International Journal of Research Publication and Reviews, Vol 4, no 10, pp 1622-1629 October 2023

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Improvement of PV Module Output Power under Partial Shading

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DOI: https://doi.org/10.55248/gengpi.4.1023.102648

A B S T R A C T

The exhaustion of energy sources is progressively escalating, posing a significant contemporary environmental concern. To address this, solar energy has gained traction due to its cost-effectiveness in PV. Modernly, solar systems are curbing worldwide energy requisites by employing innovative methods and setups. None the less, the presence of numerous peaks in the power-voltage curve triggers partial shading issues in photovoltaic arrays. This study's key aim is to mitigate the occurrence of multiple peaks in the power-voltage characteristics, thereby ameliorating the limitations of array configurations and ultimately enhancing overall system efficiency. Traditional algorithms excel in tracking the maximum power point (MPP) of photovoltaic panels under uniform conditions but struggle with complex shading scenarios, leading to being trapped in local maxima and causing power loss. In contrast, nature-inspired intelligent algorithms perform better in finding the global maximum power point (GMPP).

Keywords: *MPPT, particle Swan Optimization, global maximum., solar energy,* PV arrays, hotspots, Series-Parallel

Motivation:

As fossil fuel resources continue to dwindle, there is a growing emphasis on minimizing our reliance on these finite energy sources. Currently, one of the primary strategies for reducing our dependence on fossil fuels is the widespread adoption of renewable resources. Among the various renewable options available, solar energy stands out as a leading choice across the globe. In recent times, numerous households, offices, and companies have been increasingly installing their own solar power generation systems on their buildings. However, a significant challenge that arises when harnessing solar energy is the issue of partial shading. To maximize power output and address this concern, a concerted effort is being made in the form of projects and research initiatives.

Introduction:

The ability to transform solar energy into practical electricity is called solar power. Solar energy can be used for a variety of reasons, including heating, lighting, cooling, and running appliances. To use solar electricity, you will need the following fundamental components: Solar panels are used to harvest energy from the sun. An inverter is used to convert the energy into a form that may be used to power your appliances. Racking is the base on which your system is mounted. A battery is used to store extra energy for later use or in the event of a power outage. Solar power is a renewable and clean form of energy with numerous advantages, including lower electricity costs, a more resilient electrical grid, job creation and economic growth, and reduced greenhouse gas emissions. Partial shading occurs when a solar cell is obstructed from direct sunlight by various objects or factors. This obstruction can result from nearby buildings, passing clouds, the presence of bird droppings, accumulated dust, or fallen leaves. The consequence of partial shading is a notable decrease in the power output generated by a solar panel. Furthermore, it can trigger undesirable conditions such as hotspots and reverse bias situations, both of which have the potential to inflict permanent damage on the photovoltaic (PV) cells. In situations of partial shading, the unshaded segments of the PV array receive solar irradiation at a certain level, while the shaded segments receive less irradiation. This disparity can lead to a mismatch between the different modules and give rise to the hots pot phenomenon[1].

In recent times, photovoltaic (PV) energy has gained significant prominence as a renewable energy source. It boasts several advantages, primarily its friendliness and sustainability. Once PV energy systems are installed, they harness sunlight to generate electricity without contributing to greenhouse gas emissions. With an average operational lifespan spanning 20 to 25 years, these systems can produce a surplus of electrical energy compared to the demand. Moreover, they are versatile in terms of installation, whether on rooftops, in arid desert regions, or rural areas. These systems demand minimal maintenance and are free from air and noise pollution.[2] . To harness significant power from solar energy, a PV array is constructed by connecting numerous PV panels in various configurations, including series, parallel, or combinations of both. Several interconnection methods are available for assembling PV arrays: (i) Series-Parallel (SP), (ii) Bridged-Link (BL), (iii) Honey-Comb (HC), and (iv) Total Cross Tied (TCT) schemes. Among these, the Total Cross Tied arrangement is the most utilized interconnection scheme for enhancing output power while reducing mismatch losses, especially under partial shading conditions. Partial Shading (PS) occurs when certain portions of a PV panel are shaded due to factors like passing clouds, building shadows, or debris like bird droppings. Additionally, such shading events can lead to specific issues, including (i) the development of hotspots within PV panels, (ii) multiple peaks in the P-V (Power-Voltage) characteristics, and (iii) disruptions in the Maximum Power Point Tracking (MPPT) algorithm.[3] The basic types of maximum power point tracking algorithms are perturb and observe , incremental conductance. In a series connection, a string of PV cells is created by joining them end to end. The next cell's negative terminal is connected to the positive terminal of the previous cell. This setup raises the output voltage while maintaining a steady current. To attain greater voltage levels for particular applications, series connections are used .Multiple PV cells are linked together with their ¨positive and negative terminals combined in a parallel connection. In this setup, the current is increased while the voltage remains unchanged. In order to increase the current output, parallel connections are used. The voltage and current levels are balanced in this design by combining parallel and series connections. Cells are first linked together in series, and then these groups are linked together in parallel. In order to satisfy the unique requirements of the application, it enables both voltage and current to be modified.

