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Research paper

ROAC: Recursive optimization of Ant colony assisted perturb and observe for a photo voltaic resonant boost converter

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Abstract

This paper introduces a new Hybrid MPPT algorithm by combining new Ant Colony Optimization (ACO) and Perturb & Observe (P&O) method. The maximum power from a solar panel is extracted from all conditions like solar irradiance variation, temperature variation and partial shading conditions. Ant Colony Optimization (ACO) method tracks maximum power from panel under all variations and Perturb & Observe algorithm used in final stage to achieve faster MPP tracking. This proposed algorithm is implemented both in Simulink and hardware. A 5kWp grid connected solar photovoltaic power plant is designed and implemented for the 15 stage 31 level Cascaded Multi-level Inverter (CMLI) with the Selective harmonic elimination algorithm. From the analysis of results, it is found that the proposed hybrid MPPT provides higher MPP tracking performance in any weather conditions compared with other MPPT algorithms

Keywords: *Photovoltaic system, Ant Colony Optimization, Perturb and Observe optimization, MPPT, Partial Shading Conditions, MATLAB Simulink*

1. Introduction

Electrical Power is generated when sunlight falls on photo voltaic panels. But this power generated is reduced due to poor solar irradiation. This poor irradiation is mainly due to irregular falling of sunshine on Earth. Partial shading on PV array is another reason for the reduction of power. Series and parallel configuration are used getting Maximum power point tracking even in conditions of partial shading. But poor solar radiation time to get maximum power from panel by the implementation this proposed hybrid MPPT method. From the literature the maximum power from panel is analyzed. A new Hybrid MPPT algorithm by adding the Grey Wolf Optimization and Perturb & Observe method for efficient tracking of maximum power from a Photovoltaic under all conditions [1]. The hardware results are presented for conventional MPPT algorithms and improved MPPT algorithms with PI and perturb and observe MPPT [2]. The Simulation and hardware result with P&O at high perturbation frequency with better efficiency develops non periodic waveforms of the system. [3].The performance of the ICT algorithm perturbs and observe MPPT algorithm with various advantages and drawbacks in [4]. The results obtained in INC algorithm with higher energy efficiency and better system performance of the system [5]. PI control in duty cycle control and PSO MPPT track the global maximum point [6].the MPPT techniques under irradiances and relatively analyze them for their merits and demerits [7]. The new MPPT using Hill Climbing method is analyzed with simulations in SIMULINK model [8].The study of ICT with maximum power point by integration of swarm intelligence with PO algorithm in [10]. The New Sensor less Hybrid MPPT Algorithm based on Fractional Short Circuit current measurement and P&O MPPT was discussed in [11]. The tracking by varying the duty ratio of the DC-DC converter was discussed in [12]. The mathematical expressions with synergetic controllers do not require in of the PV system [13].The Improved Particle Swarm Optimization Based MPPT for PV with Reduced Steady-State Oscillation was analyzed in [14]. A New MPPT Design using GWO for Photovoltaic system under partial shading conditions discussed in [15].From the analysis it is concluded that the extraction of maximum power from PV panel under different weather condition is done by older methods are not sufficient. The proposed hybrid method is efficient to track maximum power from panel under all weather conditions efficiently.

2. Modeling of photovoltaic system

The US breast image is pre-processed using filter and tan function for effective distinguishes between normal and lesion regions. From the pre-processed image, the features are extracted from the normal and lesion regions and using these features the BPN network is trained. After training the network, the image is feed for the testing and automatically segmented. The block diagram for automatic segmentation is shown in Figure. 1

The practical single diode model of PV cell is shown in figure 1. The model has current source Iph, diode D parallel to current source I_D which represents the photocurrent, a series resistance Rs and a parallel resistance Rsh. Equation 1 represents the analytical circuit of single PV cell.

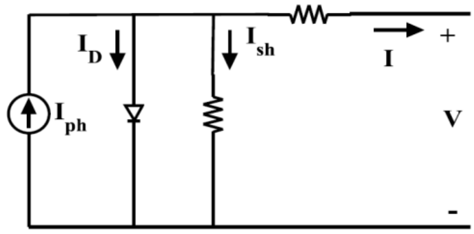


Figure 1

2.1 Practical circuit of PV Cell

$$I = I_{PV} - I_0\left[exp\left(\frac{V+IR_s}{aV_T}\right)-1\right]-\left[\frac{V+IR_s}{R_p}\right] \quad (1)$$

Where
I_0 is the reverse saturation current
V_T is the thermal leakage voltage
a is the ideality factor of the single diode
The temperature and irradiance effect can be written in equation 2 shown below.

