# Comparative Analysis to the Solution of Partial Shaded Condition in Grid-Connected PV system

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***Abstract :*** Solar power is one of the essential renewable resources. The solar energy is either stored and used or directly connected to the grid for satisfying utility load. Partial shaded condition (PSC) is one of the problems of the solar power plant where the maximum peak cannot be identified. Algorithms which are all used for identifying the global solutions can be used in this condition. Here Particle swarm optimization (PSO) and Cuckoo search algorithm (CSA) are used in the PSC conditions and the results are compared with the conventional method incremental conductance method (IC). MATLAB software is used for the implementation of algorithms and analysis of results.

***Index Terms* – partial shaded condition, global Maximum power point tracking, Particle Swarm Optimization, Cuckoo Search Algorithm.**

## I. INTRODUCTION

Partial shaded conditions are one of the important problems in solar system efficiency. In 2014 Kinattingal Sundareswaral has proposed a colony of flashing fireflies' algorithm to track the MPPT for PSC conditions and compared with PSO and P&O methods. Pikatis M has proposed ANN with Incremental conductance method for MPPT. ANN makes the tracking faster and accurate. Sridhar R has discussed the differential evolution with MPPT and compared the performances with conventional techniques. Indu Rani Balasubramanian discusses the impact of PSC on the output of the power of PV systems under partial shading conditions. Kai-chen proposed improved MPPT method to identify the GMPP. Shiva moballegh discusses the electrical models of PV arrays under different irradiance levels and temperature is developed. These models are used in power prediction scheme to identify the GMPP. Kinattingal Sundareswaran has implemented random search method for PSC in PV panels to get GMPP. It uses very less memory. Compared to PSO random search method is better. Rambi MZ an analog energy recovery circuit is used to recovery the partial shaded energy in cells. It improves the overall efficiency. Pooja Sharma using current compensation concept the MPPT is done with distributed MPPT (DMPPT). The DMPPT with shunt and series compensation is introduced. It operates at exact MPP. Koksoon Tey introduced modified incremental conductance method to find GMPP. Mohammad Mehdi seyed Mahmaodial introduced hybrid differential evolutionary algorithm with PSO for tracking GMPP. Jubaer Ahmad has proposed cuckoo search algorithm for partially shaded conditions and compared the performance is compared with PSO and P&O algorithm. But recent algorithm, which gives better performance is firefly algorithm and it is not compared to it. In 2015 a detailed literature survey is presented with referring nearly 52 papers and comparison is tabulated by P.Sivachandran.

This paper deals with the problem of PSC in solar system. The Incremental Conductance method, Particle Swarm Optimization and Cuckoo Search Algorithm are implemented. The comparisons of power delivered to the grid is maximized. And the performance with and without PSC is analyzed.

## II. PROBLEM DEFINITION

The maximum power point tracking can be implemented by many hill climbing techniques. but on the partially shaded conditions power-voltage curve takes multiple peaks. So global optimum power cannot be identified by the conventional hill climbing techniques, which may produce incorrect tracking of power.

The objective function for the maximization of power is given below.
The power from the input of the PV array is

$$P(t) = V(t) * I(t) \quad (1)$$

$$\text{Maximize } (P(t)) \quad (2)$$

With respect to

$$Dl < D < Dh \quad (3)$$

t – sampling time in secs
Dl – Lower limit of duty cycle
Dh- higher limit of duty cycle