PV cell modelling:

In modelling PV cell we have to consider some of the factors they are physical properties of PV cell, Temperature effect, Irradiance, Diode model. The choice of semiconductor material used in PV cells is important. Material properties, including band gap energy, electron mobility, and carrier lifetime, affect cell performance and electrical behaviour. Temperature fluctuations affect the performance of PV cells. Temperature coefficients of current and voltage should be considered to account for temperature changes in electrical properties. PV cells can be represented using the diode equation to describe their electrical characteristics. Parameters such as diode reverse saturation current and thermal voltage are important in describing diode behaviour. The module calculates the photo current generated by the PV cell using inputs for temperature and irradiance. [4]

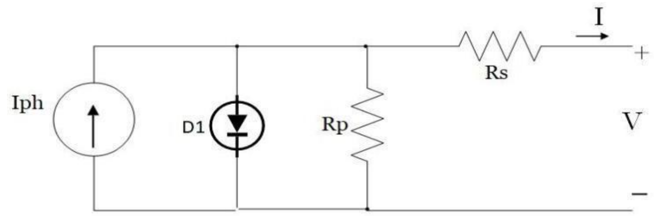


Fig.1-Electrical equivalent circuit model of PV cell

The basic Equations of the above circuit are

Figure 1 shows the electrical equivalent circuit model of the PV cell. The output current of the PV cell is given in Equations (1) – (3).

$$I = I_{ph} - I_d \quad (1)$$

$$I = I_{ph} - I_0 [e^{\left(\frac{V+IR_S}{a}\right)} - 1] - \frac{V+IR_S}{R_P} \quad (2)$$

$$a = \frac{N_S nkT}{q} \quad (3)$$

In the above equations,

I_0- represents reverse saturation current of the diode

N_s-number of cells connected in series

n-ideal diode constant

k-the Boltzmann constant,

T- the cell Temperature,

q-electron charge.

The current obtained by the effect of the light falling on the light failing on the PV cell is given by equation (4)

$$I_{ph} = (I_{pn,n} + K_1(T - T_n))\frac{G}{G_n} \quad (4)$$

Maximum Power Point Tracking using the Perturb and Observe

The P&O algorithm is a widely employed traditional method for monitoring Maximum Power Point (MPP) in a commercial Photovoltaic (PV) controller due to its straightforwardness and ease of use. Perturb and Observe (P&O) for solar panel optimization Pros:1. Simplicity: Easy for beginners and experts.2. Low Processing: Doesn't strain controllers.3. Cost-Effective: No extra hardware.4. Quick Response: Adapts to changing conditions.5. Real-Time Tracking: Maximizes power output. Cons:1. Power Fluctuations: Efficiency can suffer.2. Slow Response: May miss quick changes.3. Shading Issues: Struggles with shadows.4. Energy Consumption: Can waste power during optimization. This method is among the most used conventional ones. The principle of the conventional P&O algorithm consists of perturbing the PV voltage (VPV) and observing the variation of PV power (PPV), if an increase of the voltage generates an increase of the power that means a convergence towards the maximum power zone; on the other hand, if the power decreases, the voltage must be reduced to coincide with the MPP. Figure 11 presents the P&O flowchart, where d is the TLB converter's duty cycle and Δd is the duty cycle variation. The modified P&O algorithm is based on a comparison of PPV with PMPP. Then, VPV is reduced or increased to coincide with the MPP. Figure represents the proposed P&O flowchart. The possible cases of the modified algorithm are reduced compared to the classic P&O algorithm.

