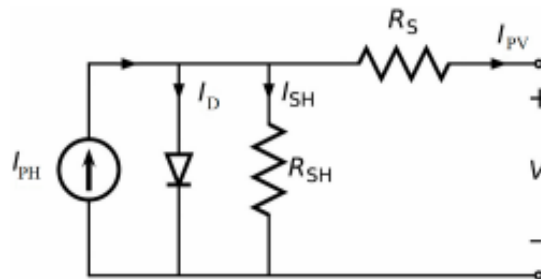
The PV array is built of strings of PV modules connected in parallel. Each string consists of modules connected in series which allows modelling of a variety of preset PV modules available from national renewable energy laboratory system advisor model as well as user defined PV module. Input 1 = sun irradiance, in W/m2, and Input 2 = cell temperature, in deg.C. Module data are as follows

Maximum Power(W)=250.205, open circuit voltage Voc (V)=37.3, Voltage at maximum power point Vmp (V)=30.7, Temperature coefficient of Voc(%/deg.C)= -0.36901, Cells per module(NCell)=60, short-circuit current Isc (A)=8.66, Current at maximum power point Imp (A)=8.15, Temperature coefficient of Isc (%/deg.C)=0.086998, Temperature=25, Insolation (G)=1000.

Perturb & Observe Algorithm is one of the widely used MPPT algorithms due to its simplicity. P&O is implemented and analysed under varying insolation conditions (Ali et al. 2020). The main objective is to adjust the solar panel output to extract maximum possible output power with reduced oscillations and transfer it efficiently to the load circuit P&O firstly it starts sensing the voltage and current and calculates the power. Secondly , it compares the power and voltages of the present instant with the previous instant. The flow chart for the P & O MPPT algorithm is given(Yıldırım 2020) in the following Fig. 2.

Fig. 2 - Perturb and Observe algorithm flowchart
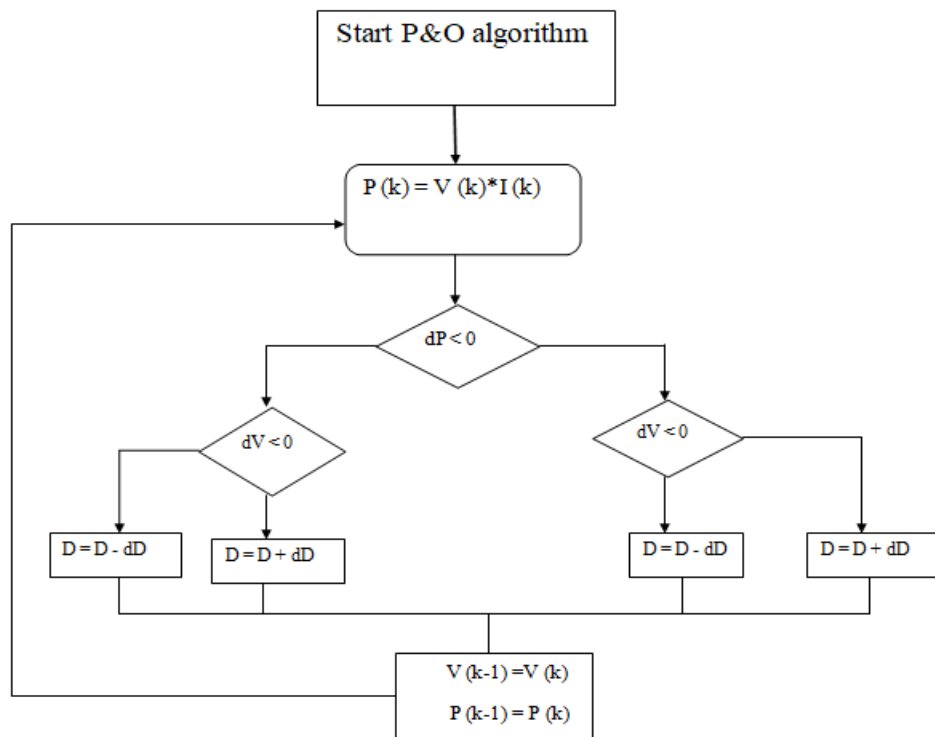
Incremental conductance algorithm is also the maximum power point tracking (MPPT) algorithm. It uses the ratio of the output power of the solar panel to the output voltage of the solar panel, which is also called the slope. This algorithm finds the MPP where the value of the slope is equal to the zero. Under varying insolation conditions the peak power is not efficiently traced. The flowchart of INC algorithm(Banu, Beniuga, and Istrate 2013) is shown in Fig.3.

