Performance Analysis of Solar MPPT techniques Under Partial Shading Condition

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***Abstract*—Nowadays, Solar photovoltaic (PV) technology is considered as a prominent alternative to fossil fuels. It has received great attention due to its nonpolluting operation. The two main factors which influence the performance of PV system are irradiance and temperature because during partial shading conditions, irradiance and temperature changes which in turn reduces the generated power. However, Conventional tracking techniques fails to track the maximum power point under partial shading condition because during this condition, the characteristics of PV exhibit many local maxima and conventional methods are unable to track the global maximum power point. This paper presents a comparative analysis of three MPPT methods which are perturb and observe(P&O), incremental conductance(IC) and particle swarm optimization(PSO) under partially shaded conditions. MATLAB SIMULINK has been used for the analysis and the relevant results are discussed in detail.**

Keywords — PV array, PV system, Maximum power point tracking(MPPT), partial shading condition(PSC), perturb and observe(P&O), incremental conductance(IC), particle swarm optimization(PSO).

I. INTRODUCTION

Increasing environmental concerns, dwindling fuel reserves and rising energy needs has directed our attention towards the glimmer of aspiration for a future totally based on renewable and non polluting energy supply technology. Power generation through Photovoltaic (PV) is increasingly becoming popular in comparison to other renewable resources owing to its advantages like easy availability, low cost, negligible environmental pollution and lesser maintenance tariff [1]. Despite having so many advantages, performance of PV generation is greatly opposed by its sensitivity towards two environmental factors namely temperature and irradiance.

In earlier times, single PV modules were in high demand but due to the increasing demand of power in modern world, these are replaced by group of PV modules

Connected in series – parallel(SP) combination. The relationship between voltage and current of a PV panel follows a non-linear path and hence it becomes imperative for us to find the optimum operating point so that we can extract the maximum output from the panel. However, the conversion efficiency of PV panel is quite low and is greatly affected by weather conditions like change in irradiation and temperature levels. The environmental conditions are not always constant as we don't always have constant value of irradiance and temperature as a result we obtain multiple peaks on P-V characteristics under partial shaded conditions.

Within this context, this paper presents the performance analysis among three MPPT techniques under partial shading conditions.

The specific scope of my research paper comprehends the following issues:

1. brief discussion on PV modules
2. Description of three MPPT techniques namely Perturb and Observe, Incremental Conductance and Particle Swarm Optimization.
3. Performance analysis under partial shading conditions.

The Modeling and Simulation has been done under MATLAB 2018a environment and the algorithms are tested under two patterns of shading.

II. MODELLING OF PV CELL

A photovoltaic cell is basically an electrical device which uses photovoltaic effect to convert light energy into electrical energy. The equivalent circuit of single diode photovoltaic cell as shown as under. The below shown model basically consists of a current source, a diode, a parallel resistance and a series resistance.

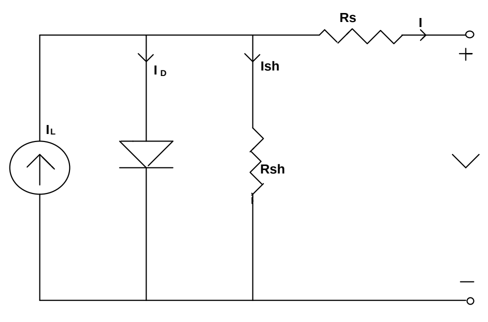

Fig. 1 Single diode PV model

Whenever the sun rays falls on the cell, direct current is generated which can easily be obtained by applying Kirchhoff law equation as shown below:

$I = I_L - I_d - I_{sh}$ (3.1)

Where

I_L = Photovoltaic Current

I_d = Diode Current

I_{sh} = Current leak in parallel resistor

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Hence, the diode current equation can be written as

$$I_d = I_O \left[\exp\left(\frac{V}{A.Ns.Vt}\right) - 1\right] \quad (3.2)$$

$$V_T = \frac{KTc}{q} \quad (3.3)$$

Where,

V = Voltage imposed on the diode (V)