## III. METHODOLOGY

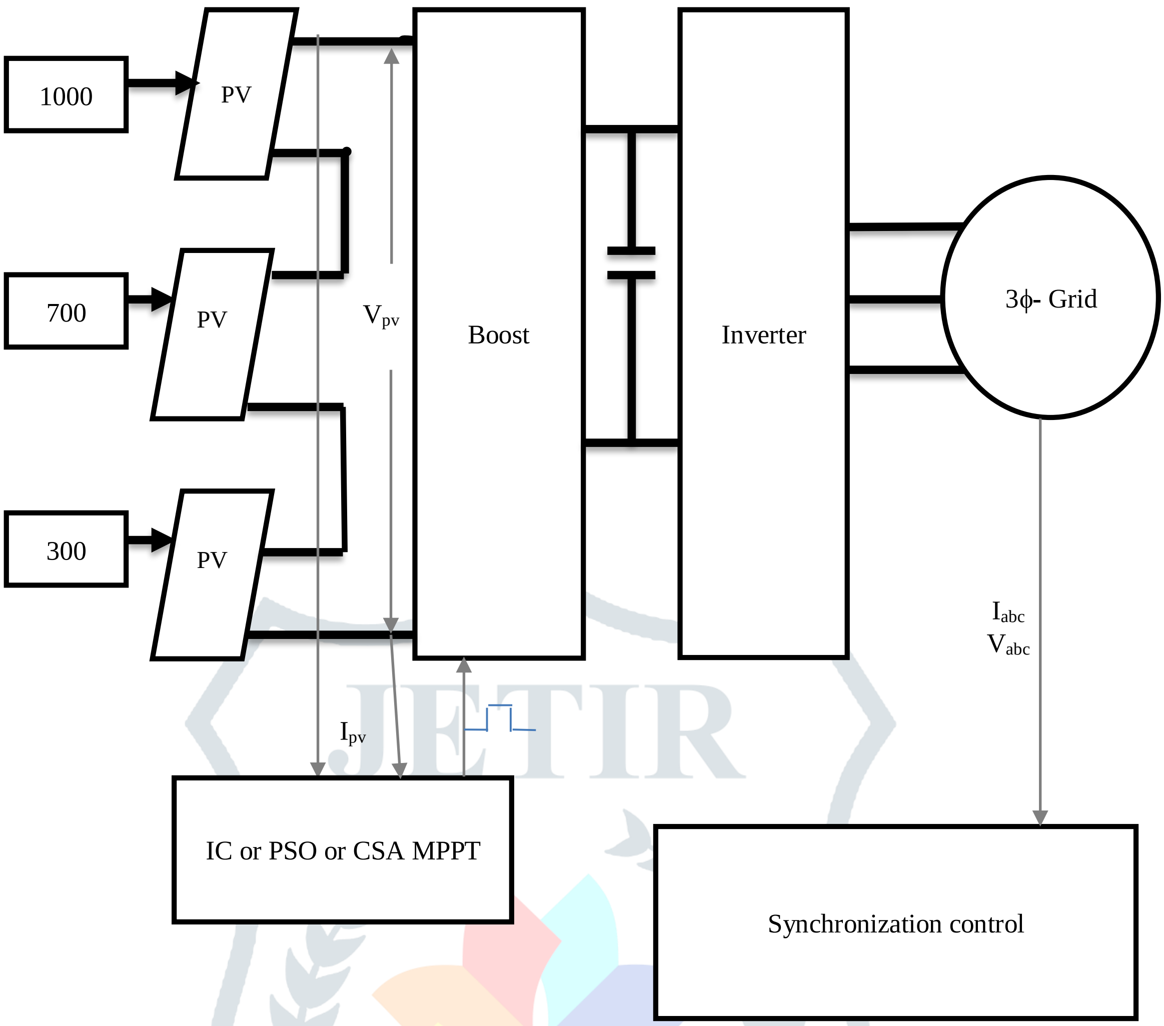


Fig 1. Implementation Block diagram of Solar power plant

There are there controls present in this proposed approach. Maximum power point tracking (MPPT), synchronization control and Hysteresis PWM control. The maximum power point tracker is given with Ipv and Vpv as input and required output power absorbed by the synchronization controller is decided by MPPT controller. According to the Pref the synchronization controller produces the reference current. The hysteresis controller is used to produce the PWM. This PWM controls the inverter such that the MPP is tracked and injected to the grid. The detailed explanation of each control is given in next section.

## IV. SYNCHRONIZATION CONTROL

The synchronization controller is depicted in fig.2. Vabc and Iabc are transformed to dq0. Then power is calculated. The reference power is taken from MPPT technique. Both the powers are subtracted and the error is given to PI controller. The PI controller produces proportional current value of direct axis (Id). This current is summed up with measured Id from grid side after removing higher order harmonics.

