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Power Generation from Photo Voltaic Cell with MPPT Control Technique

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ABSTRACT: The global electrical energy demand is increasing gradually and the power generation is not meeting consumer demand due to the deficit of fossil fuels. In this paper we study and analyze the Photovoltaic power system operation and its properties. The PV power system is environment friendly and it is clean and pollution free.PV Power generation does not contribute to global warming . The PV power system is one of the best renewable energy source. This project we have been designed PIC Microcontroller to track the Maximum power point for a 70W PV module under various climate. The proposed model has been designed using Matlab software. And by the simulation results we have proved the effectiveness of the proposed incremental conductance MPPT method for the system over perturb and observe MPPT method.

KEYWORDS: PIC Microcontroller, Photovoltaic cell, MPPT

I.INTRODUCTION

The need for renewable energy sources is raising because of the acute energy crisis in the world today. India plans to produce 20 Gigawatts Solar power by the year 2020, But we have realised that, we haven't generated half of the Gigawatts in 2010. Solar energy is one of the most important renewable energy sources. Compared to conventional non - renewable resources such as gasoline, coal, etc... , solar energy is clean, inexhaustible and free Solar energy is a vital untapped resource in a tropical country like ours. Photovoltaic (PV) generation is increasing since it offers many advantages such as no fuel costs, pollution free, requires little maintenance, and emits no noise. The power generated by the PV array is not stable because of its dependence on irradiation level and temperature. In order to achieve the highest efficiency from the solar panel, Maximum power point tracking technique is used. A unique operating point is specified by the The I –V and P –V characteristic curves at which maximum possible power is delivered. Incremental conductance technique is used to track the maximum power point. At the MPP, the PV operates at its highest efficiency. Therefore, many methods have been developed to determine MPP. In this work, a maximum power point tracker for photovoltaic panel is proposed. A photovoltaic system including a solar panel, a DC-DC converter and a resistive load is modelled and simulated.

Basic Principle of PV Cell

PV cell is a very large area p-n junction diode. The junction between the P and N type material forms the diode. Photons of light falls on the PV cell, it gets directly converted into electrical energy. The energy of photons is used to excite the electrons in the semiconductor material. This transmitted light causes the electrons to move from valence band to the conduction band. When a PV cell is illuminated, The transmitted light generates excess electron-hole pairs , hence the p-n junction is electrically shorted and current will flow .

II. PV MODELLING

Photovoltaic cells are connected in series and parallel connections to form PV arrays. Series connection are increases the voltage of the module whereas the parallel connection increases the current in the array. Typically a solar cell can be modelled by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n to p junction and parallel resistance is due to the leakage current. In this model we consider a current negligible effect and can be neglected.

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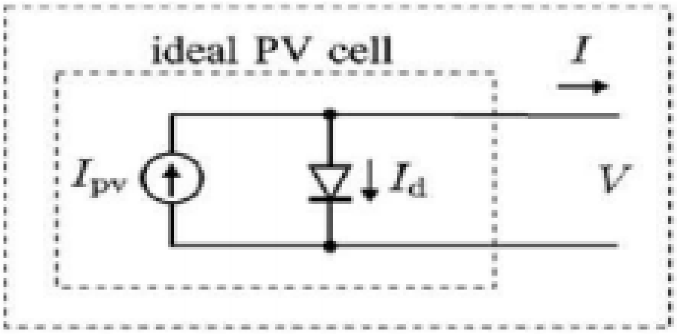

Fig.1 Ideal PV cell

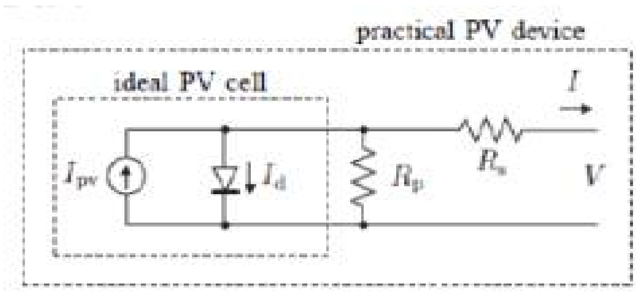

Fig 2. Practical PV cell

The output current from the photovoltaic array is

$\mathbf{I=I_{sc}-I_d}$

$\mathbf{I_d=I_0\,(eqvd^{/KT}-1)}$

where Io is the reverse saturation current of the diode, q is the electron charge, Vd is the voltage across the diode, k is Boltzmann constant (1.38 * 10 -19 J/K) and T is the junction temperature in Kelvin (K).