I_O = Reverse Saturation Current (A)

T_C = Actual Cell Temperature (K)

V_T = Thermal Voltage

N_S = Number of PV cells connected in series

A = Ideality Factor

K = Boltzmann Constant ($1.38 * 10^{-23}$ J/K)

q= Electron Charge ($1.602 * 10^{-23}$ C)

Hence, the relationship between load current I and output voltage V can be written as:

$$I = I_L - I_O * \left\{\exp\left(\frac{q}{nKTc}(V + IR_s) - 1\right\} - \frac{V+IRs}{Rsh}\right\} \quad (3.4)$$

Where,

I_L = Light Current (A)

I_O = Saturation Current (A)

I = Load Current(A)

V = Output Voltage (V)

R_S = Series Resistance (ohms)

Hence the mathematical model is developed by using the above set of equations.

III CHARACTERISTICS OF SOLAR CELL

Characteristics of Solar cell basically illustrate the relationship between three commonly known electrical parameters namely voltage, current and power. I-V and P-V characteristics are very critical in determining the performance analysis of solar cell. The point where the cell generates the maximum power is denoted by maximum power point and is near the bend of the curve. However, under normal conditions of temprature and radiation there is only single maximum power point but partial shading condition give rise to multiple peaks which contains several local maxima point and a single global maximum point as shown in the figures below:

IV MPPT TECHNIQUES

Maximum power point tracking techniques are used to extract the maximum power in solar PV system so that most stable and maximum possible power can be transferred from source side to load end. The main aim of MPPT techniques is to hunt the global maximum point. There are various kinds of MPPT techniques for the optimization of solar power and all differ from each other in respect of effectiveness, cost, complexity, speed and popularity.

The scope of this paper comprises of only three aforementioned MPPT techniques which are discussed below:

A. Perturb and Observe algorithm

It is abbreviated as P & O method and works by perturbing the terminal voltage of the PV array in a regular interval of time and then comparing the output power of the PV with previous perturbation cycle. It is the simplest and the most widely used approach. The basis of this technique is the relationship between output power of PV module and its output voltage. Here, the duty cycle ratio is adjusted until it reaches the maximum power point. However, this method suffers with two major drawbacks namely oscillation of output around the point of maximum power and deviation from the maximum power point in case of changing atmosphere.

Hence we can say it is not reliable in case of fast variations in weather conditions. It lacks the required speed and adaptability feature which is a must for keeping a track of the fast transients.

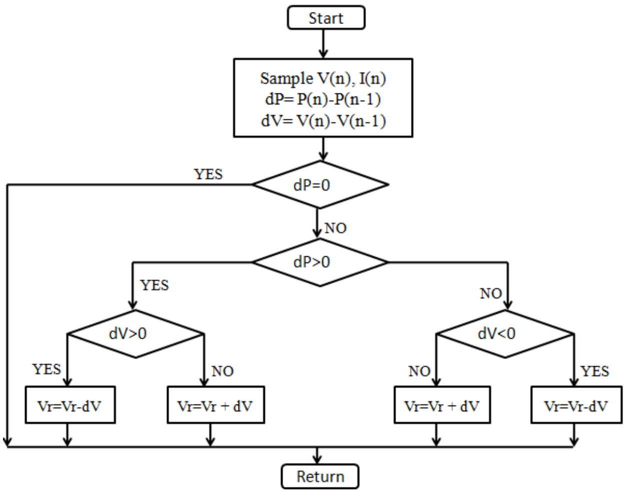

Fig. 2 Flowchart of Perturb and Observe Algorithm

B. Incremental Conductance Method

This approach is somewhat different from the one discussed above in the way that it works by assuming that the ratio of the change in output conductance is equal to the negative output conductance. Its basic principle is that the slope of the PV array power curve is zero at the peak power point. This method produces the peak power near to 98% of its incremental conductance. In this method, when the maximum power point is attained, the incremental conductance method stops perturbing the operating point further.