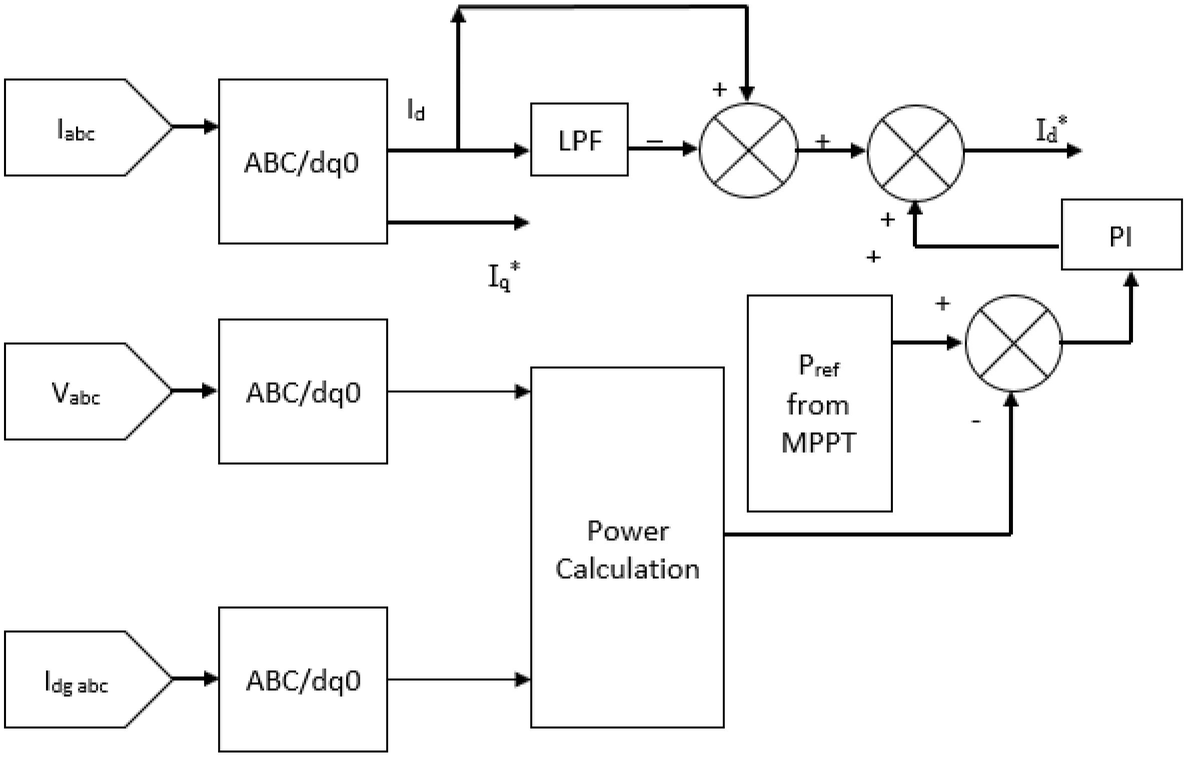


Fig.2 Block diagram of Synchronization control

## V. HYSTERESIS CONTROL

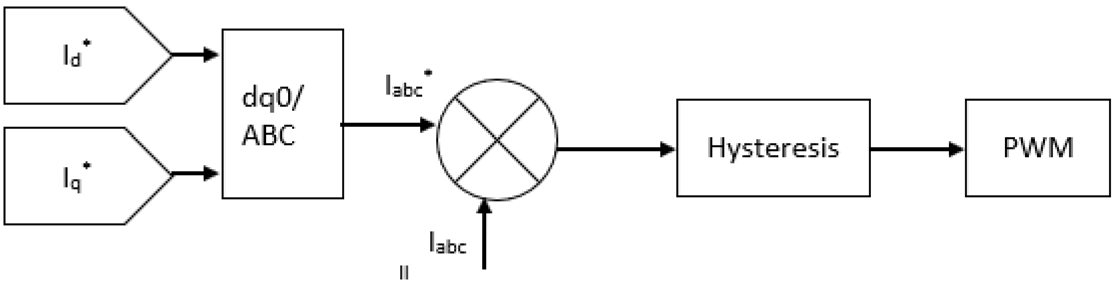


Fig.3 Block diagram of Hysteresis control

The error current is given to hysteresis control for producing the pulses for three phase inverters. Hysteresis controller is one of the simple methods for injecting current to the grid. Each phase error is given with a specific band width for getting higher switching frequency to make the size of filters smaller.

## VI. INCREMENTAL CONDUCTANCE METHOD

The incremental conductance algorithm is based on the slope of the curve power vs. voltage (current) of the PV module is zero at the MPP, positive on the left of it and negative on the right of it.

