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RESEARCH ARTICLE

Comparison of Maximum Power Point (PO & GMPP) Algorithm Under Varying Environmental Factors to Extract Maximum Peak Power from Photovoltaic System

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ABSTRACT

Aim: This paper deals with efficiency enhancement on extraction of maximum peak power under varying environmental conditions from the photovoltaic green energy systems (PV). **Materials & Methods:** Perturb and Observe (P&O) and Global maximum power point (GMPP) algorithms have been implemented to analyse tracking efficiency. **Results:** Based on results obtained, GMPP has higher efficiency of about 93.37 % than PO has the efficiency of about 90.71%. **Conclusion:** GMPP appears to produce more consistent efficiency under varying environmental conditions than P&O MPPT algorithm for the selected data set.

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Introduction

Photovoltaic systems are the best known available resource for generating electric power in the environment. The sunlight which falls on the photovoltaic system is converted into electricity by photovoltaic effect. The main purpose of this research project is to extract the maximum power generated from the PV system using appropriate MPPT algorithm. Energy demand has been rapidly increasing in today's life and PV systems play a vital role to compensate for the energy requirement. Applications of this research are hybrid systems interface, grid power transfer, electric vehicles (Selvamuthukumaran, Kumar, and Gupta 2016; Liu, Chen, and Huang 2014).

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During non uniform environmental conditions the annealing global maximum power point tracking method is implemented and its performance has been analysed (Lyden and Haque 2016). Multiple peaks occur during partial shaded condition and tracking of global peak is carried out using Novel flower pollination based global maximum Power Point Method and its performance is estimated (Ram, Prasanth Ram, and Rajasekar 2017). The global MPPT technique has been implemented and analysed under uniform and dynamic solar irradiance conditions. The performance is compared with conventional algorithms (Ramyar, Iman-Eini, and Farhangi 2017). Global peaks are analysed by determining the maximum power trapezium (MPT) area using reduced voltage range global maximum power point tracking algorithm (Furtado et al. 2018).

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.

In conventional MPPT algorithm tracking of peak power is not efficiently carried out and hence proper MPPT technique is implemented which traces the global peak power with minimum oscillation and high efficiency. In this paper, P&O and GMPP algorithms are implemented and its performance is analysed.

Materials & Methods

This study was conducted in a Renewable Energy lab at Saveetha School of Engineering. Sample size was calculated by using previous study results (Elgendy, Zahawi, and Atkinson 2012). Two algorithms have been compared and its sample size has been calculated using GPower software and it is determined that each algorithm has 7 samples and totally 14 sample tests have been carried out.(g power setting parameters: statistical test-difference between two independent means, α-0.05, power-0.80, effect size-0.5, mean PO-0.9071, mean GMPP- 0.9337, sd-0.018). The system is simulated using the MatLab Simulink© model.

Photovoltaic System

The PV panel is modelled using one diode model (1)-(4) which consists of a current source in parallel with a diode (Zevallos et al. 2021; Ramaprabha and Mathur 2008; Villalva, Gazoli, and Filho 2009), a shunt resistance and a series resistance as shown in Fig.1.

$$I_{pv} = I_{ph} - I_D - I_{sh} \quad (1)$$

$$I_0 = \frac{K_0(T-T_n)+I_{scn}}{exp[(K_v(T-T_n)+V_{ocn})/V_{ta}]-1} \quad (2)$$

$$I_{pv} = [K_i dT + I_{pvn}]\frac{G}{G_n} \quad (3)$$

$$V_{ta} = \frac{N_s aKT}{q}$$

$$I_m = I_{pv}N_{pp} - I_0 N_{pp} exp\left[\frac{V_t}{N_s}\left(V + IR_{se}\frac{N_{ss}}{N_{pp}}\right) - 1\right] \quad (4)$$

Where,

V_{ocn}=21.24; I_{scn}=2.55; N_{ss}=14; N_{pp}=1; R_s=0.47; R_p=145.67; a=1.5, q=1.6022e^{-19}; k=1.3807e^{-23}; N_s=36; K_i=0.0032; I_{pvn}=2.5546; K_v=-0.1230; T_n=298.15; G_n=1000

Maximum Power Point Tracking Algorithm

P & O Algorithm

In this algorithm the initial value of PV voltage and current is identified. The PV power is calculated and initial step size is given (G. et al. 2018; Femia et al. 2004; H.Mahmood et al. 2020). The deviation in previous and present value of power (dP) and voltage (dV) is calculated. If dP > 0 then analyse the dV value. If dV > 0 then duty cycle is decreased, else duty cycle is increased. If dP < 0 then analyse dV value, dV > 0 then duty cycle is increased else it is decreased. This step continues until the maximum power point is reached (Sias and Robandi 2016). The flow chart of P&O algorithm is shown in Fig. 1.