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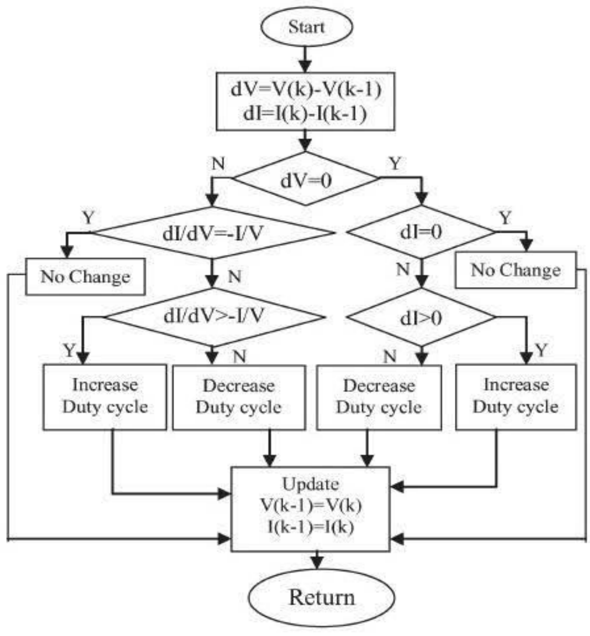

Fig. 3 Flowchart of Incremental Conductance Algorithm

C. Particle Swarm Optimization

It is based on the swarm optimization and works by analyzing the social behaviour of particles in the swarm. It rectifies the inability of classical methods to work under varying environmental conditions. It searches the whole area and finds the best by making comparisons in their fitness values. It is a random optimization algorithm and in order to obtain the global best solution by making adjustments in the trajectory of each and every individual towards the best position and towards the best particle in each step. Here, numerous particles come together to form a 'swarm' which fly through feasible hyperspace in search of regions where there is possibility of optimal solution. In a particular search area of N dimensions, there are two vectors namely position vector(X_i) and velocity vector (V_i) and the previous position of each particle is recorded as P_i which is also known as pbest. During each iteration, particle having the best solution shares its position with the rest of the members of swarm. In this research, fitness function has been employed to calculate the position of each particle of the swarm and hence the global and best position is the one having highest power and is GMPP. It works effectively by utilizing very few parameters in changing weather where multiple peak points are present and it becomes somewhat difficult to search for MPP region. Comparing to other optimization techniques, PSO method somewhat has lower sampling time, simple mathematical analysis, easy to implement, economical to use provides faster tracking under changing environmental parameters. It gives updated convergence velocity steadily. In addition to this, it provide us with the utmost efficiency utilization with no requirement of initial parameter calculation.

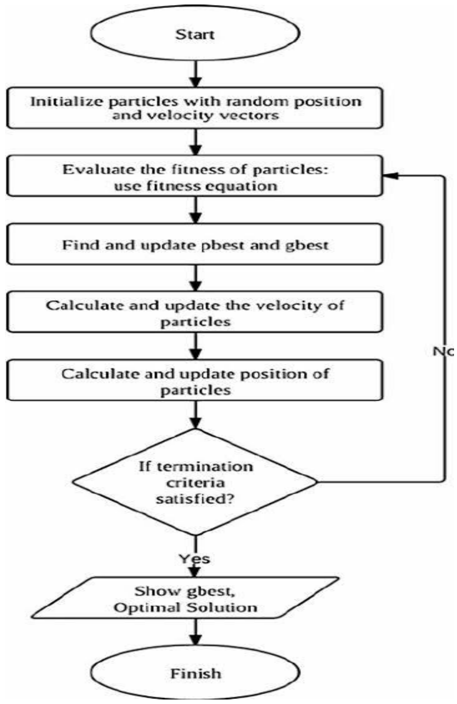

Fig. 4 Flowchart of Particle Swarm Optimization Algorithm

V MPPT SYSTEM

The proposed system consist of four blocks namely PV array, MPPT system, Controller and measurement system which are connected as shown above to perform the required simulation. The main objective of our work is to track the power under partial shading condition and hence we created partial shading condition through our first block where we connected four PV modules in series each of which is getting different inputs of irradiance and temprature. The output of array block is directly fed to optimization block to maximize our output. The duty cycle output from MPPT algorithm is being fed to boost converter via pwm converter. Here, the output from boost converter is connected via resistive load so as to know the amount of power we are obtaining from the proposed system.

