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# Grid Connected PV Systems: Performance and Responsible Factors

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**Abstract:** Aim of this paper is to study the factor responsible for affecting the performance of grid connected PV Systems along with the impact of PV system over the fundamental properties of grid. Power generated by photo voltaic cells depends on various factors such as Irradiation level, Temperature of module, Dust particles, Shading, Orientation, Location of module etc. These factors are need to be taken into account before installing a PV system to extract the maximum power. Output of PV system can be maximized using different type of MPPT algorithms. In this paper we will be comparing different MPPT algorithm using simulation model and suggesting the effective one by referring the obtained results.

**Keywords:** MPPT, P&O, InCon, Irradiance, Temperature, Soiling, MATLAB, SIMULINK, PV Module

## I. INTRODUCTION

India is a tropical country where the amount of sunlight is mostly available to meet up the demand of electricity. Solar energy is a perfect solution because it is completely clean in terms of pollution and health hazards. Now a days, Grid connected PV systems are very popular to be used as they are capable of supplying power to the load and excess generated power can be transferred to grids also. In Grid Connected PV Systems, electricity flows back-and-forth to and from the mains grid according to sunlight conditions and the actual electrical demand at that time. This increases the reliability of the system simultaneously reduces the cost. But solar energy is very unpredictable and depends over various environmental and geographical factors as well as it is expensive also which arises the need of maximum extraction of power from the PV Systems. For extraction of maximum power from modules we have various Maximum Power Point Tracking algorithms such as Incremental Conductance (InCon), Perturb & Observe Algorithm, Fractional open circuit Algorithm etc. We need to choose the best one to get the maximum output. There are some negative impacts of PV Systems also which affects the performance of Grid which we will be discussing in this paper.

## II. FACTORS AFFECTING PV SYSTEM PERFORMANCE

Performance of PV Module is influenced by various factors, some of the factors are related to module itself and some depends upon the geographical location and surrounding. These factors can adversely affect the output power so need to be kept in balance.

### A. Varying Irradiation Level

Irradiation level is one of the main factors which directly impacts the power generation. Irradiation is controlled by nature and hence it is very unpredictable and hence it has a severe impact. Variation in solar irradiation impacts various PV factors such as Short Circuit Current, Open Circuit Voltage, Efficiency and Power.

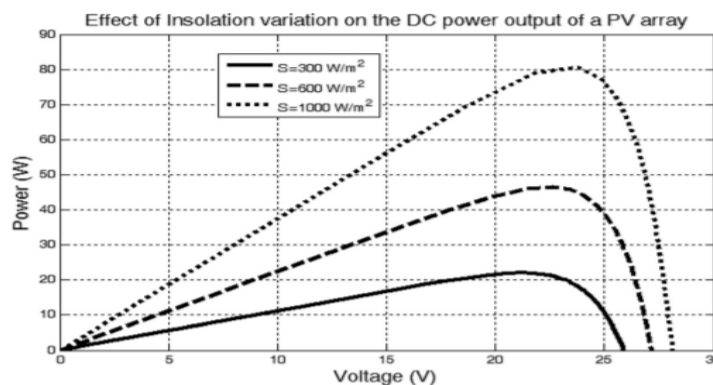


Fig. 1 : Variation of power with Temperature and Irradiation Variation

**B. Temperature of Module**

PV cell are same as any other semiconductor devices. Increase in temperature also affects their performance. When ever there is increase in temperature of module, there is decreases in power output. This happens because in semiconductor cells, when solar energy falls over it electrons gets excited and jumps to higher energy level and the difference between lower and higher energy level is taken as output. But when lower temperature gets high due to high module temperature, energy difference decreases and hence power output decreases.

In PV module, when temperature increases there is slight increase in module current but drastic decrease in Voltage which overall reduces the power output of PV Cell.