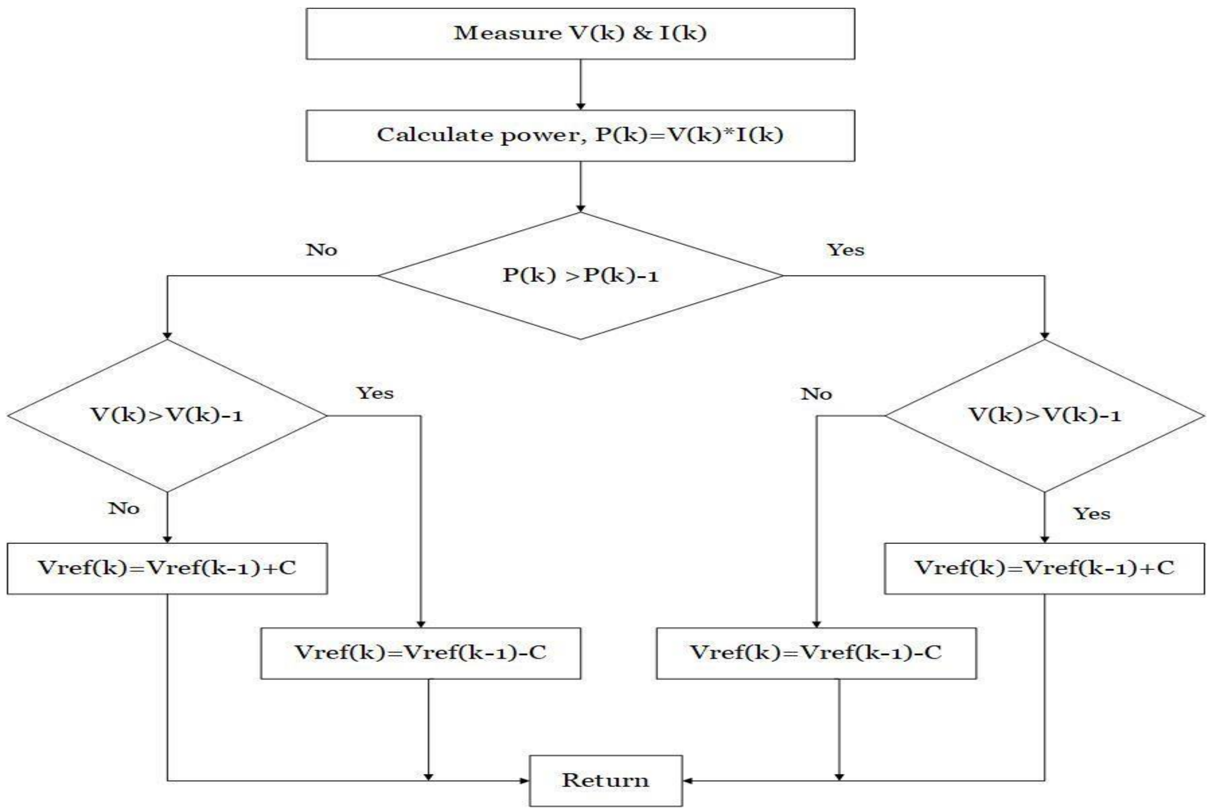


Fig.2-PO Algorithm flowchart

Maximum Power Point Tracking using the Particle Swarm Optimization Algorithm

For a photovoltaic (PV) system made up of three different PV arrays, the Particle Swarm Optimization (PSO) method was used to perform Maximum Power Point Tracking (MPPT). Under various climatic situations, function determines the PV arrays' ideal working voltage and current values. Int this we considering three PV cell, which are modelled considering all factors. The function takes input parameters related to the environmental conditions and PV arrays. For the three PV arrays under consideration, Tcell1, G1, Tcell2, G2, Tcell3, and G3 represent the ambient cell temperature (in degrees Celsius) and solar irradiance (in W/m2). The function uses the PV characteristics function to determine the voltage-current (V-I) characteristics of each PV array. Depending on the given environmental conditions, a range of output voltages are generated, and the appropriate current values are calculated. [5]To obtain the voltage-current characteristics of each PV array, the function employs the PV characteristics_ function. A variety of output voltages are produced according on the ambient conditions, and the proper current values are calculated. The function calculates the combined total power produced by the three PV arrays as the product of the total current and the total voltage. This function essentially conducts MPPT for three separate PV arrays before determining the combined system's best operating point. In order to maximize power output while considering various environmental factors for each PV array, it uses PSO for MPPT. Here, MPPT under PSC with direct control is implemented using the PSO method explained in the prior section. The proposed system's block diagram is shown. In this study, a DC-DC boost converter is used to connect the solar system's voltage to a load or the grid. Each particle is defined as the duty cycle of a boost converter in order to achieve direct control of MPPT using the PSO algorithm. Thus, there is only one parameter that needs to be optimized (D=1). [5]