Fig. 3 - Incremental Conductance algorithm flowchart
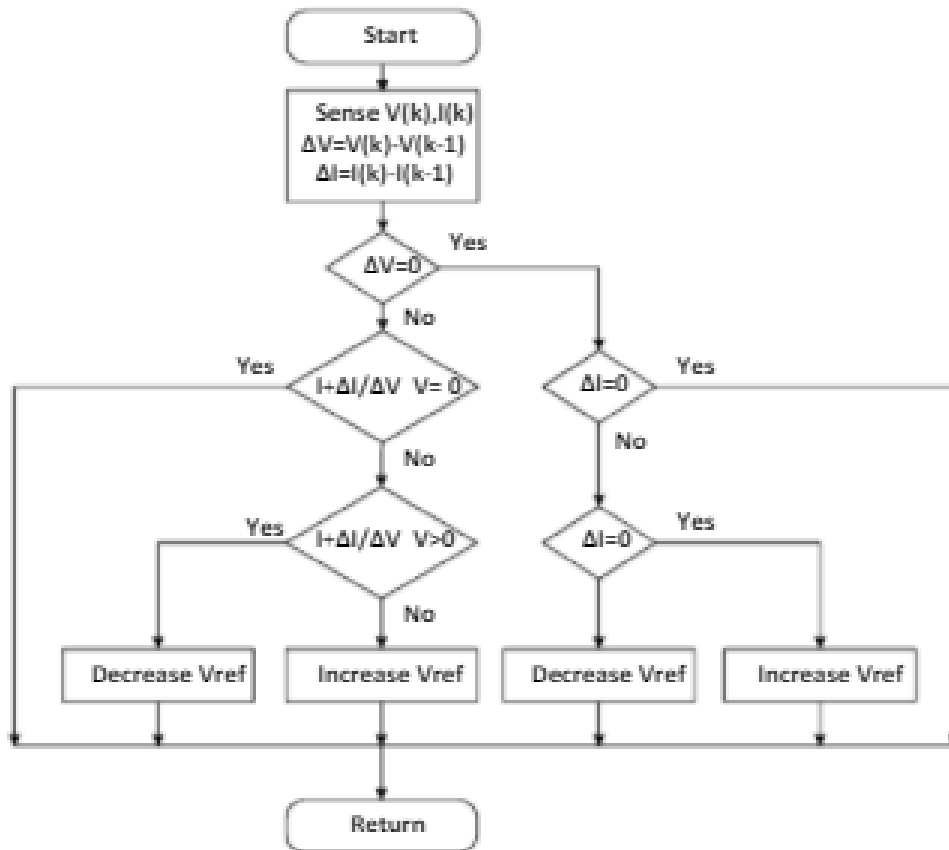
The proposed system has been tested in the MATLAB/Simulink environment, and the results are verified by changing the value of insolation. The variations in the output power in both the algorithms are presented in Table 1, which show that the proposed P&O algorithm tracks the maximum output power with minimum oscillations than the existing incremental conductance method (INC).