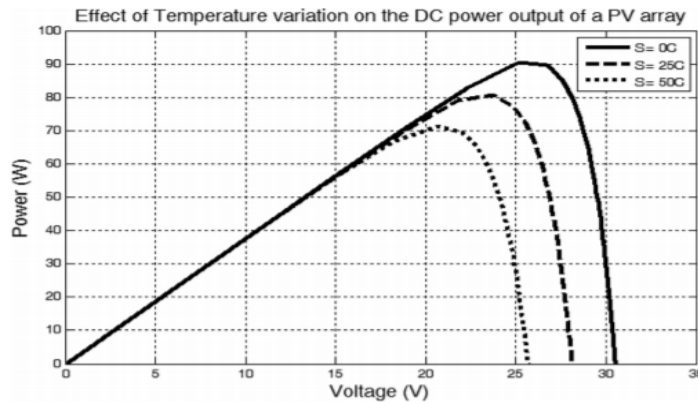


Fig. 2 : Variation of power with Temperature Variation

**C. Degradation in PV Module**

Solar panels generally come with the working life of 25yrs but their degradation late is high in first 10yrs which reduces their output up to 5-10% and reduces in the later years with the decrease of 8-10% in next 15yrs. Degradation can be of any type i.e. Physical, Chemical or Electrical. This degradation happens mainly due to the poor quality of used manufacturing materials.

**D. Fill Factor of PV Cells**

The Fill Factor (FF) is a criterion of quality for the PV cell. It can be obtained by comparing the maximum power to the theoretical power which is the product of open circuit voltage and short circuit current.

Basically, fill factor is the measure of squareness of the cell, it is also given by the area of the largest rectangle possible under I-V curve for that cell. More is the fill factor, better will be the efficiency. It is better to have fill factor more than 75% for a normal used PV Cell.

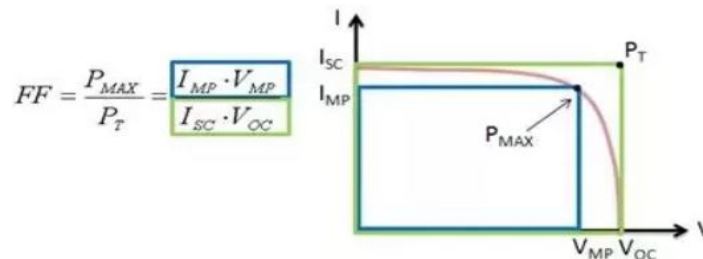


Fig. 3: Fill factor representation

**E. Shading of PV Module**

As mentioned earlier, solar power is very unpredictable and is very dependent over the location, weather and position. Shading can affect the output power very hardly. In PV Module, a string of cells has cells connected in series. If there is shading over a single cell also, due to decrease in irradiation current from that cell will decrease resulting in the decrease of current in whole string as current in series always remain same for all cells.

A common solution to avoid this is by using Bypass Diodes. A bypass diode is connected across a sub-string of PV cells in the module. During general operation time with uniform light falling on each cell, the bypass diode will work as an open switch. When current mismatches occur due to shading, the diode across the string act as closed switch and bypasses string.

**F. Soiling of Module**

Soiling can be defined as the accumulation of a layer of Dust, Dirt and other contaminants which reduces the density of falling light. Due to decrease in the light density, power output gets decreased. Dust accumulation depends on various factors such as Tilt angle of module, Shape and Size of dust particles, Location dependent variations such as Humidity, Cold, Hot as well as the speed of wind. Soiling can be controlled by timely cleaning of solar module or to use a washing device for automatic panel cleaning.