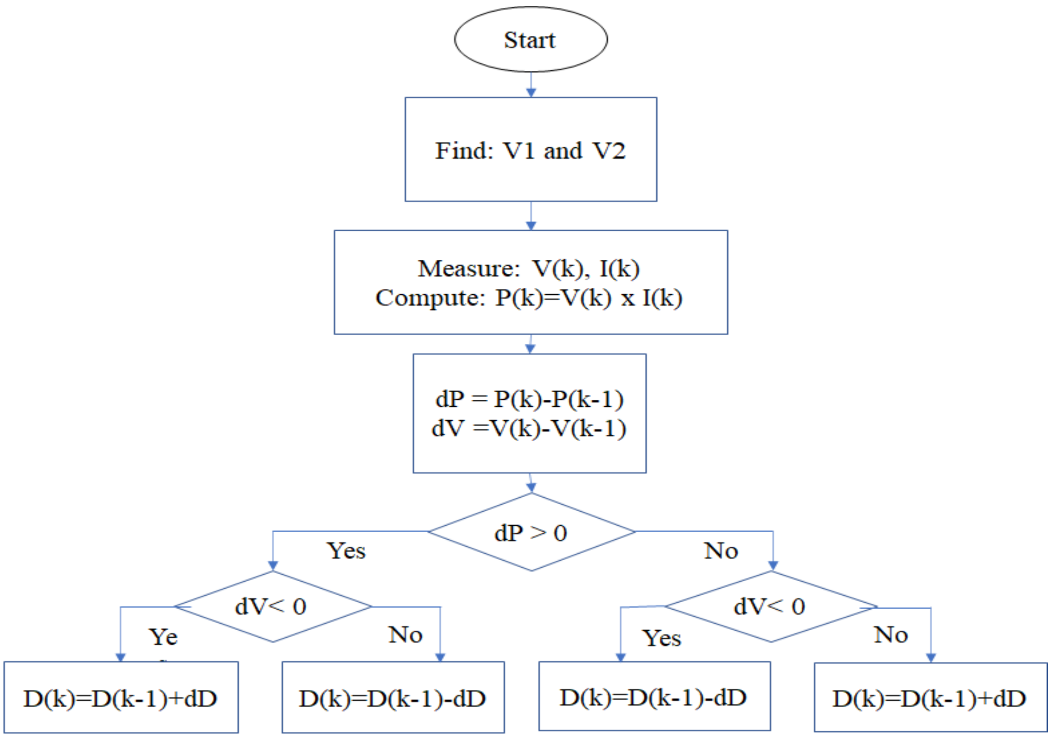

Fig. 1. Flow chart of P&O algorithm

GMPP Algorithm

Under the partial shading condition, the global maximum power point algorithm (Fig.2) is used to track the peak power effectively under varying climatic conditions & irradiance. The Global maximum power point traces the number of modules (m) in a string of PV array & stores in a memory lane (Sias and Robandi 2016; Daraban et al. 2013).The initial stored value in memory is initialized as i=1, Ppeak=0, Pgmpp=0. The GMPP scans the entire cycle & applies the duty cycle (d) value & measures the power value. If power (P) is greater than the peak power (Ppeak) then update the value of P = Ppeak and dpeak=d. The process continues by incrementing the i value as 2,3,... till it reaches i > m (Mao et al. 2016; Bifaretti et al. 2012). At this point update the value of power and duty cycle and the process continues with PO method to trace the peak power.