Table 1 - Simulation results of P&O and INC algorithm

Insolation(G)	Temperature(T)	Perturb & Observe attained output Power	Incremental Conductance attained output Power
1000,800,600	25	83.35	83.27
800,600,500	15	87.07	83.27
900,600,400	10	88.98	88.79
800,700,400	15	86.9	87.19
900,700,500	15	87.07	87.14
900,700,500	20	85.27	85.11
900,500,400	10	88.98	88.79

SPSS software is used for statistical analysis of P&O and INC algorithms. The independent variable is insolation and the dependent variable is output power. Two independent group analysis tests are carried out to determine the maximum output power in both algorithms.

3. Results

Fig. 4 depicts the Output current, voltage and power waveforms in a system with P&O MPPT and the expanded view of output voltage is shown in Fig. 5. Similarly, Fig.6 depicts the Output current, voltage and power waveforms in a system with INC MPPT and the expanded view of output voltage is shown in Fig. 7. An Incremental Conductance algorithm is used to shift the operating point of the system to that particular voltage level. It is found that there is some loss of power due to this incremental conductance and hence fails to track the power under fast varying atmospheric conditions. But the P & O algorithm is used to track the power efficiently by shifting the operating point to a particular voltage level. Hence P&O is found to be better than INC because of its simplicity.

Fig. 4 - Simulation results with PO algorithm with output power of 301.3W, Output Voltage of 205V and Current of 0.7A
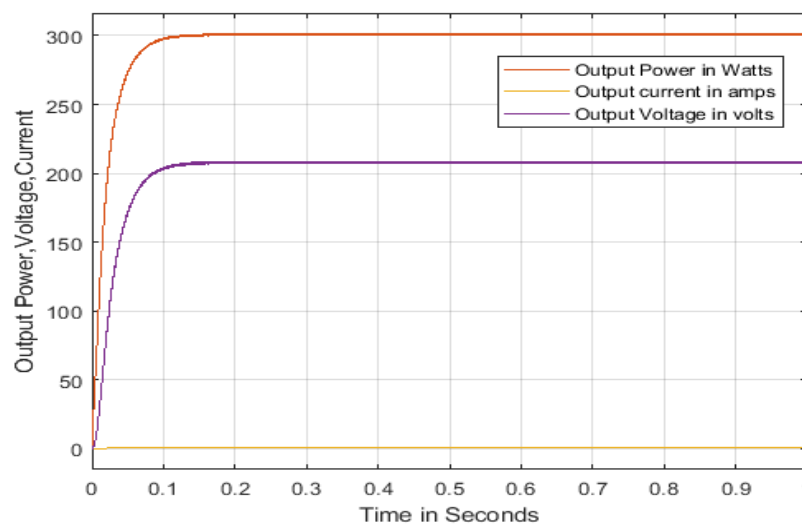