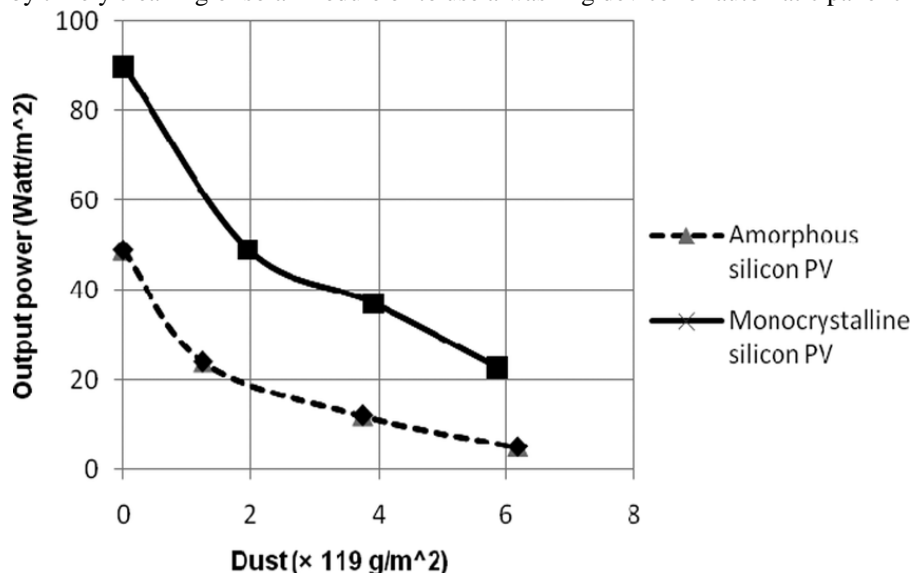


Fig. 4: Decrease in output due to Soiling

**G. Series/Shunt Resistances**

Series and shunt resistances of a module results into increase of  $I^2R$  losses which eventually the decreases in module efficiency. Series resistance is responsible for internal losses which is due to the resistance of metals, impurities and the semiconductor itself. Shunt resistant represents the leakage resistance which comes from the I-V Curve.

For optimum performance Series resistance should be very low and shunt resistance should be very high. Ideally it is not possible because decrease in series resistance also decreases shunt resistance. So, we need you use the best balance between both.

**III. POWER OUTPUT ENHANCEMENT USING MPPT ALGORITHMS**

An MPPT control is important to withdraw maximum power from the PV modules. In last few years, various techniques have been proposed for obtaining the maximum power point. This paper presents a comparison between different MPPT methods and suggests one and also analyses their suitability for systems which experience a wide range of operating conditions. In this paper we will be simulating the PV Models for

**A. Importance of Maximum Power Point Tracking**

PV System output is very unpredictable and unstable as it depends on the external factors such as geographical location, environmental conditions, weather etc. As solar PV are very expensive, we need to exploit its complete power so that economic efficiency also remains maintained. So, for maintaining the operating point at maximum power point, we use different type of algorithms which helps to extract maximum power.

These algorithms differ in their convergence time, complexity, speed, cost, implementation and sensors required. These algorithms dynamically adjust the extraction point to obtain the maximum output. Convergence speed and complexity are two main factors which are responsible for deciding the type of algorithm used.

**B. Types of MPPT Algorithms**

There are different types of algorithms, all have different features and hence their properties vary from each other. These MPPT algorithms are applied to provide gate pulses of varying duty cycle to a switching device. This duty cycle varies with respect to the change in module current and voltage to track the maximum power point:



1) *Incremental Conductance Algorithm*: This algorithm works on the principle that slope of I-V curve is zero at Maximum Power Point. So that  $(\frac{dP}{dV})$  remains zero where  $P = VI$ . So, tracking of MPP can be done by comparing Instantaneous conductance with Incremental conductance. Algorithm increases or decreases the reference till the MPP is achieved. Once the MPP is achieved, system is maintained at that point only to extract the maximum power. If any changes happen in V or I then system again hunts for MPP in same way as earlier.