$$I_{PV} = \left(I_{PV\_STC} + K_I\Delta T\right)\frac{G}{G_{STC}} \quad (2)$$

Where
I_{PV_STC} is the photocurrent under STC
$\Delta T = T - T_{STC}$ (in Kelvin) and T_{STC}=25°C
G is the irradiance effect on the surface of the PV cell
G_{STC} is the irradiance effect under STC (1000W/m²)
K_I is the SC current coefficient (normally given by maker)
The equation for the reverse saturation current of the diode is specified in equation 3

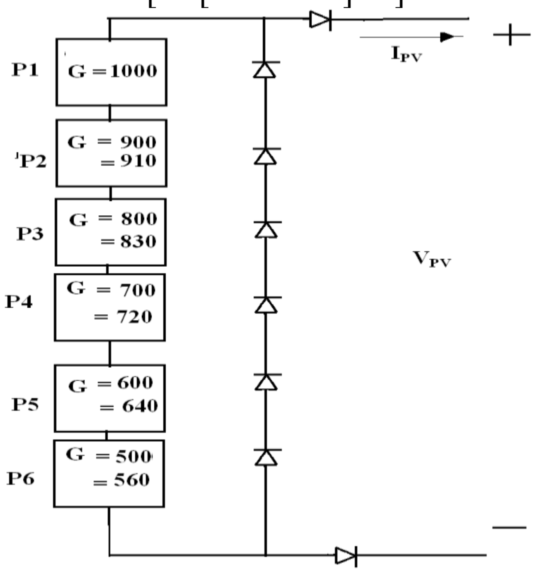
$$I_{0\_STC}\left(\frac{T_{STC}}{T}\right)^3 exp\left[\frac{qE_g}{aK}\left(\frac{1}{T_{STC}}-\frac{1}{T}\right)\right] \quad (3)$$

Where
Eg is the energy gap of the silicon semiconductor
I_{0_STC} is the nominal saturation current
The reverse saturation current equation can be further enhanced as a function of temperature as shown in equation 4.

$$I_0 = \frac{(I_{SC\_STC}+K_I\Delta T)}{exp[(V_{OC\_STC}+K_V\Delta T)/aV_T]-1} \quad (4)$$

Where
K_V is the temperature coefficient of OC voltage
I_{SC_STC} is the nominal SC current
V_{OC_STC} is the nominal OC voltage
All the above equations are used to represent a single PV cell. But actual PV panels are connected in series and parallel in order to fulfill the supply demand gap. Series combination of the PV cells increases the output voltage and the parallel combination of the PV cells increases the output current of the entire module .so the output current equation of this series parallel combination can be shown in equation 5.

$$I = I_{PV}N_P - I_0N_p\left[exp\left[\frac{V+IR_S\left(\frac{N_s}{N_p}\right)}{aV_TN_s}\right]-1\right] - \left[\frac{V+IR_S\left(\frac{N_S}{N_p}\right)}{R_P\left(\frac{N_S}{N_p}\right)}\right] \quad (5)$$



The series parallel structure of PV module is shown in figure 2

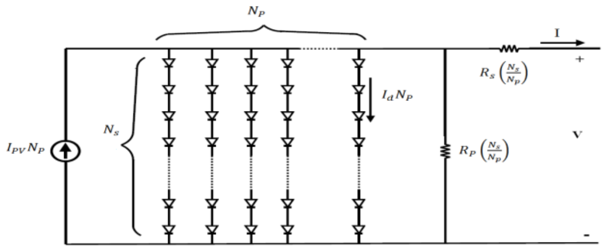


Figure 2: Series Parallel Combination of PV module

The typical characteristics of a PV energy system with 1000W/m² at 25 °C are shown in fig.3 (a) and (b). The peak point of the P-V and I-V curve gives the maximum power point in each PV cell. This point will be varies for different PV model cells. But the maximum power point tracking algorithms tracks the MPP of the system on a whole plant. The design details of PV panel for the proposed system as shown in Table 1.

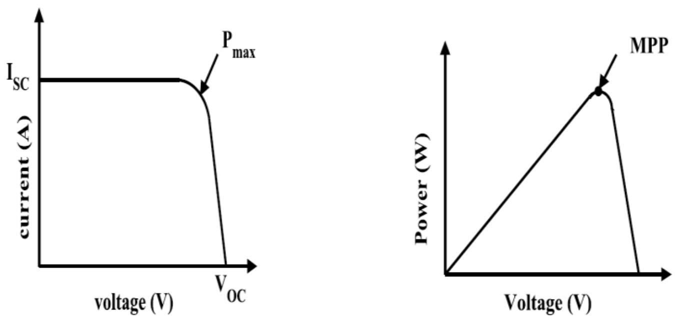


Figure 3 (a) I-V characteristics at 1000W/m² Figure 3 (b) P-V characteristics 1000W/m²