- $\Delta V/\Delta P = 0$ ($\Delta I/\Delta P = 0$) at the MPP
- $\Delta V/\Delta P > 0$ ($\Delta I/\Delta P < 0$) on the left
- $\Delta V/\Delta P < 0$ ($\Delta I/\Delta P > 0$) on the right

$V(t)$ – measured voltage
$\Delta t$ – time difference
$V(t-\Delta t)$ – measured voltage after $\Delta t$
$I(t)$ – measured current
$I(t-\Delta t)$ – measured current after $\Delta t$

Measured Power $P(t) = V(t)*I(t)$
Measured change in power $P(t-\Delta t) = V(t-\Delta t)*I(t-\Delta t)$

If the ratio of $\Delta V/\Delta P$ and $\Delta I/\Delta P$ are equal to zero maximum power is absorbed, no change in reference power. And if $\Delta V/\Delta P > 0$ and ($\Delta I/\Delta P < 0$) then increase the $P_{ref}$ value of the synchronization control, else decrease the $P_{ref}$.

So, whenever there is available power then it can be absorbed. Or the duty cycle is maintained constant.

## VII. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization is algorithms framed based on the food searching behaviour of birds. In the bird flock when one bird locates the food or target (maximum of the power) it instantaneously transmits the information to all other birds. All other birds are attracted to the food or target but not directly. It depends on the birds independent thinking based on it past memory. The algorithm steps for maximum power point tracking is as follows

Step 1: initialize the particles (duty cycle) by assuming the number of population (N).

Step 2: Generate initial population of D in the range of $D^l$ and $D^h$ randomly. As $D_1, D_2..D_N$.
For convenience, the particle (position of) j and its velocity in iteration i are denoted as $D_j^{(i)}$ and $V_j^{(i)}$ respectively. Thus the particle generated initially are denoted $D_1(0), D_2(0),\ldots D_N(0)$. This $D_j(0)$ ( j = 1,2, ….,N) are called particles. Evaluate the fitness function (maximization of power) and take it as $f[D_1(0)], f[D_2(0)], \ldots. f[D_N(0)]$.

Step 3: find the velocities of particles. All the particles moves towards the optimal point with a velocity. Initially all particle velocities are assumed to be zero. Set the iteration number as 1.

Step 4. In *i*th iteration find the personal best ($P_{best}$) and global best ($G_{best}$) of the particle.
The best value of $Dj^{(i)}$ in current iteration $i$ is $P_{best\ j}$ holds the highest value of $f[D_j^i]$. The best value of $Dj^{(i)}$ in all previous iterations by any of the N particles is $G_{best}$ holds the highest global value of $f[D_j^i]$.

Step 5. Find the velocity using the following formula.

$$V_j(i) = V_j(i\text{-}1) + c1r1[P_{best,j} - D_j(i\text{-}1)] + c2r2[G_{best} - D_j(i\text{-}1)] \quad \text{here } j = 1,2,..N$$

c1 and c2 are the cognitive and social learning rates respectively. And r1 and r2 are uniformly distributed random numbers between 0 and 1. c1 and c2 are assumed as 2.

Step 6. Find the position or coordinate of the *j*th particle in *i*th iteration as

$$D_j(i) = D_j(i\text{-}1) + D_j(i) \; ; \text{ where } j = 1,2,\ldots N$$

Now again evaluate the fitness function for the new updated particles.

Step 7. Now do the operation from step 4 again till it reaches the final iteration count.

## VIII. CUCKOO SEARCH ALGORITHM

This algorithm is based on the obligate brood parasitic behavior of some birds and fruit flies. Some species such as the *Ani* and *Guira* cuckoos lay their eggs in communal nests, though they may remove other's eggs to increase the hatching probability of their own eggs. Many species engage the obligate brood parasitism by laying their eggs in the nests of other host birds. If a host bird discovers the eggs are not their owns, they will either throw these alien eggs away or simply abandon its nest and build a new nest elsewhere.

Levy flights called fruit flies or *Drosophila melanogaster* explore their landscape using a series of straight flight paths by a sudden 90 degree turn, leading to a scale free search pattern. Combining the both cuckoo search algorithm is made.