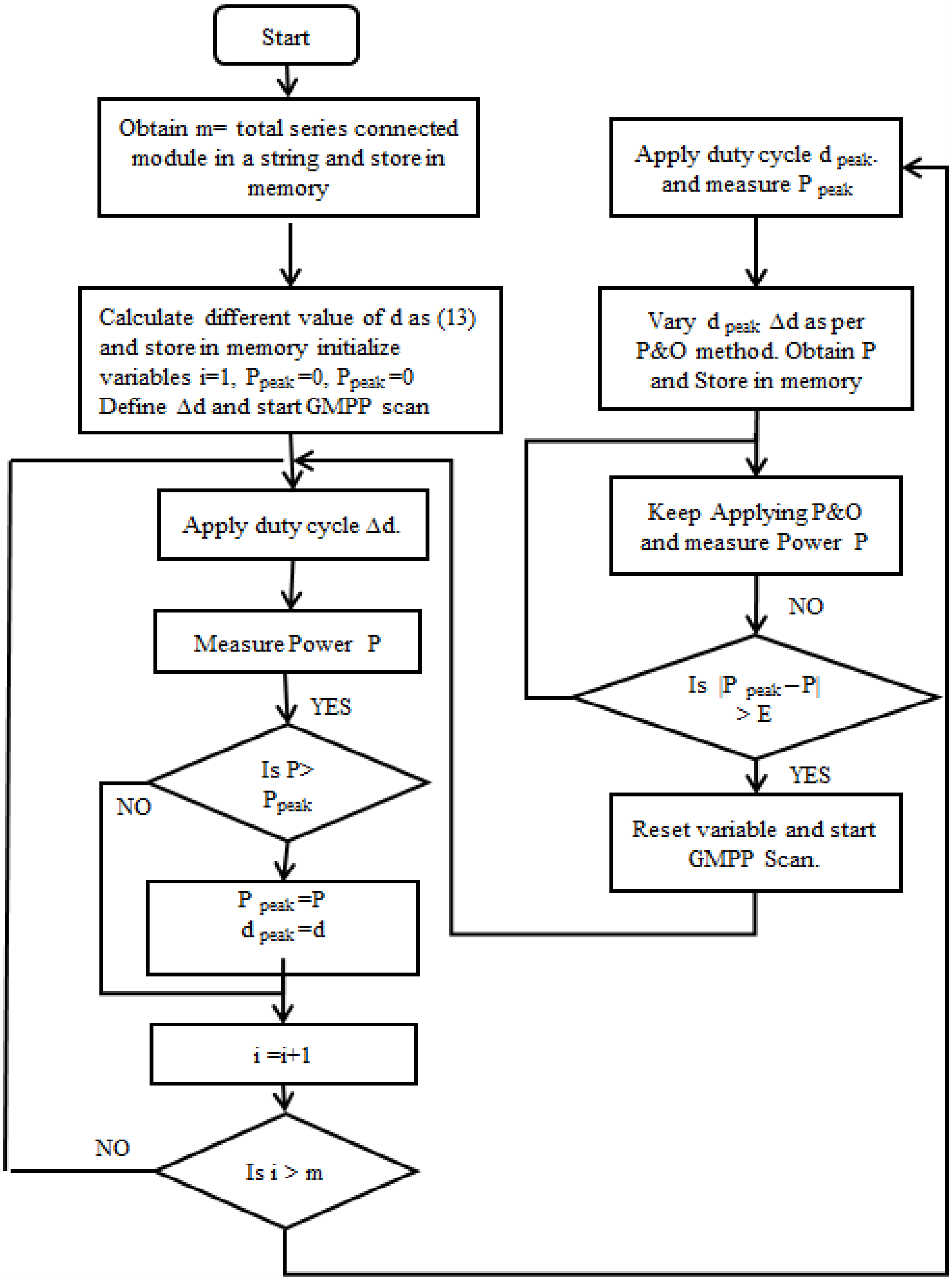

Fig. 2. Flow Chart of GMPP algorithm

Statistical Analysis

SPSS software is used for statistical analysis of P&O and GMPP algorithms. The independent variable is input insolation to the PV system and the dependent variable is output power extracted. Two independent group analysis tests are carried out to determine the efficiency of both the algorithms.

Results

VI and PV characteristics for different insolation is simulated and depicted in Fig.3. Multiple peaks in Fig.4 is due to bypass diodes present across the output end of the PV cell. Hotspots arising due to variation in the insolation condition damages PV cells. This damage is reduced by bypass diodes.

Due to variable step change in GMPP algorithm the peak power tracking is carried out efficiently with less tracking time (depicted in Fig. 6). P&O algorithm has fixed step change that results in high oscillation around the peak power (depicted in Fig. 5).