Table 1 Design Details of PV Panel

S.No.	**Model Name**	**Vicram Solar Eldora 250P**
1	Rated peak power (Pmpp)	250 W
	Normal Power (W)	185.97
2	Open circuit voltage (Vmpp)	30.85 V
	Open circuit voltage(Voc)	37.45 V
3	Rated current(Impp)	8.0 A
4	Type	polycrystalline solar cells
5	No of modules	5 Nos
6	No's of modules per KW	4 Nos
7	Fill factor	76.48%
8	Efficiency	15.53%
9	Temperature	Min -40 degree and max 85 degree centigrade
10	Dimensions of single module (mm)	1639X982 X36 mm

3. System Description

A 6S configuration of series solar panel under different solar irradiance is shown in Fig.4 (a) in this configuration six panels are connected in series. Fig.4 (b) shows the 6S2P configuration consisting of twelve PV panels connected in two parallel paths under different solar irradiance, each path consisting of four series connected PV modules. The PV curve of five different shading patterns with GP locations for the series 6S configuration is shown in Fig.5 (a). The PV curves of two different radiation shading for parallel 6S2P configuration is shown in Fig.5 (b)

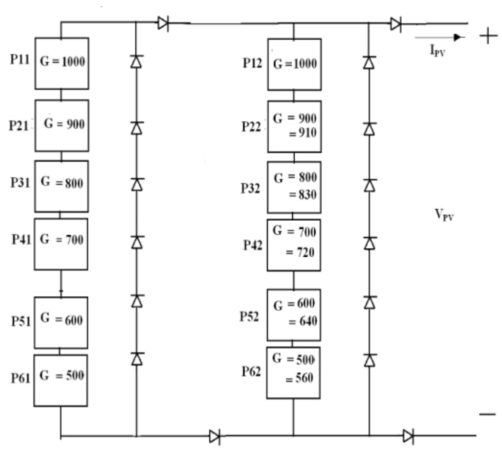


Fig. 4(a) 6S configuration (b) 6S2P configuration

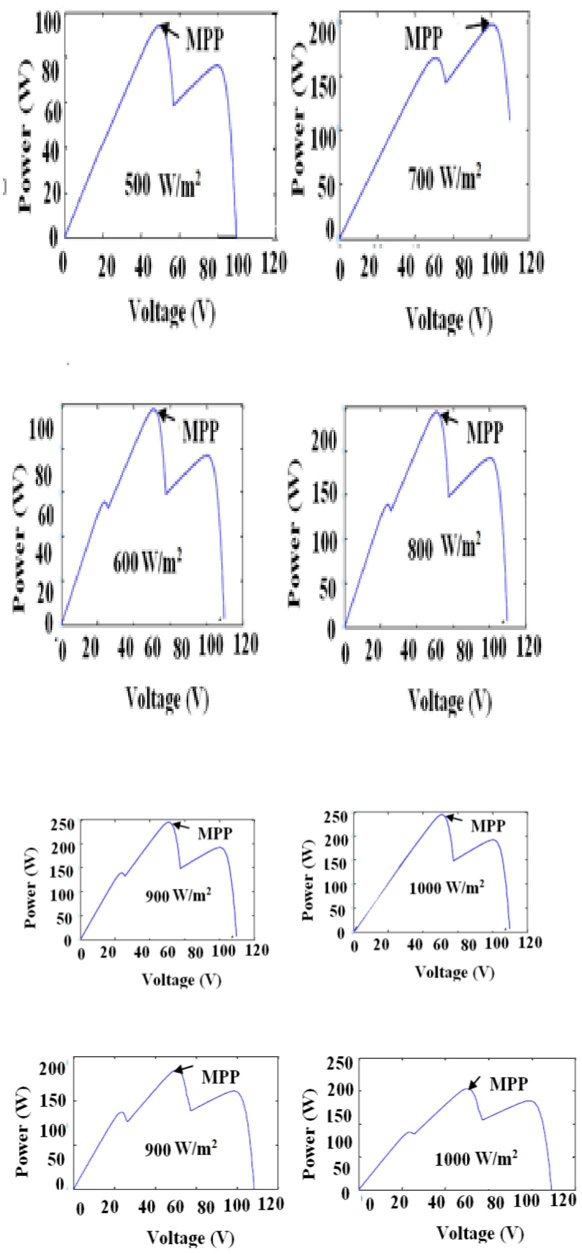


Fig. 5 P-V curves with MPP (a) 6S series configuration (b) 6S2P parallel configuration