Step 1. Generate initial population of n host nests $D_i$ ($i$= 1,2,…,n)
Step 2. Get a cuckoo randomly by levy flights and find the fitness function (maximization of power) $F_i= f(D_i)$ , $D_i = (D_1,\ldots,D_n)$
Step 3. Choose a nest among n (say, j) randomly and evaluate fitness (say $F_j$)
Step 4. If $F_i < F_j$ replace $j$ by new solution
Step 5. A fraction (pa) of worse nests are abandoned and new ones are built. Keep the best ones and rank the solutions and find the best one (duty cycle responsible for highest power).
Step 6. Do from step 3 till the end of iteration (t) occurs.

Here $pa \in [0,1]$

$$D_i^{(t+1)} = D_i^{(t)} + \alpha \oplus \text{Levy}(\lambda)$$

$$\text{Levy}(\lambda) = t^{-\lambda}$$

Where $1<\lambda\leq 3$ and $\alpha >0$.

## IX. RESULTS AND DISCUSSION

The solar power plant of 2kW is constructed with the implementation of PSO and CSA algorithms in MPPT peak power detection. Three solar arrays are used in this simulation model one carries 1kw/m$^2$, second one carries 0.7 kw/m$^2$ and third one 0.3kw/m$^2$. This makes three different peak power in P-V characteristics. This model is connected to the boost converter and inverter then connected to the grid. The maximum power is transferred from solar system to grid using the synchronization controller. The inverter output power is controlled with hysteresis controller. The analysis of the waveform is given below.

### (i) Without PSC

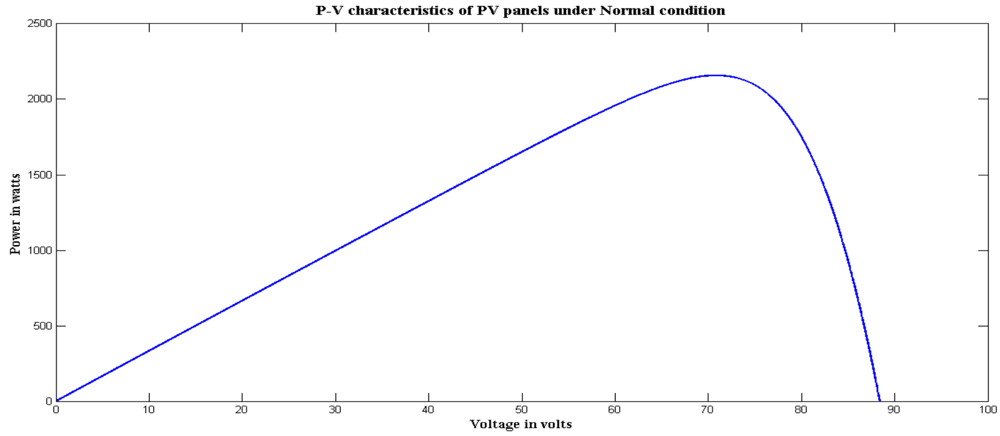


Fig 4. P-V characteristics of normal condition

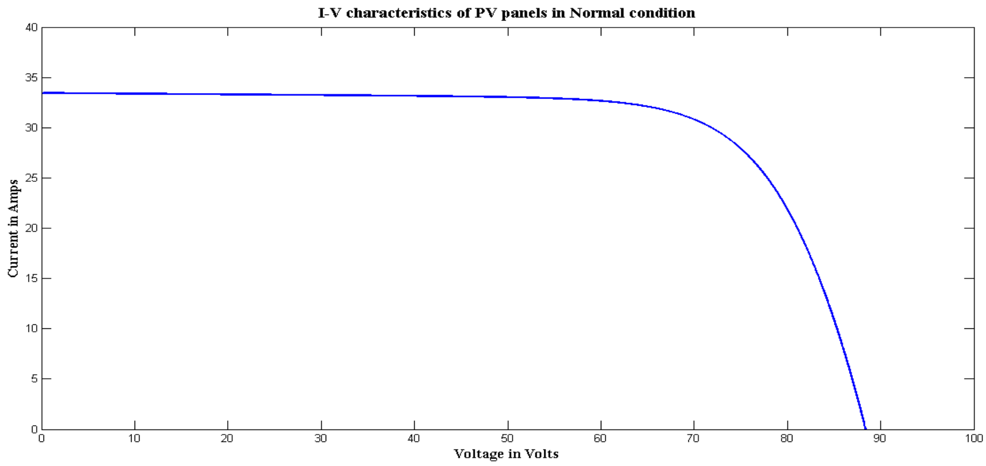


Fig 5. I-V characteristics of normal condition

Figure 4 shows the power and voltage graph of solar panel with 1kw/m$^2$ irradiance. The peak power can be seen that 2.12kw. This peak is possible at 71.2 V. fig.5 show the I-V characteristics of the same solar rating and irradiance.