Fig. 5 - Expanded View of Output Voltage in PO algorithm with a ripple magnitude of 1.5V. The oscillations around maximum power point leads to more losses, resulting in reduction in efficiency of the system. Hence, it is observed that P&O extracts maximum power (301.3W) with minimum oscillations(1.5V) in voltage than INC method (297.8W)
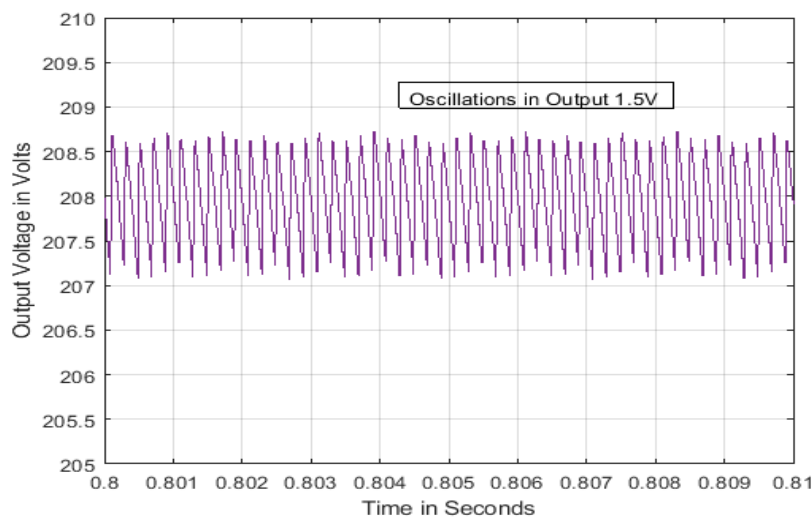
Fig. 6 - Simulation results with INC algorithm with output power of 297.8W, Output Voltage of 203.9V and Current of 0.7A
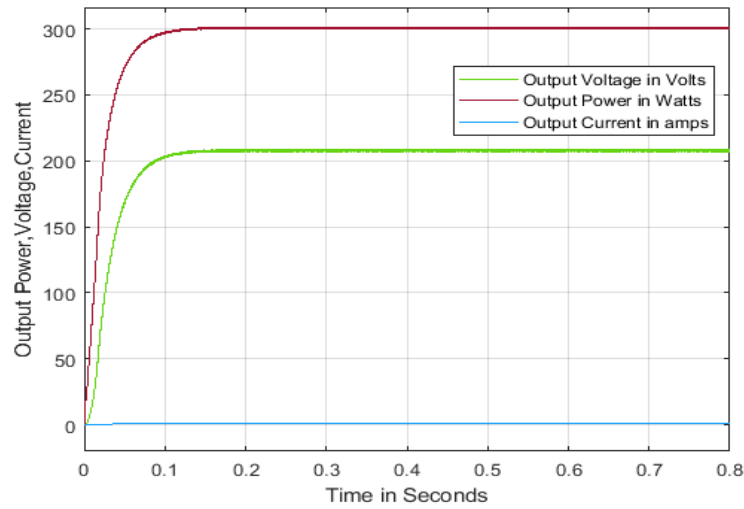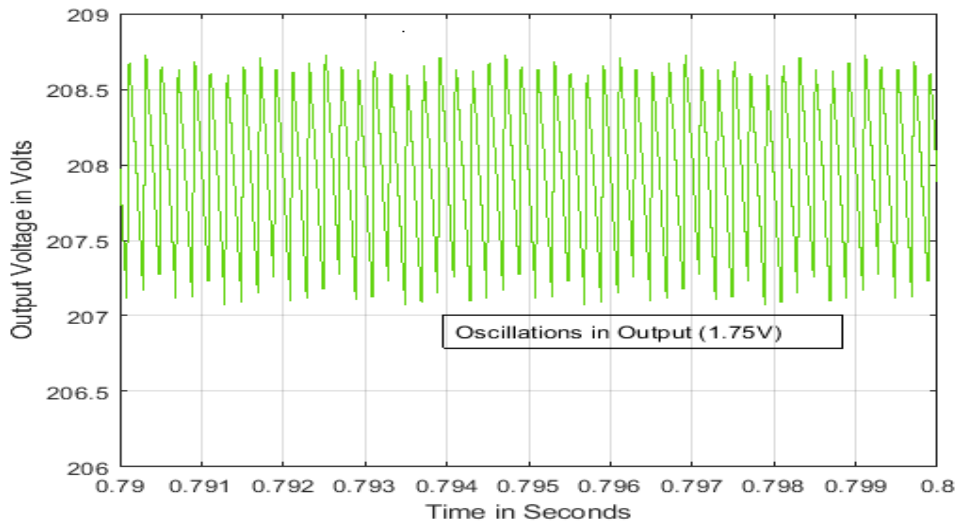

Fig. 7 - Expanded View of Output Voltage in INC with a ripple magnitude of 1.75V

In performing statistical analysis of 7 samples, P&O obtained 1.99 standard deviation with 0.75 standard error while INC controller obtained 2.36 standard deviation with 0.89 standard error (Table 2). The significance value is smaller and is equal 0.353. With respect to changes in solar irradiation (independent variable) the corresponding load power (dependent variable).