4. Ant Colony MPPT

The ant colony optimization algorithm based on different starting points arbitrarily caused by the each ant, searches path in a row by use of pheromone concentration and method constituted by idea function, renews pheromone constantly, and figures out the optimal answer according to the pheromone density. Since basic ant colony optimization algorithm is built in disperse field, while output curve of PV model is a straight curve in practice, the ant colony optimization algorithm is brought in continuous field, and introduce Gaussian alteration to optimize its algorithm so as to realize tracking the maximum power point combined with practical situation of photovoltaic power generation. Ant colony optimization Maximum power tracking is implemented by the making most out of the ant's behavior .This process starts with randomly initializing the ants. The purpose of function is framed by including each PV panel's different irradiation and temperature. The pheromone attention is given by the formula

$$T_{ij} = \rho T_{ij}(t-1) + \Delta T_{ij} \quad (6)$$

Where t=1, 2, 3, 4, 5, 6…….T
Where
Tij - Revised attention of pheromone
ΔTij - Change in Pheromone attention
 ρ - concentration rate (0-1) of Pheromone
The pheromone rate ρ plays an essential role as absurd values. Attention rate would wrongly direct the difference of opinion to happen at local maximum. Pheromone concentration ΔTij is given by equation 7.

$$\Delta T_{ij} = \begin{cases} \frac{R}{fitness_k} & I_{ij} \\ 0 & \text{otherwise} \end{cases} \quad (7)$$

is choosen by ant k

4.1 Perturb and Observe (P&O) MPPT

The perturb and observe (P&O) algorithm usually used in PV systems due to easy implementation and simplicity. The P&O algorithm normally used to find the Maximum power by two techniques. The two techniques are Reference voltage perturbation and direct duty ratio perturbation. The reference value for the PV output voltage is used as the control parameter and where as the duty ratio of the MPPT converter is used directly as the control parameter.

5. Proposed Hybrid MPPT

The implementation of hybrid ACO MPPT WITH P&O MPPT technique is used track the maximum power and fill factor from PV panel all over the weather conditions. Hybrid MPPT tracks the exact GP with staring ACO MPPT followed by P&O MPPT. When the ant colony reaches nearer MPP, the P&O MPPT gets started at the location of the best ant colony optimization process. The proposed hybrid MPPT is applied to the PV system operating under all lower and higher partially shaded conditions. In the proposed hybrid MPPT algorithm ant colony refers to duty ratio of the dc-dc converter eliminates the PI control loop. This makes the controller easier and reduces the computational load in tuning the controller gain.
The functional equation of Ant colony algorithm Initialize the pheromone trails and parameters;

Step 1: generate the population of 'm' ant's colony solutions
Step 2: find the fitness (k) for every individual ant
Step 3: Evaluating the best position for each ant;
Step 4: Track the global best position for ant
Step 5: renew the pheromone trail;
Step 6: verify if convergence is satisfied;

Step7: After finding the MPP, P&O loop begin for tracking the maximum power by choosing a small perturbation step size to obtain reduced oscillations and higher tracking efficiency in each PV panel.
Fitness function= Panel1 (V1* (I1 (S1, T1) + Panel 2 (V2*(I2 (S2, T2) + Panel 3 (V3*(I3, S3, T3) (8)

T represents panel temperature; suffixes 1, 2, 3 represents corresponding PV panel array.
Equation 8 shows the fitness equation of the ant colony optimization. The Figure 7 shows the flowchart of the proposed Hybrid MPPT technique. The following steps are used to implement the hybrid MPPT algorithm