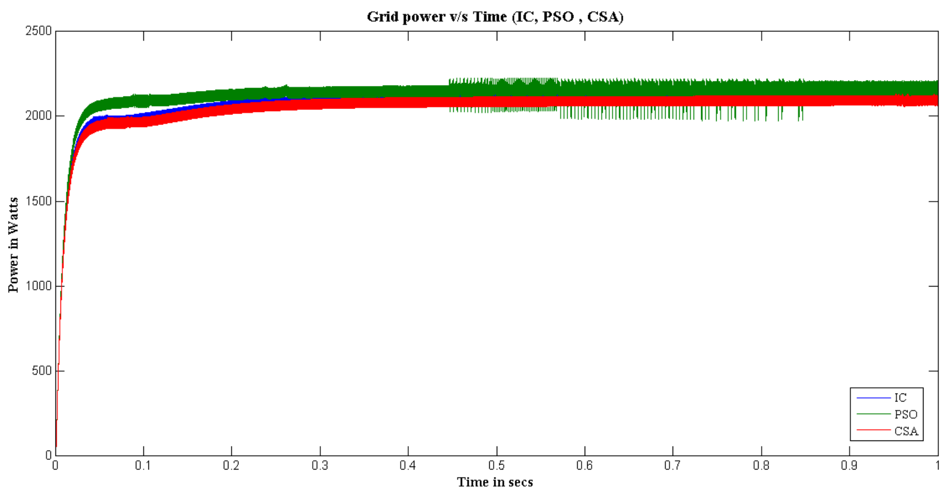


Fig. 6 Grid power in IC, PSO and CSA

Figure 6. Shows the power at grid side after connecting solar and without applying PSC. The maximum power is absorbed with PSO method as 2.1kw from the solar panel. Where other method like incremental conductance absorbs 2.0kw and CSA absorbs 2.05 kw. So PSO algorithm absorbs maximum power.