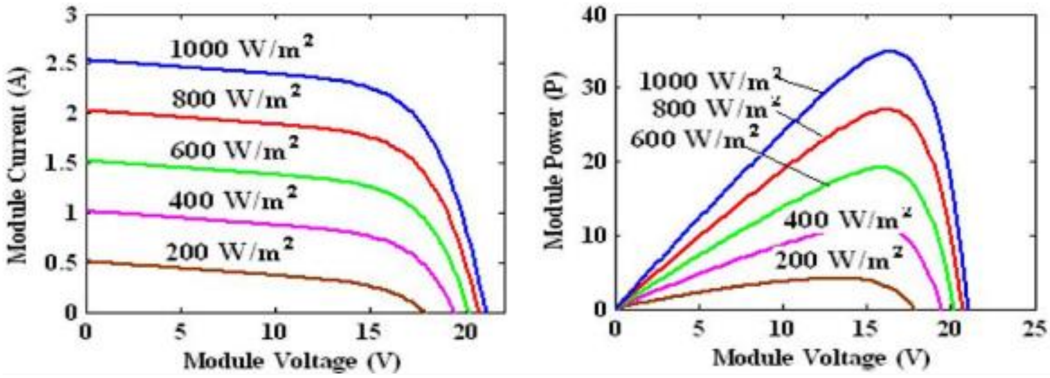

Fig. 3. Simulated V-I and PV characteristics for various Insolation value and standard temperature value T=25 degree

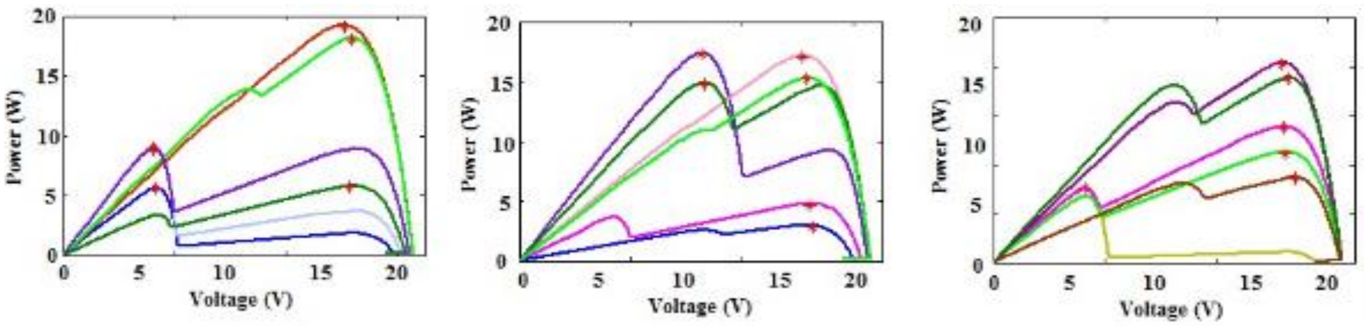

Fig. 4. Simulated VI & PV characteristics of PV array under different partially shaded pattern and Red dot (*) represents the global peak power point for different curves

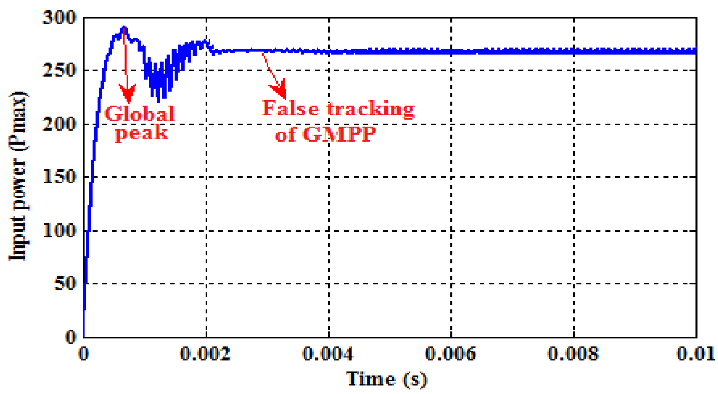

Fig. 5. Output power using PO algorithm where the tracing of the peak power is not done efficiently. Difference peak power value is traced using this PO algorithm is app 280W