Duty cycles are initially produced at random using the following equation.

$$d_i = d_{Min} + rand(N, D)(d_{max} - d_{min}) \quad (5)$$

The PSO algorithm can function without exact knowledge of the PV system's parameters, making it easier to implement in practical applications. One of the downsides of this algorithm is its tendency to get stuck in local optima, especially in high-dimensional search spaces. This can lead to reduced efficiency and power output. Moreover, the PSO algorithm can suffer from premature convergence, which occurs when the algorithm stops exploring the search space too early and fails to find the global MPP. Furthermore, the PSO algorithm requires many iterations to converge to the MPP, which can increase the computational time and energy consumption of the PV system.[2]

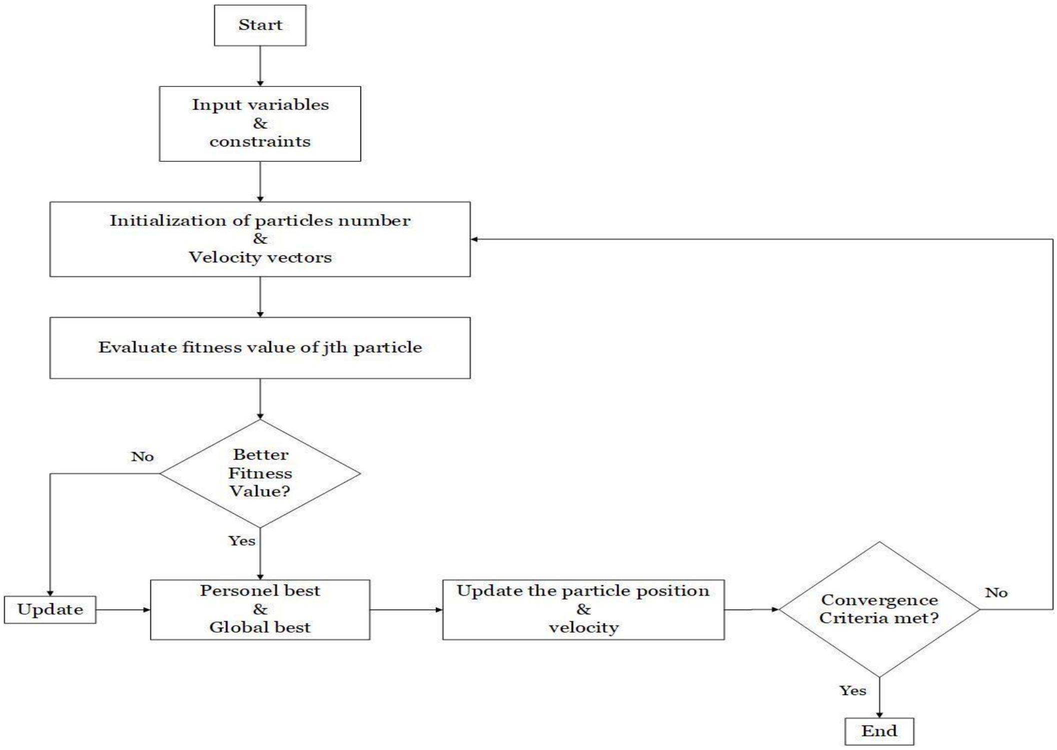


Fig.3- PSO algorithm flowchart

Due to sudden change in the climatic or environmental conditions and other reasons the irradiation and temperature change due to such change in factors the output also varies to optimize and provide the optimal output from the uncertain conditions. From disturbed curve to an optimized curve.