Table 2 - T-test comparison of P&O and INC MPPT algorithm by varying insolation 250 to 1000 and temperature 10 to 25. P&O has a mean value of 86.8029 which is greater than INC. INC has a mean value of 86.2229

Group Statistics					
	GROUPS	N	Mean	Std. Deviation	Std. Error Mean
Output Power	PO	7	86.8029	1.99599	0.75441
	INC	7	86.2229	2.36763	0.89488

Table 2 T-test comparison of P&O and INC MPPT algorithm by varying insolation 250 to 1000 and temperature 10 to 25. P&O has a mean value of 86.8029 which is greater than INC. INC has a mean value of 86.2229. Table 3 Independent Samples test: The independent sample test has been carried out and has a significant difference in output power between P&O and INC algorithms. There is a significance difference between the two groups since p<0.05(t value is 0.496 and mean difference is 0.58000).

Table 3 - Independent Samples test: The independent sample test has been carried out and has a significant difference in output power between P&O and INC algorithms. There is a significance difference between the two groups since p<0.05(t value is 0.496 and mean difference is 0.58000)

Independent Sample Test										
Levene's Test for Equality of Variances			T-test for Equality of Means							
		F	Sig.	t	df	Sig.(2-tailed)	Mean Difference	Std. Error Differences	95% confidence Interval of the Difference	
									Lower	Upper
Output Power	Equal Variances assumed	.933	.353	.496	12	.629	.58000	1.17045	-1.97019	3.13019
	Equal Variances not assumed			.496	11.666	.629	.58000	1.17045	-1.97830	3.13830

Fig. 8 - Comparison of PO and INC MPPT algorithm in terms of Mean output power. The Mean output power of PO is better than INC and the standard deviation of PO is slightly better than INC. X-axis: PO vs INC algorithm Y-axis: mean output power of detection ± 1 SD

Simple Bar Mean of OUTPUTPOWER by GROUPS
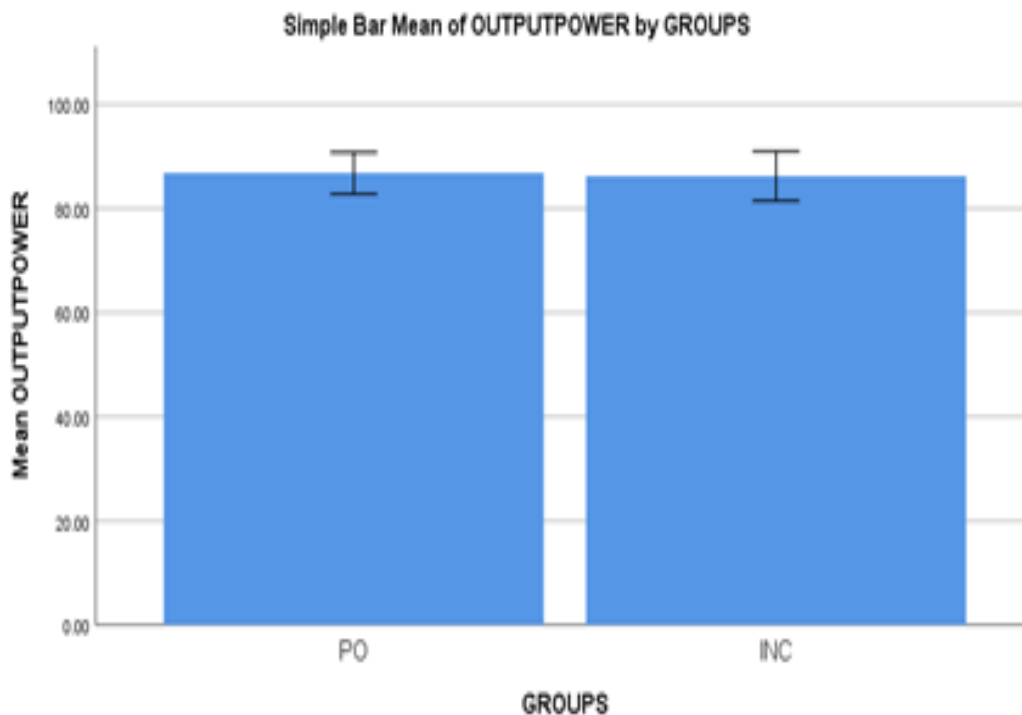
From Fig. 8, it shows the comparison of output of two groups for extracting maximum power of P&O (301.3W) compared with INC (297.8W). P&O appears to produce more consistent results with standard deviation ranging from (82-90).