### (ii) With Partial Shaded Conditions

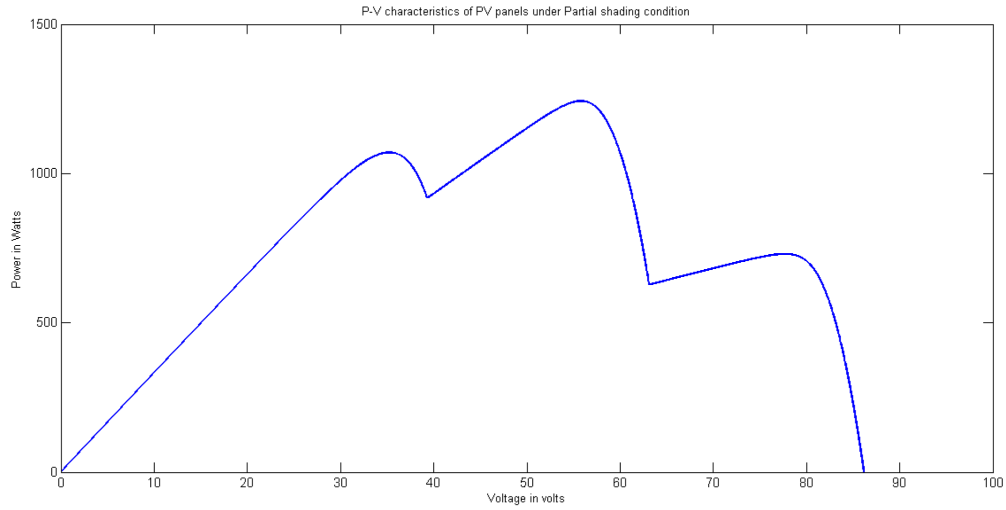


Fig. 7 P-V characteristic with under PSC

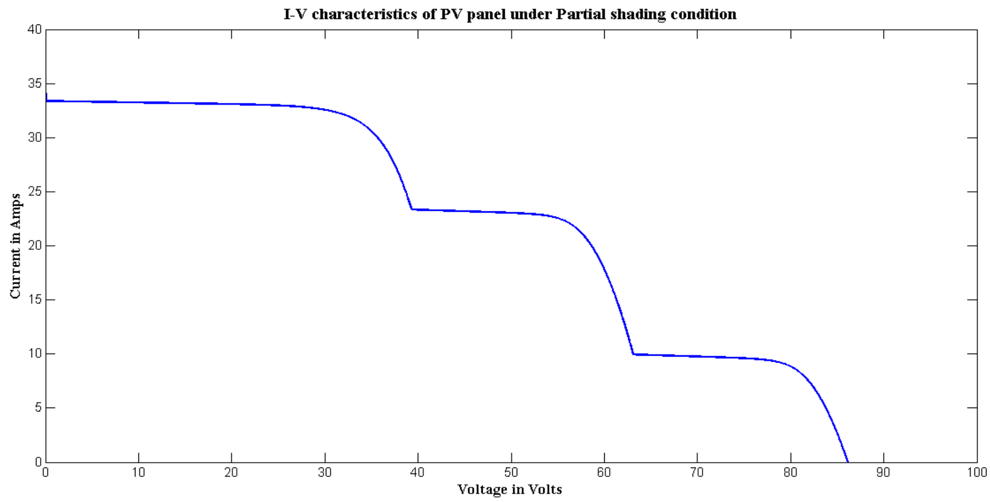


Fig.8 I-V characteristics under PSC

The fig 7 and 8 shows the P-V characteristic waveform and I-V characteristic waveform of solar array. This waveform is taken by applying 1kw/m$^2$, 0.7kw/m$^2$ and 0.3kw/m$^2$. The peak power of 1.3kw is achieved at 55V.

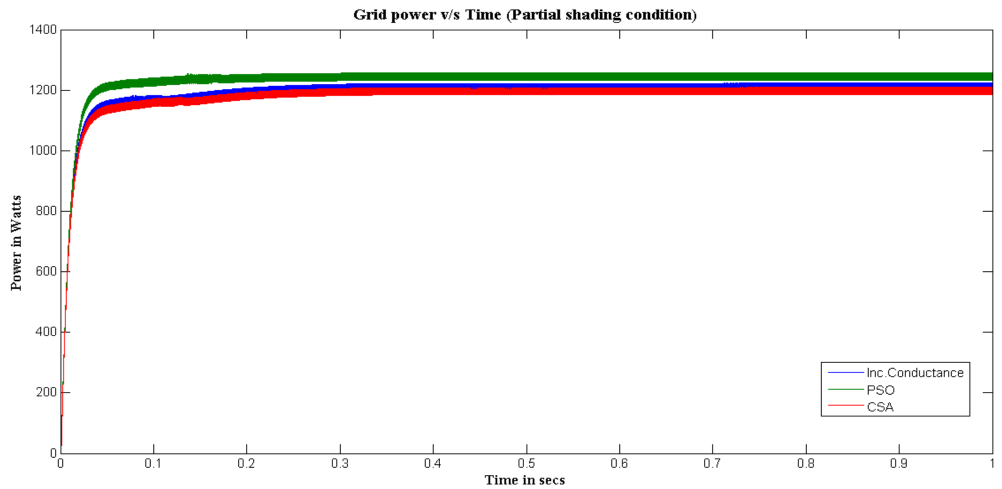


Fig .9 Power supply to the grid with IC, PSO and CSA under PSC conditions.

Figure 9 shows the maximum power supplied to the grid under PSC condition with IC, PSO and CSA. It shows that PSO supplies more power compared to other two algorithms. 1.24kw is supplied to grid with PSO, 1.1kw with CSA and 1.05 with IC.

So PSO algorithm performs better compared to CSA and IC in without PSC and with PSC conditions. The maximum power is absorbed by grid due the duty cycle created by PSO algorithm. CSA and IC also absorb the maximum power but PSO absorbs few 100s of wattage extra.

## X. Conclusion

Grid connected Solar power plant is designed and analysed for 2kW. Due to PSC condition traditional algorithm like IC fails to absorb the maximum power. This is caused due to the inability of obtaining global best solution in IC. So recent optimization techniques like PSO and CSA algorithms are used to absorb the maximum power. In these two PSO outperforms CSA by absorbing few 100w extra comparatively.

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