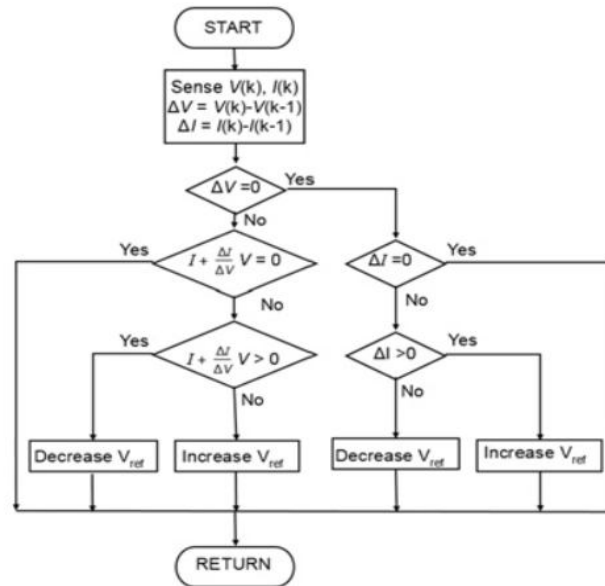


Fig. 5: Flow chart of Incremental Conductance

2) *Perturb & Observe Algorithm*: P&O is a simple, easy to implement technique which does not require previous knowledge of system temperature or the solar intensity measurement. It can be easily used with Analogue and Digital circuits. It works on the principle of perturbing the Voltage value and comparing it with previous one causing the PV terminal voltage to fluctuate around MPP. This is widely used algorithm because of its balance between performance and complexity. It suffers from the lack of speed which is a bit slow in this algorithm and very necessary to find MPP in the cases of fast transients.

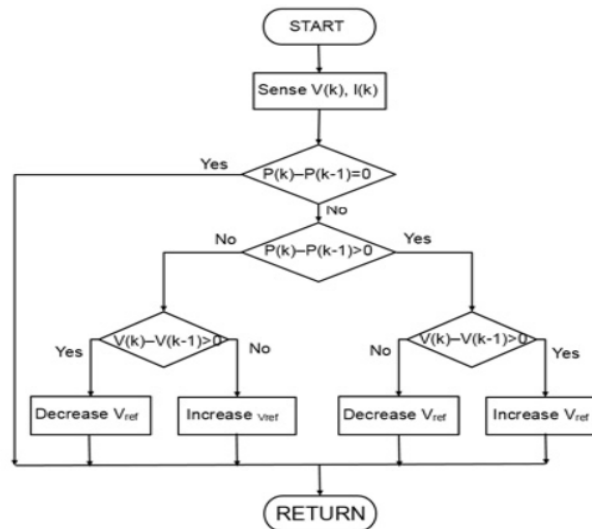


Fig. 6: Flow chart of P&O Algorithm

3) *Fractional Open Circuit Voltage Algorithm*: This algorithm is based on the principle that the maximum power point voltage is always a constant fraction of the open circuit voltage. The open circuit voltage of the cells in the photovoltaic array is measured and used as in input to the controller.

### C. Simulation Results

Following simulation results were obtained for a system with 100kW PV Panel connected to a grid of 25kV through a DC-DC Boost converter stepping up 260V output of PV panel to 500V and a DC-AC VSC which converts DC of PV System to 3-Ph AC represents the impact of change in temperature of module and irradiation level over the power output. Simulation is performed over two different MPPT Algorithm to also perform the side by side comparison of performance of these algorithms.