4. Discussions

P&O and INC algorithms are implemented and its maximum power output is analysed and compared. P&O has better output power when compared to the INC algorithm.

Based on the previous literature study, the comparative analysis of fuzzy and P&O PWM techniques have been carried out and it is found that P&O has maximum power(1300W) extraction than a fuzzy based system which extracts 1200W (Liu and Wang 2011; Ali et al. 2020; Wu, Li, and Li 2017). A detailed theoretical (97.9%) and experimental comparison of the two P&O implementation techniques on basis of system stability the experimental P&O gives better performance (99%) for pumping applications (Elgendy, Zahawi, and Atkinson 2012). In (Pilakkat and Kanthalakshmi 2020) the simulation results validate the efficient maximum power point tracking characteristics of ABC-PO algorithm(325V) over ABC algorithm(320V) for a grid connected network. In (Mendez et al. 2020), the proposed system achieved to reduce the power loss in PSO (33.8%) when compared to classic P&O (36.48%).

The simulation results show that the FL based MPPT can track the MPP with better results as compared to the conventional (P&O) and (InC) algorithms in terms of accuracy, (Al-Gizi and Al-Chlaihawi 2016). A New Neural Network based MPPT (149.98W) has better results when compared to P&O (149.66W) and INC (149.97W). In (Harrag et al. 2017) the results demonstrate the high performances of neural network MPPT controllers analyzed under fast changing insolation, response time and overshoot power (0.04 s, 3W).

Even with more developments in PV based MPPT, there is reduction in output power and conversion efficiency with considerable oscillations around the peak point. The efficiency of solar cells are reduced due to variations in areas with poor climate conditions that may not favor the use of solar panels (Hashim et al. 2018). The value of output current and voltage waveforms will also increase if the converter capacitance and inductance value increases and vice versa. If these L and C values are chosen to be small, it is possible to maintain minimum oscillation as well as the tracking speed and accuracy of the system can be improved under step changes in irradiance.

Our institution is passionate about high quality evidence based research and has excelled in various fields (Vijayashree Priyadharsini 2019; Ezhilarasan, Apoorva, and Ashok Vardhan 2019;

Ramesh et al. 2018; Mathew et al. 2020; Sridharan et al. 2019; Pc, Marimuthu, and Devadoss 2018; Ramadurai et al. 2019). We hope this study adds to this rich legacy.

Artificial Intelligence based MPPTs are becoming popular nowadays to track the maximum power efficiently. Out Of which Artificial Neural Network (ANN) is preferred over others because it is not required to solve the complex equations which relates different environmental conditions such as solar irradiance, solar temperature and total resistance.

5. Conclusion

Based on the simulation results, the proposed system (P&O) has better output power of 301.3w with 1.5V oscillation compared to INC of 297.8w with 1.75V oscillations for the selected data.

Declarations

Conflicts of Interest: No conflict of interest in this manuscript.

Author Contributions

Author PB was involved in data collection, data analysis and manuscript writing. Author SJR was involved in conceptualization, data validation and critical review of manuscripts.

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