Simulations& Their Results

Graphical Representation of the characteristics

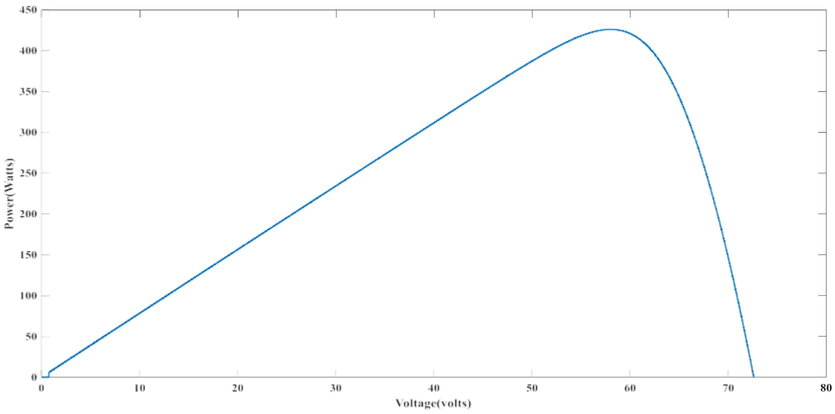


Fig.4-power vs voltage graph

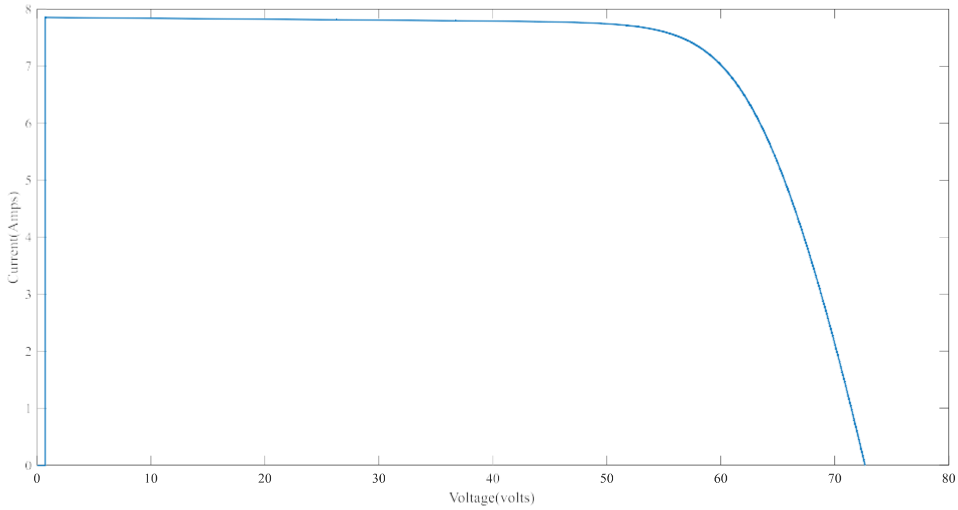


Fig.5-current vs voltage graph

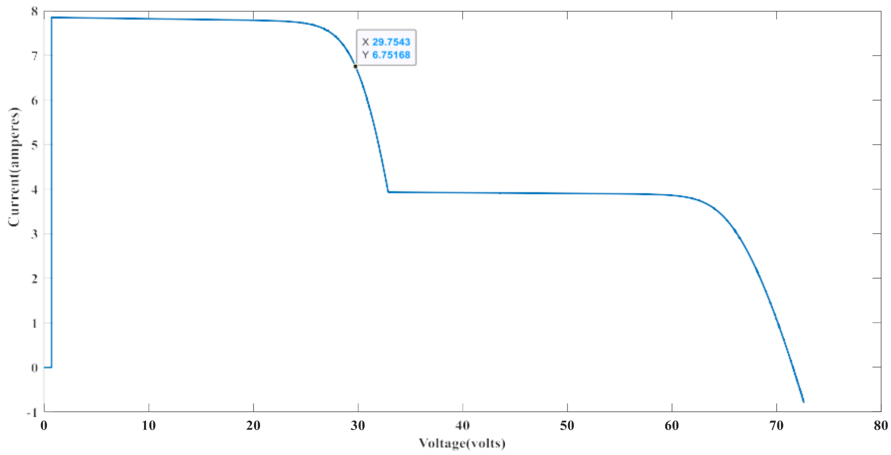