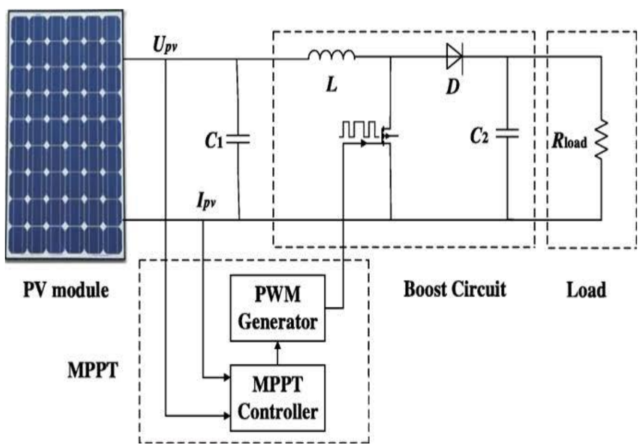

Fig. 5 Configuration diagram of PV system

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VI MODELLING AND SIMULATION

The proposed model is being built by MATLAB 2017a and consists of four blocks namely PV array, MPPT system, Controller and measurement system which are connected as shown above to perform the required simulation. The main objective of our work is to track the power under partial shading condition using three different MPPT techniques.

In this paper, I have studied and simulated a PV system under partial shading conditions using three different MPPT algorithms. The simulations have been carried out under variable irradiance and variable temperature conditions. The simulation model of proposed PV system using three aforementioned algorithms have been shown below:

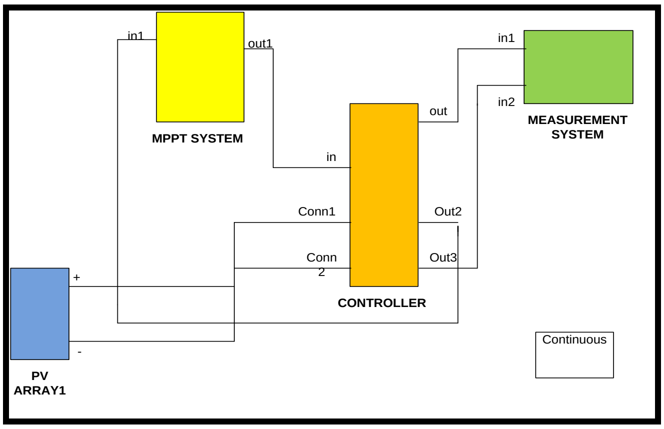

Fig. 6 Simulation Circuit of proposed PV system

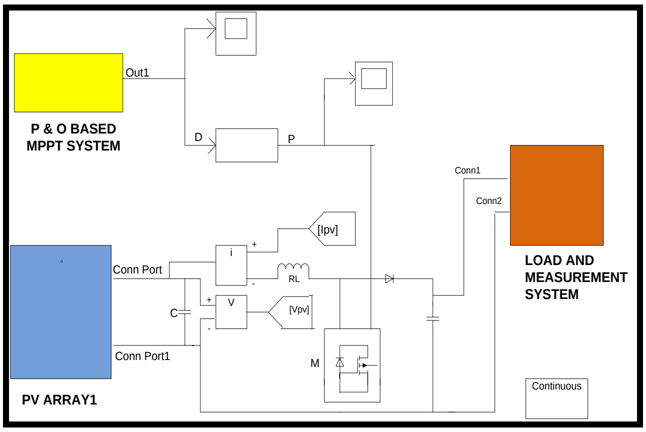

Fig. 7 Simulation Circuit of proposed PV system using P & O Algorithm

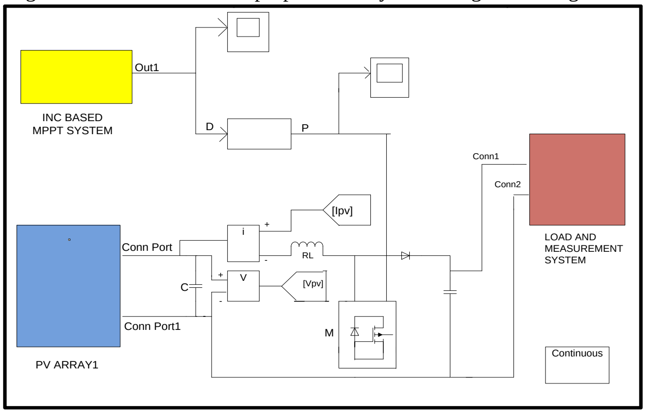

Fig. 8 Simulation Circuit of proposed PV system using Incremental Conductance Algorithm

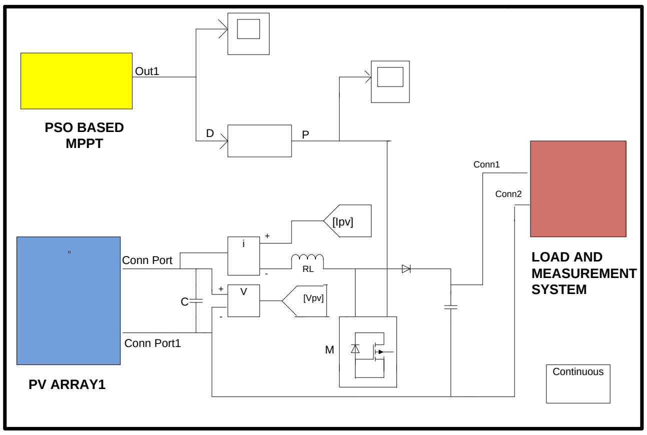

Fig. 9 Simulation Circuit of proposed PV system using Particle Swarm Optimization Algorithm

VII RESULTS

In case of partial shading, multiple peaks appear in the system and in this work we have compared three different power point techniques under two test cases as shown below:

Test Case -1 (Partial shading with different radiations)

MODULE	IRRADIATION (in W/m^2)	TEMPRATURE (in °C)
1	500	25
2	800	25
3	1000	25
4	1000	25

In this case, fixed temperature input has been provided To the system whereas radiation is increasing in all the Series connected modules.

Test Case -2 (Partial shading with different temperature)

MODULE	IRRADIATION (in W/m^2)	TEMPRATURE (in °C)
1	500	26
2	800	28
3	600	27
4	700	27.5

In this case, variable temperature and randomly varying radiation has been provided to the system.

Simulation results of proposed PV system with P & O algorithm have been presented below:

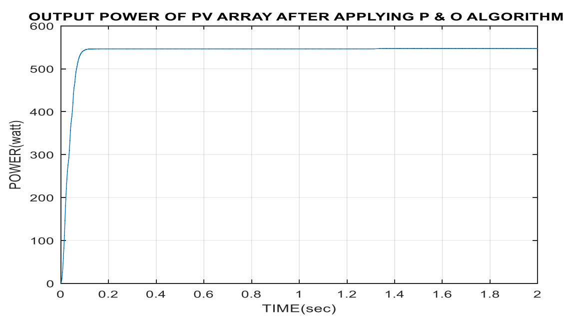

Fig. 10 Simulation result of proposed PV system using P & O Algorithm

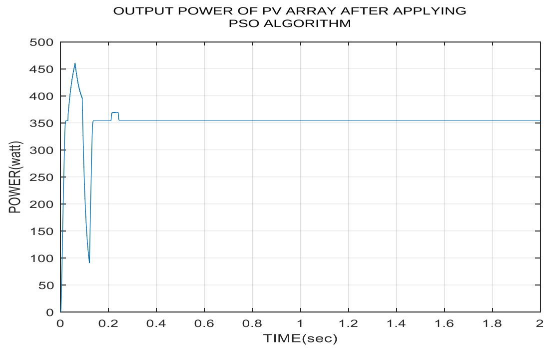

Fig. 11 Simulation waveform of proposed PV system using Particle Swarm Optimization Algorithm