#### 1) Incremental Conductance Algorithms

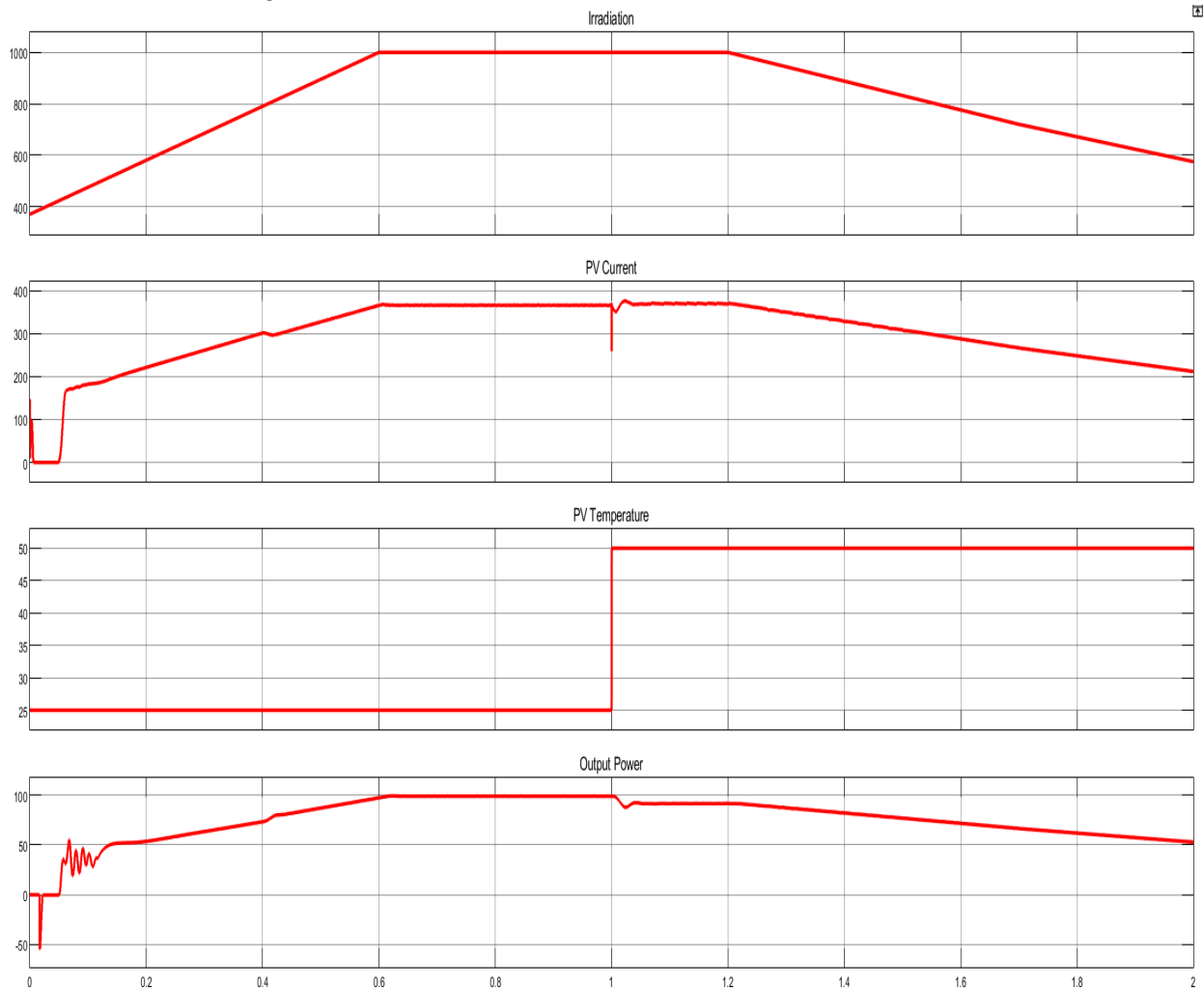


Fig. 7: Simulation results for Incremental Conductance

#### a) Impact of Irradiation (Considered variable Irradiation)

- i) In the results of simulation, we can see that initially Irradiation was  $< 400 \text{ W/m}^2$  and hence the PV Current was less.
- ii) As we know, change in irradiation is directly proportional to the Current so as the Irradiation increases solar panel current also increases and becomes maximum when Irradiation =  $1000 \text{ W/m}^2$ .
- iii) As the Output power is directly proportional to the current, as current increases output power also increases.
- iv) Using Maximum Power Point Tracking Algorithm, system finds out the best possible combination of Voltage and Current at which Power becomes maximum and keeps the system stable around that point.

#### b) Impact of Module Temperature

- i) Earlier at  $t=0.6 \text{ sec}$ , Irradiation is  $1000 \text{ W/m}^2$  and temperature is  $25 \text{ degree}$  which result into the extraction of maximum power.
- ii) At  $t=1 \text{ sec}$ , as temperature changes from  $25$  to  $50 \text{ degree}$ , this increase decreases the output power from  $99.8 \text{ kW}$  to  $92.3 \text{ kW}$ .
- iii) When temperature increases, energy of electrons which raises the energy of the electrons at rest and hence decreases the energy gap between rest and excited states eventually decreasing the output power.