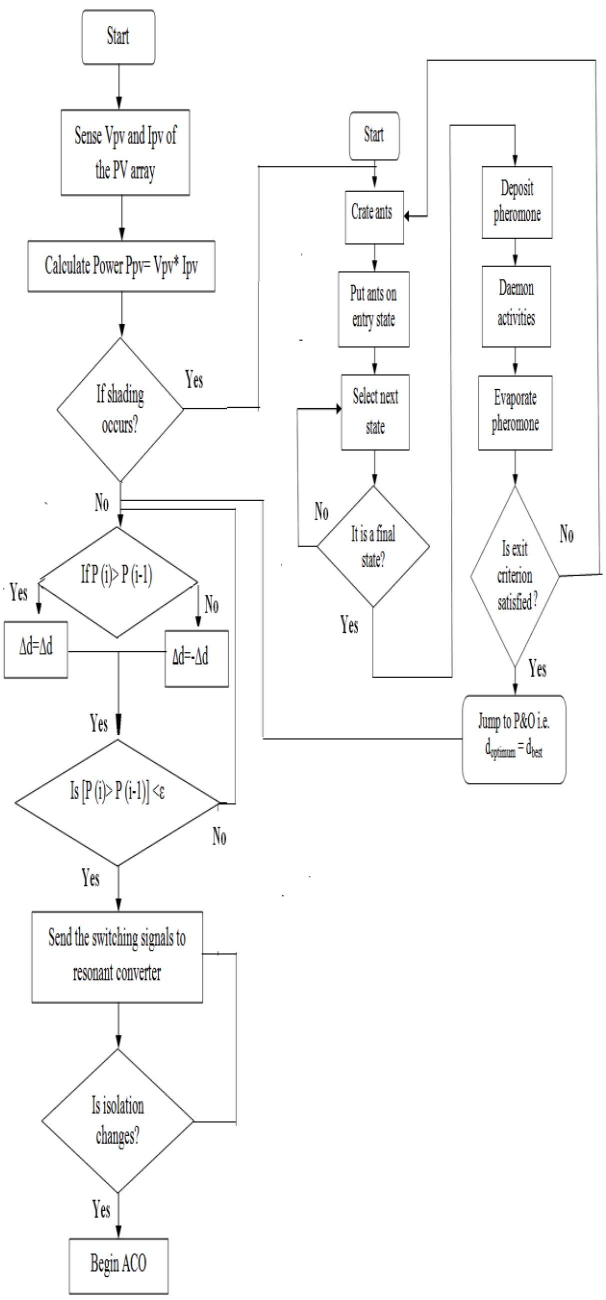


Fig. 7. Flowchart of the Hybrid-MPPT algorithm

Simulation result analysis

The proposed hybrid MPPT implemented in Simulink model were performed for both 6S series and 6S2P parallel configurations under both all partial shading conditions and rapidly changing insulation levels. Fig.8 shows the hardware and Simulink model of the proposed PV power system plant consisting of PV array, resonant boost converter, hybrid MPPT controller and a load. The design parameters of the PV module used in hardware as follows: $Pmax$ = 250W, Voc =37.5V, Isc =8A, Vmp =30.85V and Imp 7.61A. The design parameters of resonant boost converter both in simulation and experimental set up are listed in table 2.

Table 2. Resonant boost converter design parameters

Resonant converter parameters	Value
Nominal input voltage	0-300V
Nominal output voltage	500V
Nominal switching frequency	40KHz
Resonant capacitor	70nF/630Vrms
Resonant inductor	230μF/16A
Input capacitor	40μF/100V
MOSFET	200V/26A
IGBT	1200V/30A
Freewheeling diode	1200V20A
Output diode	2 series 1000V/8A
Snubber diode	1000V/8A