Fig.6-PV partial shaded output at 25^{0}C irradiation

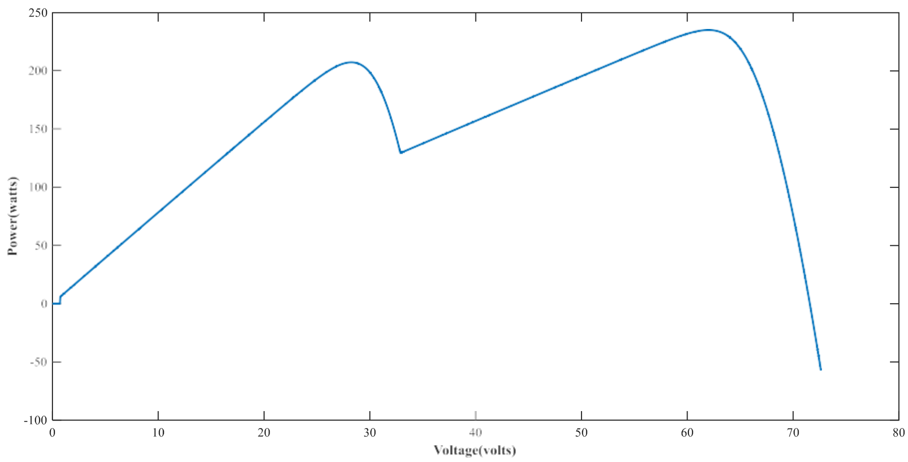


Fig.7-PV partially shaded output 25^{0}C irradiation

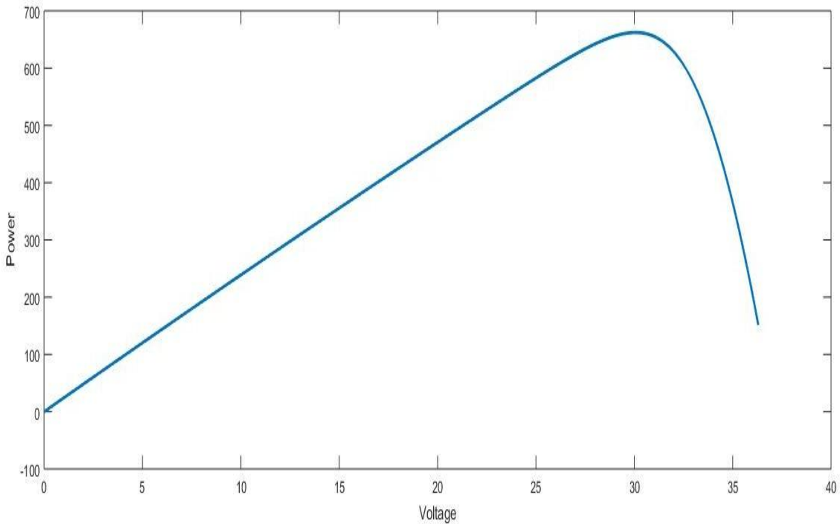


Fig.8-PV output at 1000 W/m²

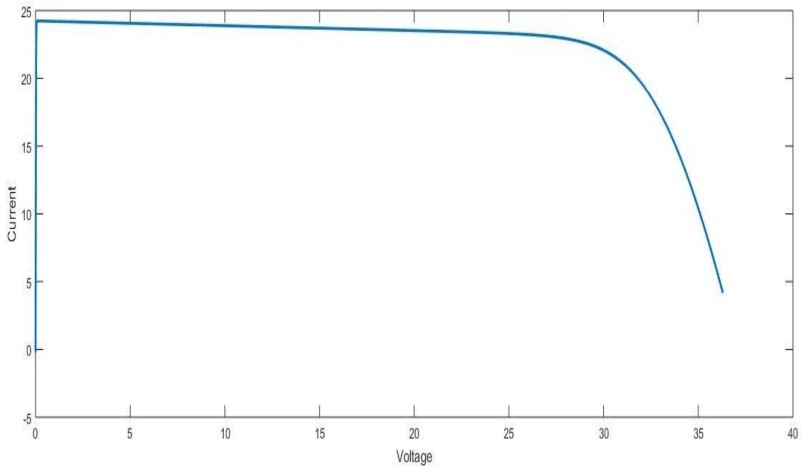
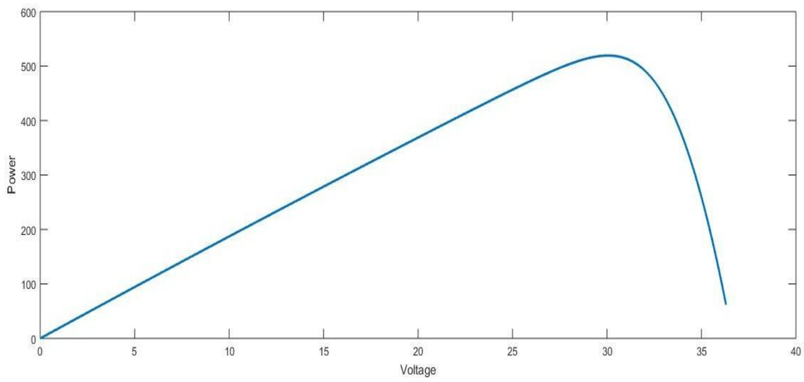