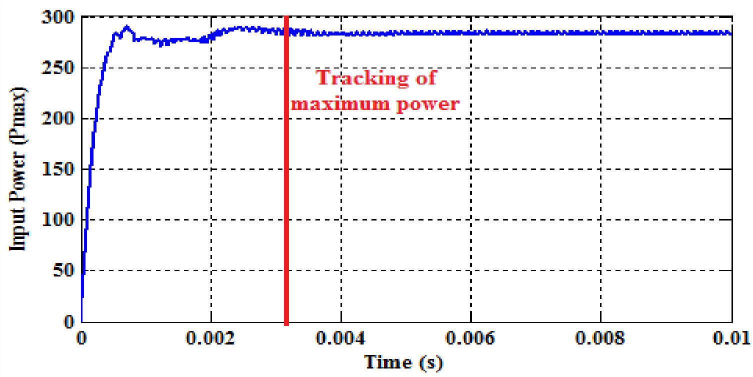

Fig. 6. Output power using GMPP in which the peak power is traced efficiently with minimum oscillations is app 290W

Table 1. Simulation data, efficiency of P & O and GMPP algorithm for different set of insolation parameters

S. No	Insolation (G)	Expected Output	PO	GMPP	PO	GMPP
			Attained Output	Attained Output	Attained Output	Attained Output
1	1000,800,500	61.3	59.4	60.2	96.9	98.2
2	800,700,400	52.0	48.3	50.6	92.9	97.3
3	1000,400,700	54.0	51.8	52.4	95.9	97.0
4	900,600,400	47.3	46.0	46.4	97.3	98.0
5	800,500,700	59.6	57.3	58.1	96.1	97.5
6	900,400,700	53.2	51.6	52.2	97.0	98.2
7	400,700,200	29.3	27.6	28.1	94.2	95.9

Table 2. Statistical analysis of PO and GMPP controller. Mean Output voltage, Standard deviation and standard error values are obtained for 14 sample data sets. When compared GMPP has better performance than PO controller

Group Statistics					
	GROUP	N	Mean	Std. Deviation	Std. Error Mean
EFFICIENCY	PO	7	95.7571	1.63080	.61639
	GMPP	7	97.4429	.82231	.31080
POWER	PO	7	48.8571	10.47980	3.96099
	GMPP	7	49.7143	10.58780	4.00181

Table 2 exhibits T-test Comparison of PO and GMPP algorithm by varying insolation level between 200 to 1000. GMPP has a mean value of 49.71 for power and 97.44 for efficiency which is higher than PO algorithm. PO algorithm results in a mean value of power is 48.85 and 95.75 for efficiency.

Table 3 is the Independent Samples Test showing significant difference between the two algorithms is $p<0.05$ [t value is -0.152 (power), -2.442 (efficiency), mean difference is -0.857 (power) and -1.685 (efficiency)]

Table 3. Independent sample T-test t is performed for the two groups for significance and standard error determination. P value is less than 0.05 and it is considered to be statistically significant.

Independent Samples 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 Difference	95% Confidence Interval of the Difference	
									Lower	Upper
EFFICIENCY	Equal variances assumed	2.848	.117	-2.442	12	.031	-1.68571	.69031	-3.18977	-.18165
	Equal variances not assumed			-2.442	8.866	.038	-1.68571	.69031	-3.25092	-.12051
POWER	Equal variances assumed	.000	.985	-.152	12	.882	-.85714	5.63063	-13.12522	11.41094
	Equal variances not assumed			-.152	11.999	.882	-.85714	5.63063	-13.12537	11.41108

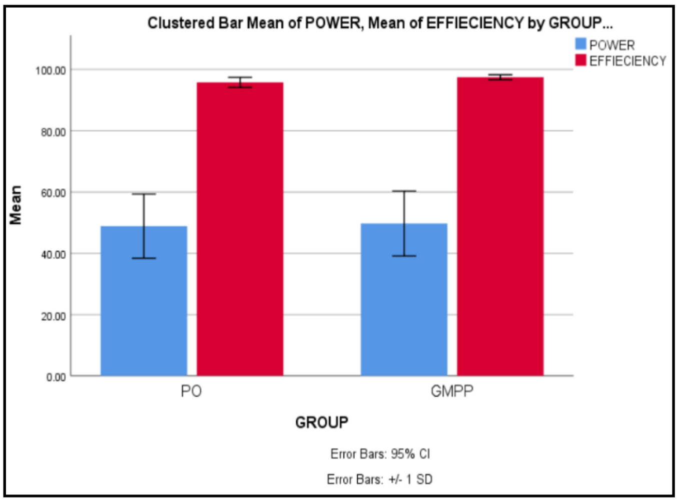

Fig. 7. Comparison of PO and GMPP MPPT controller in terms of mean efficiency and Output Power The mean efficiency of GMPP is better than PO MPPT controller and the standard deviation of GMPP is appr. equal to PO. X Axis: GMPP Vs PO controller Y Axis: Mean output voltage of detection ± 1 SD