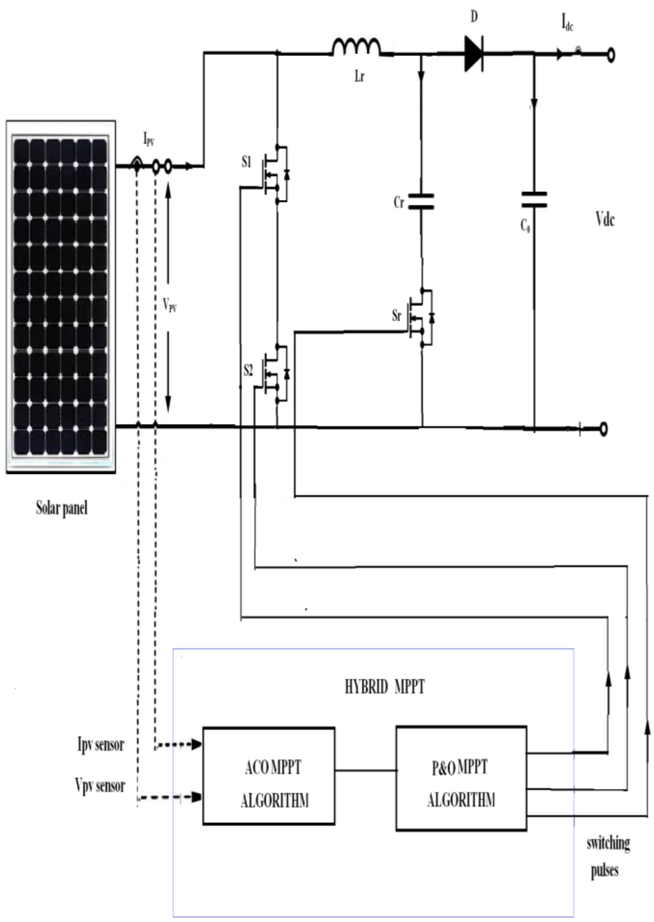


Fig. 8. Block diagram of proposed Hybrid-MPPT method

Solar panel partial shading conditions

The proposed ACO-PO hybrid MPPT algorithm is applied to the 6S configuration for 500W/m2 under PSCs to track the global peak (GP) and it is compared with fast converging techniques such as ACO and ACO-PO based MPPT techniques as shown in Fig.9(a) Similarly, the simulation was repeated for 6S2P configuration for 500W/m2 shown in Fig.9(b). Both Fig.9 (a) and Fig.9 (b) clearly show that the proposed MPPT clearly tracks the GP with faster convergence as compared to ACO techniques. From the above results it is concluded that the proposed ACO-PO hybrid MPPT exhibits faster convergence amongst ACO and other MPPTs. the solar intensities of the PV modules are arbitrarily varied i.e. 500W/m2 shifts to 600W/m2 as shown in Fig. 10(a)and (b). Fig. 11 shows the Tracking curves for 4S series configuration in PV power of proposed Hybrid MPPT compared with other techniques with different pattern.

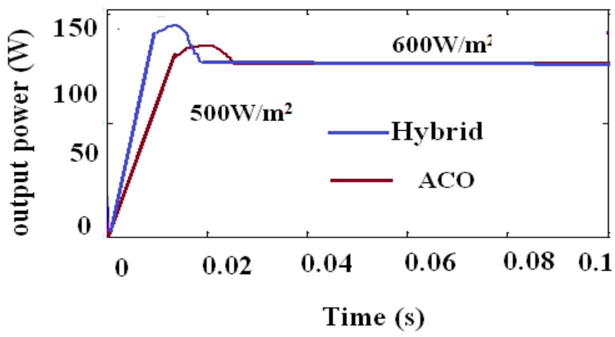
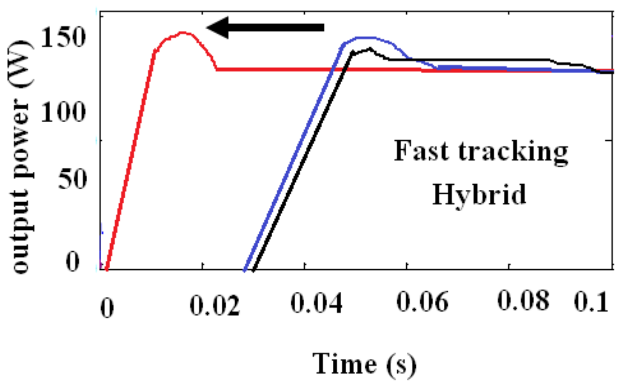
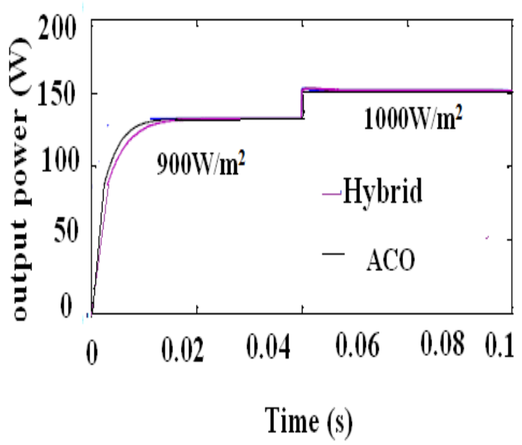


Fig. 9 Tracking curves for 4S configuration (a) PV power of proposed Hybrid MPPT compared with other techniques





(b)) PV power of proposed Hybrid MPPT with fast tracking

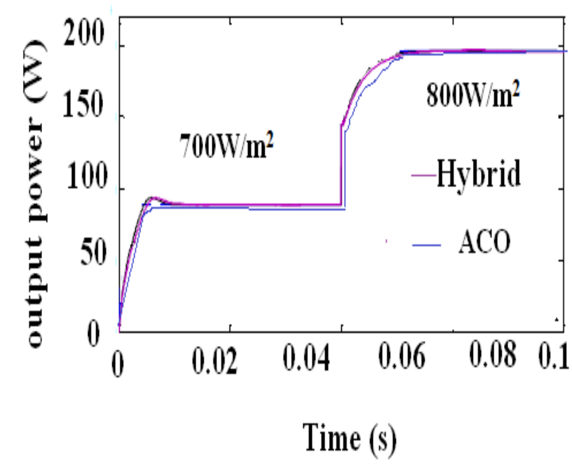
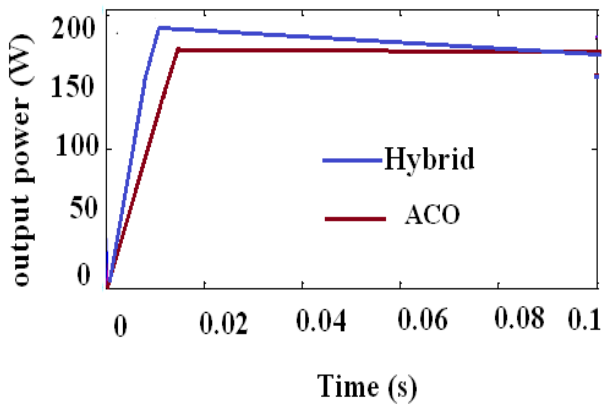