Fig.9- PV output at 1000,1000,900 W/m²



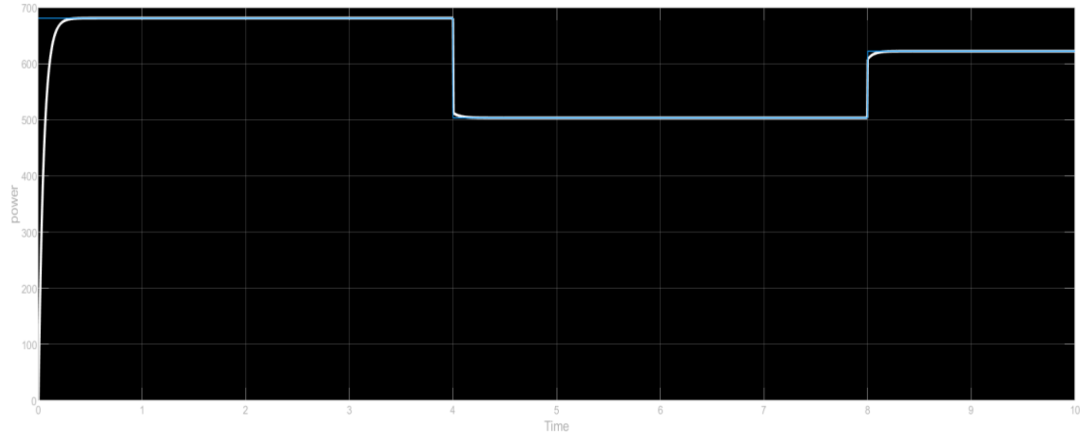


Fig.10-PV output power after using PSO as MPPT Algorithm

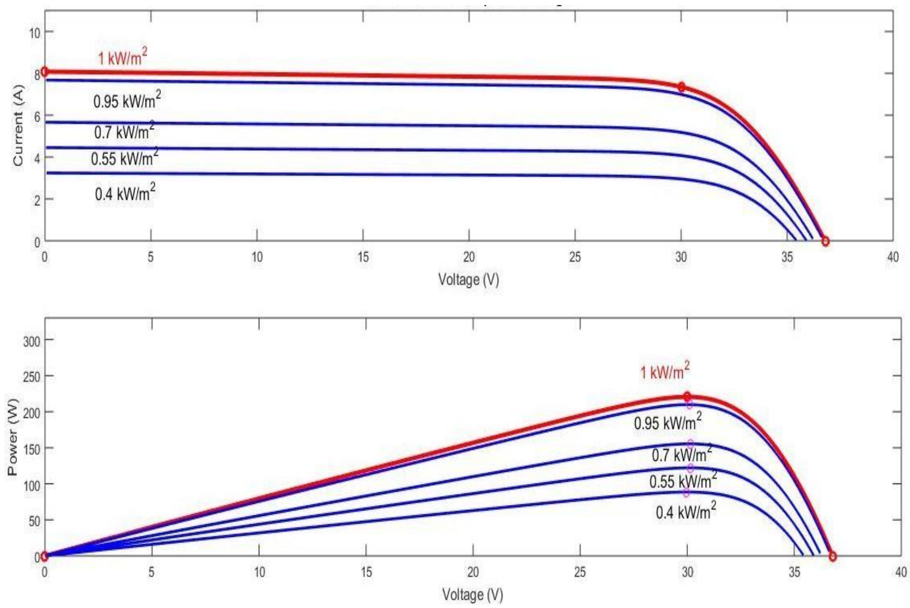


Fig.11-IV and PV curves of PV at different irradiation

Conclusion:

At partial shading condition the PV graph is plotted, In this condition output of the PV System is decreased, to run the system efficiently it should be operated at maximum power point. To operate system at this point we have to track the maximum power point, PSO algorithm made job done in tracking maximum point. In this PV module is modeled according to our requirements and duty cycles are produced at controller to maintain PV system at maximum power point. Hence the simulation results are obtained and concluded that PV system that we modeled is at anticipated condition.

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