Fig. 7 shows the comparative graph of PO and GMPP algorithms. GMPP produces a better efficiency of 97.4 % (appr) compared to PO MPPT algorithm 95.8% (appr). GMPP also produces better output power of 49.7W (appr) compared to PO MPPT algorithm of 48 W (appr).

Discussions

PO and GMPP algorithms are implemented and its peak power tracking efficiency and output power is analysed and compared. From the obtained results it infers that GMPP provides better efficiency compared to the PO algorithm with minimum oscillation around the peak power.

Based on the previous literature study, the comparative analysis of PO and GMPP MPPT techniques have been carried out and it is found that GMPP produces better efficiency based on maximum power extraction. The results show that GMPP algorithm takes 1 second for the step process and the PO algorithm takes 2.5 seconds for the same process (Yeung, Chung, and Chuang 2014). This paper deals with the novel algorithm for tracking the maximum power point (MPP) under partial shading conditions using a variable step size for PV systems to obtain the optimum output. The GMPP algorithm & PO algorithm is used to track the modifying existing of robust, optimized & efficient to avoid false readings. Thus, GMPP (93%) has a higher efficiency than PO algorithm (90%) ("Global Maximum Power Point Tracking Algorithm for Photovoltaic Systems under Partial Shading Conditions" n.d.) The proposed algorithm GMPP used to develop the facilitated tracking of the Photovoltaic generation systems (PGSs) experiencing the partial shaded conditions (PSCs). GMPP method features the advantages as high tracking speed, enhanced tracking accuracy, improves the success rate, easy integration with original PGS firmware (Liu, Chen, and Huang 2014). The GMPP algorithm uses to track the dynamic short-term testing & real weather data for a better performance analysis. The tracking of the accurate hotspot detection algorithm & GMPP algorithm is compared and the results infer that GMPP performs a better efficiency for the factors of irradiation & temperature impacting on the PV system. (Gosumbonggot and Fujita 2019).

Based on recent literature study, Novel hybrid techniques have been implemented which results in better performance than GMPP MPPT technique. This paper proposes a novel hybrid MPPT approach on the modified Perturb & Observe (PO) by the assistance of Extreme Seeking Control (ESC) strategy. By comparison of GMPP algorithm, The novel hybrid MPPT is able to track more maximum peak power under any level of the weather fluctuation with the enhancement comprehensive on all aspects of high performance, it even eradicates the oscillations around the power achieved in PV system (Mohammad et al. 2020). The multimodal PV characteristics for PV array with variable shading is proposed in this paper, the sequential ESC-based global MPPT control & GMPP algorithms is implemented. The staircase current voltage is carried out to be the variable shading situation. The modelling analysis of ESC based shows the less partial shading occurrence in PV system than GMPP and ESC provides the better efficiency (Lei, Li, and Seem 2011)

From the overall literature study, few papers cite that the ESC-based MPPT technique provides better efficiency compared to the GMPP algorithm. So we can infer that GMPPT can be implemented in many applications which may result in better tracking efficiency under varying environmental factors.

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.

Tracking of global peak power is still a challenging issue we are facing. The proposed algorithm though seems to be better still tracking efficiency is not to the expected level. Because of false tracking of peak power and oscillations the power loss is also high. Step size is not optimized properly; the tracking time also seems to be high.

To report the above mentioned issues an improvised MPPT method can be implemented by proper designing of steep size, peak power updation, beta power value to increase the tracking efficiency and maximum power extraction.

Conclusion

Based on the obtained results the GMPP algorithm provides 97% efficiency compared to the PO algorithm which results in 95% efficiency.

Declarations

Conflict of Interests

No conflict of Interest in this Manuscript

Author Contributions

Author MDRA was involved in data collection, data analysis, and manuscript writing. Author RG was involved in data validation and review of manuscripts.

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