Fig. 10 Tracking curves for 4S series configuration (a) PV power of proposed Hybrid MPPT compared with other techniques



(b)) PV power of proposed Hybrid MPPT with fast tracking

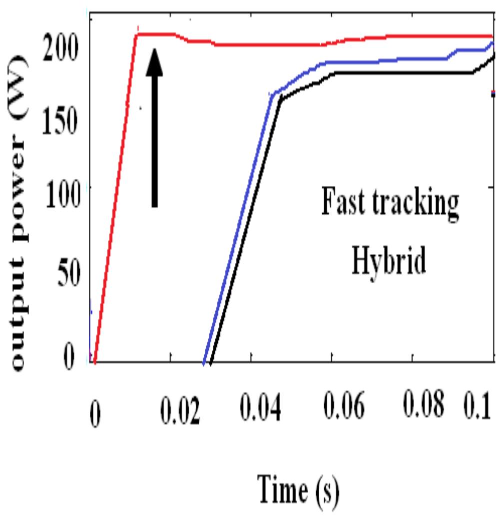


Fig. 11 Tracking curves for 4S series configuration (a) PV power of proposed Hybrid MPPT compared with other techniques with pattern (b)) PV power of proposed Hybrid MPPT with fast tracking with pattern

Hardware results

The experiments results are carried out for both 6S series and 6S2P parallel configurations under different weather conditions. The hardware experimental set up of the proposed PV plant is shown in Fig.11. A Vicram Solar Eldora 250P solar panel is used in this experiment to find the PV source power with various conditions such as rapidly changing solar insulation and temperature. DSP processor is used to provide the firing pulses to this converter. The converter has 2 MOSFET with two set of coupled inductor gate drive circuit. This DC-DC resonant converter output is given to Cascaded multilevel inverter. Gating pulses are generated using FPGA processor (Xilinx Spartan 6) and integrated in DSP (TMS320F28335) processor. A Hall sensor (Pt100) model is used to sense the voltage and current from the solar simulator. In order to verify the effectiveness of the proposed Hybrid-MPPT both series and parallel configuration are experimentally conducted with different solar radiation and temperature shown in fig.12 to fig.14.