2) Perturb and Observe Algorithm

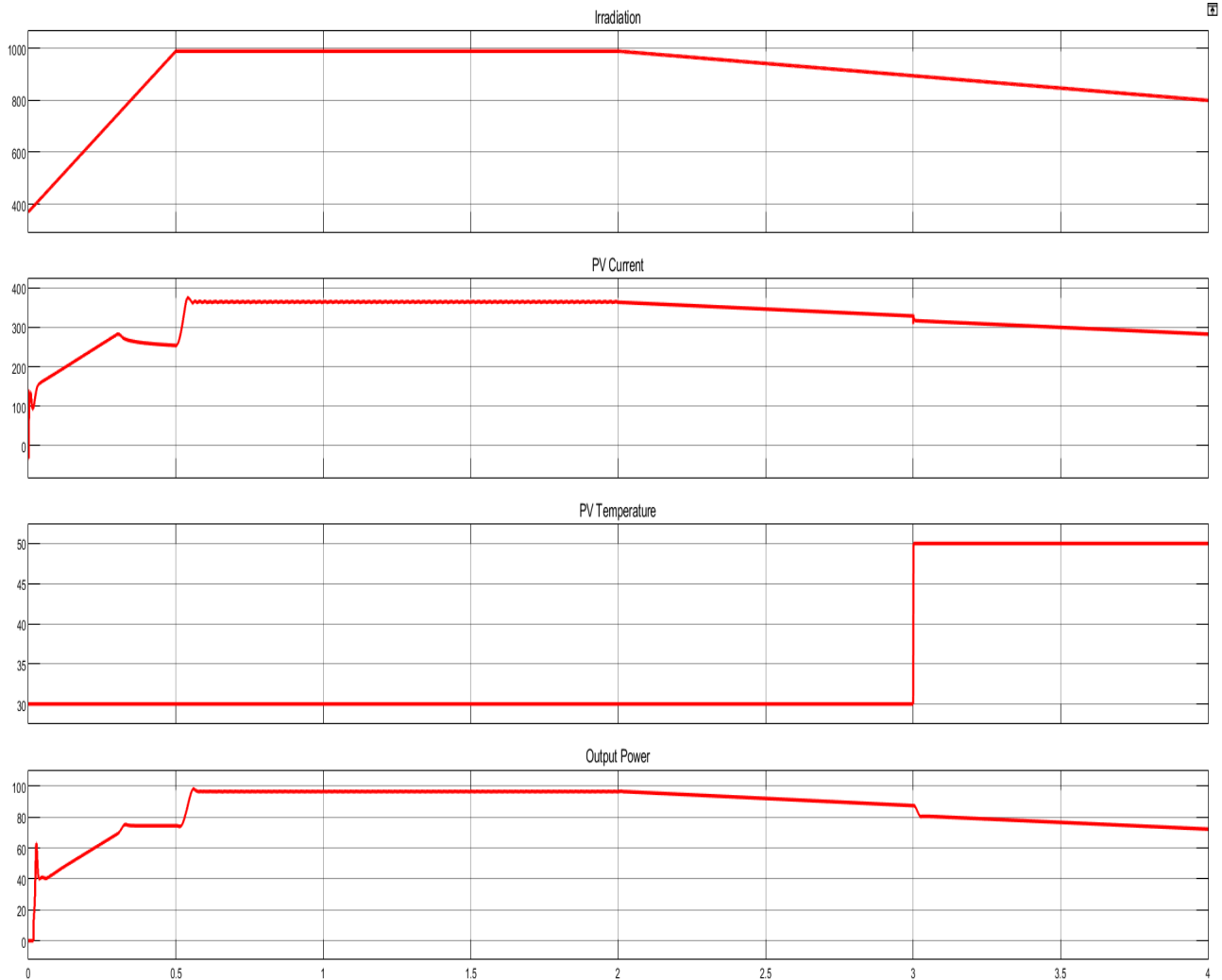


Fig. 8: Simulation results for P & O Algorithm

Variation of Power output using P&O algorithm is same as the variation in Incremental Conductance method with variation of Module Temperature and Irradiance. But due to the difference in used algorithms, there is the difference in maximum output power. We can see in the simulation result for P&O Algorithm, maximum power attained for the same value of irradiance is less than the power output attained in the case of Incremental Conductance method. This defines that the Incremental conductance have more effective output as compared to P&O algorithm.