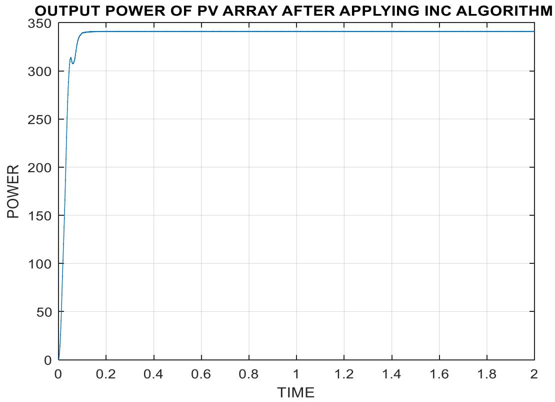

Fig. 12 Simulation Circuit of proposed PV system using Incremental Conductance Algorithm

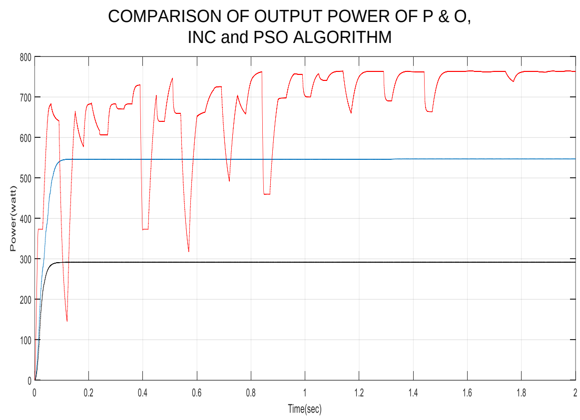

Fig. 13 Comparison of output power of P&O, INCand PSO algorithm

TABLE 1 COMPARATIVE ASSESSMENT OF MPPT TECHNIQUES UNDER PARTIAL SHADING CONDITIONS IN TEST CASE 1

Method	Peak power tracked (Watt)	Reaction Time (sec)	Stability Time (sec)
P & O	350	0.175	0.175
INC	415	0.175	0.175
PSO	625	0.001	1.58

From the above table it can be clearly concluded that under partial shading condition conventional algorithms converge at local maxima point and hence fail to search the global maxima point which proves the effectiveness of PSO technique as it tracks the global maxima accurately.

TABLE 2 COMPARATIVE ASSESSMENT OF MPPT TECHNIQUES UNDER PARTIAL SHADING CONDITIONS IN TEST CASE 2

Method	Peak power tracked (Watt)	Reaction Time (sec)	Stability Time (sec)
P & O	175	0.175	0.175
INC	350	0.001	0.001
PSO	550	0.001	0.28

It can be clearly observed from the above table that the PSO algorithm track the maximum power after transient response which occur during the first 0.001 seconds. Also, there are several iterations before the attainment of steady state response. We can clearly see that the algorithm starts tracking from the initial 0.0 second and achieve steady state in 0.001 seconds. In PSO, the no. of search iterations are 33-35. Also, there are several ups and downs before the attainment of steady state error. Hence it can be concluded that PSO algorithm is able to track under variable temperature and radiation conditions and is more reliable than conventional methods.

VIII CONCLUSION

The research work signified and explained the need of new soft computing techniques which shall be more fast and precise in tracking maximum power point and in achieving steady state in a consolidated way. Conventional algorithms fail to track the maximum power under partial shading conditions and converge before the attainment of final peak.

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