Fig. 11. (a) Experimental set up of the proposed system

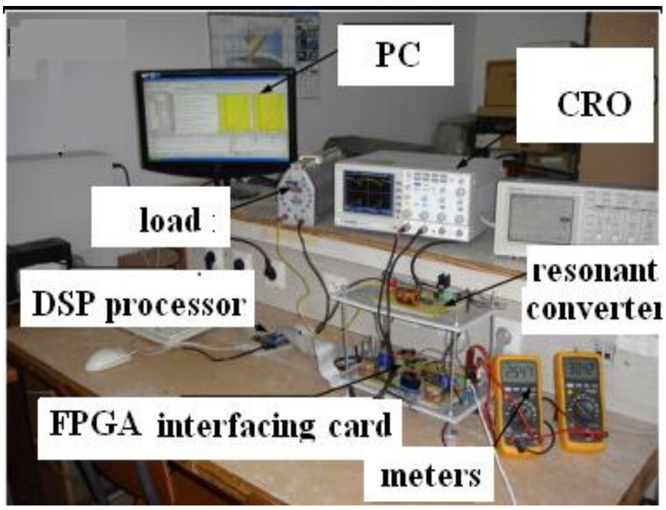


Fig. 11. (b) Control circuit of the proposed system

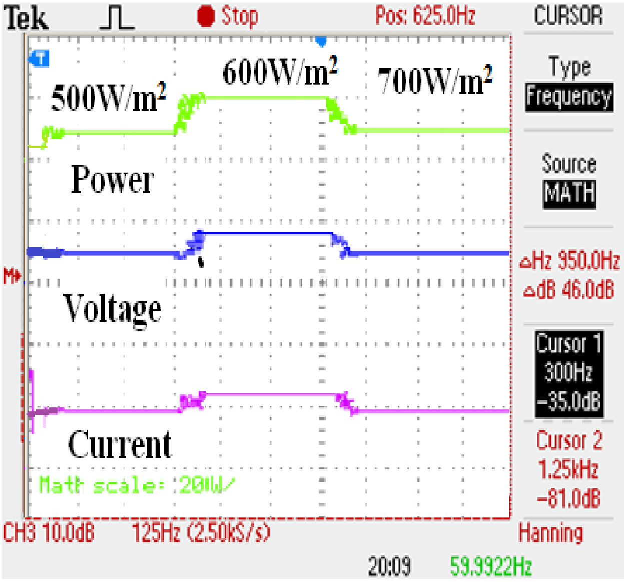


Fig. 12. Experiment results for 4S configuration for extreme rapidly changing insulation patterns of PO-MPPT

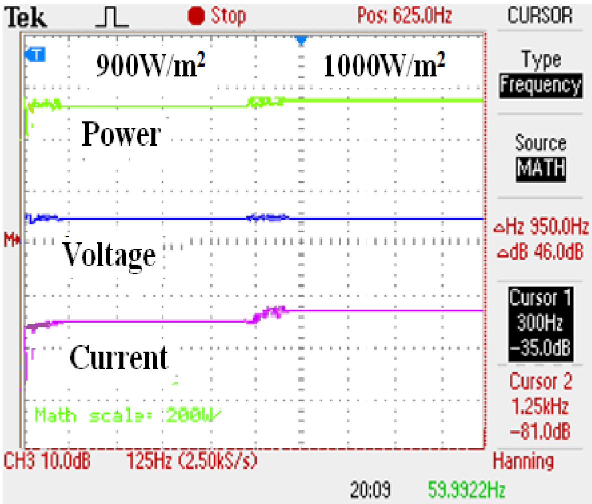


Fig. 13. Experiment results for 4S configuration for extreme rapidly changing insulation patterns of GWO-MPPT

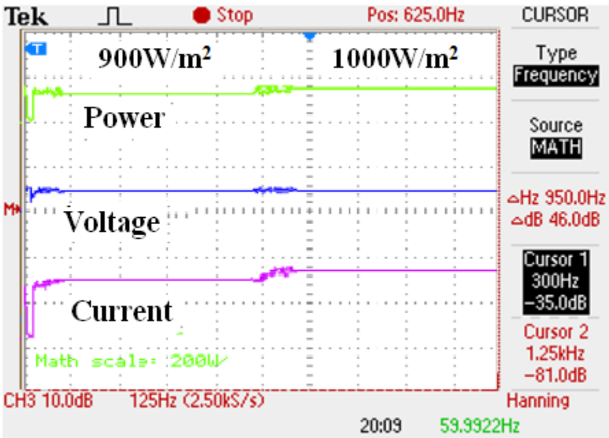


Fig. 14. Experiment results for 4S configuration for extreme rapidly changing insulation patterns of Hybrid-MPPT

Table 3: Characteristics comparison of the proposed hybrid MPPT method with other methods

Shading pattern	Maximum power	Tracking technique	Maximum power	Maximum voltage	Maximum current	Efficiency
$900W/m^2$	240	P&O	234	30	9.78	97.78
		GWO+P&O	238	31	9.65	98.95
		ACO+P&O	240.26	32	9.46	99.90
$1000W/m^2$	250	P&O	246	28	10.68	99.88
		GWO+P&O	248.56	30	9.68	99.65
		ACO+P&O	250.56	33	10.65	99.94

Table 4: Performance comparison of the proposed with other fast-converging MPPT techniques

Type	P&O	GWO	ACO	HYBRID
Power efficiency	high	high	high	Very high
Steady state oscillations	large	zero	zero	zero
Dynamic response	poor	good	good	good
Complexity in modeling	low	Medium	good	good

Table 3 shows the characteristics and comparison of the proposed hybrid MPPT method with other methods and table 4 shows the Performance and comparison of the proposed with other fast-converging MPPT techniques. This hybrid algorithm produces fast maximum power tracking with least time in each solar panel. From the analysis it found that this Hybrid MPPT is having the capacity to track maximum GP under sudden variation in insulation and any partial shading.

6. Conclusion

This paper has presents the development of a new hybrid ACO MPPT assisted P&O MPPT to Track maximum power from a PV system with different solar radiation and all temperature variation. The proposed Hybrid MPPT algorithm was analyzed with both simulation and experimental studies on a 250W prototype PV system. The performance and comparative studies of hybrid MPPT with other fast converging techniques are analyzed. From the analysis it is concluded that Hybrid MPPT has superior performance and fast tracking speed to get maximum power from solar panel than other faster tracking methods under different weather conditions.

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