D. Tabulated Comparison of Above Algorithms

Following is the comparison of the above algorithms after performing the simulation over the same PV Configuration module:

Performance Parameters	Incremental Conductance MPPT Algorithm	P&O MPPT Algorithm
Output Current	3.33 A	3.25 A
Output Voltage	19920 V	19900 V
Output Power	99.8 kW	97.5 kW
Speed of Convergence	0.36 Sec	0.6 Sec
Tracking Accuracy	More Accurate	Less Accurate
Complexity	More	Less

Table 1: Comparison table for MPPT Algorithms

#### *E. Pros and Cons of Above Algorithms*

##### *1) Incremental Conductance Algorithm*

###### *a) Advantages*

- i) This have good efficiency for tracking the Maximum power point with enhanced response.*
- ii) The adjustment of the module operating voltage is automatic with no oscillations.*

###### *b) Disadvantages*

- i) The implementation of this algorithm in the control unit is difficult and expensive.*
- ii) High sampling rate and vigorous calculation required for calculating power slope.*

##### *2) Perturb and Observe Algorithm*

###### *a) Advantages*

- i) Perturb and observe algorithm is easy and no need of previous data of the PV System.*
- ii) It is easy to apply with analogue and digital circuits.*
- iii) Good balance between performance and simplicity.*

###### *b) Disadvantages*

- i) Less speed and adaptability.*
- ii) Performance degrades is due to the trade-off between accuracy and speed upon selecting the step size*

### **IV.IMPACT OF PV SYSTEM OVER CONNECTED GRID**

PV systems imposes several negative impacts on power networks, especially if their penetration level is high. These impacts are dependent on the size as well as the location of the PV system. PV Systems are divided in three categories on the basis of their generation limits.

Large PV Systems having generation capacity more than 500kW, Medium PV Systems having generation capacity between 10kW to 500kW and Small PV System having capacity less than 10kW. Every type has different impact over the connected grid. Below is the effect of PV System over grid based on size.

#### *A. Impact due to Large PV Systems*

- 1) Fluctuation problems in Frequency, Power and Voltage: PV arrays output is unpredictable and is highly dependent on surrounding conditions such as module temperature and irradiation levels as depicted in previous figures. Shading problems due to passing clouds, temperature, and irradiation random variations are the main factors that affect PV power generation, resulting in rapid fluctuations in its power output. These fluctuations result into variations in frequency and voltage of connected grid and results into problems of voltage Sag and Voltage swell. Frequency variation takes place due to variation in Active power whereas voltage variations take place due variations in reactive power.*
- 2) Problems with grid stability: As described earlier, PV system power is very unstable and can not be predicted. This is the reason it can not be used as a variable power supply source which can adjust according to the load requirements. Hence mismatch between the Generation and Demand takes place which unbalances the power system stability and causes severe stability problems.*

#### *B. Impact due to Small/Medium PV Systems*

Various impact of Small and Medium PV Systems are listed below which affects the connected grid:

- 1) Reverse flow of excessive power.*
- 2) Interference issues due to Electromagnetic waves produced by high frequency inverters.*
- 3) Voltage control is difficult because string of grid connected PV Systems is not a unidirectional system.*
- 4) Phase unbalance problems due to connection of single-phase inverters in small PV Systems.*
- 5) Due to fluctuations, Power Quality issues arises.*
- 6) Power losses also increases.*
- 7) Distribution feeder can face overvoltage problems due to reverse power flow*
- 8) Increase in requirement of reactive power as PV Systems can only supply Active power and reactive power is need to be supplied by utility.*



### V. CONCLUSION

After this study we found that there are many factors which affect the performance of the grid connected PV System. We should consider these factors before establishing a PV generation system. As we know PV energy is expensive as the price of each module and inverters is very high, we can conclude about the importance of Maximum Power Point Tracking controller in the system. This system will help in extracting the maximum power and also increases efficiency.



With the help of simulation results, we can easily compare both algorithms and can suggest the better. On the basis of our obtained simulation results, we can easily state that Incremental Conductance Algorithm have an upper edge over P&O algorithm but its less used because of its complexity and the expensive hardware.

In this paper we also studied the impact of the grid connected PV System over the grid, we categorised those impacts on the basis of capacity of PV System. All energy systems have their own problems and we are required to select the best one. Solar energy is clean, green and inexhaustible that's why this can be seen as the future of the world.

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