I = Isc – Io (eqVd/kT - 1)

Using suitable approximations,

I = Isc – Io (eq((V+IRs)/nkT) - 1)

where, I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature (in Kelvin) and n is the diode ideality factor In order to model the solar panel accurately we can use two diode model but in our project our scope of study is limited to the single diode model. Also, the shunt resistance is very high and where, I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature (in Kelvin) and n is the diode ideality factor

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I-V CHARACTERISTICS

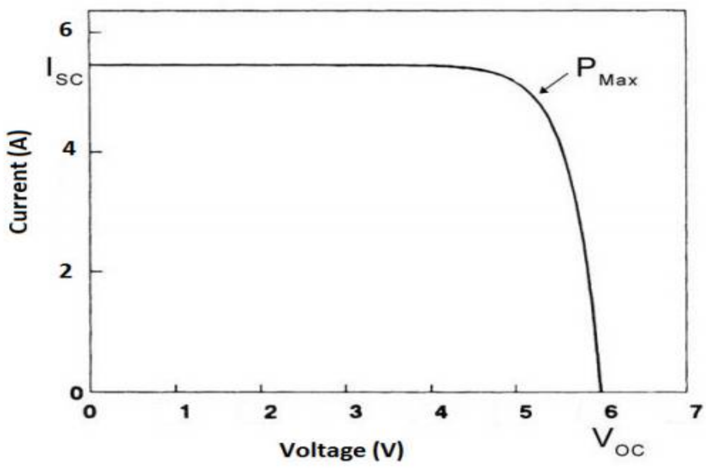

Fig 3. IV characteristics of PV cell

P-V CHARACTERISTICS

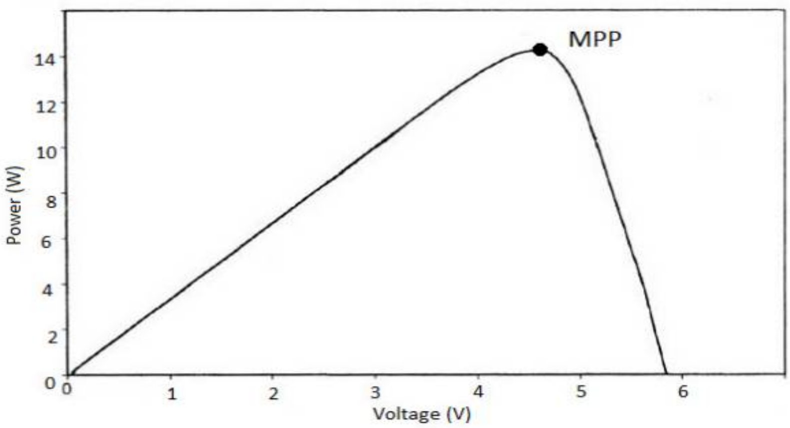

Fig 4.P-V characteristics of PV cell

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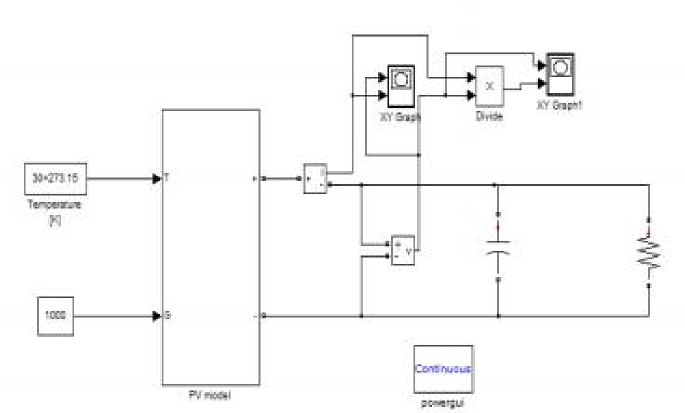
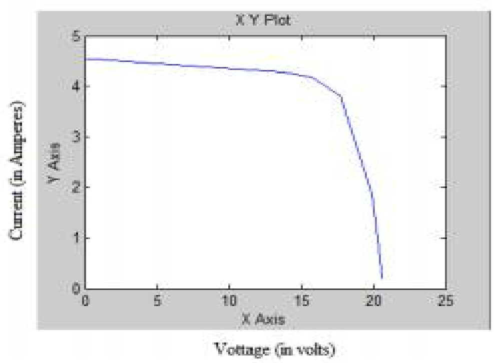
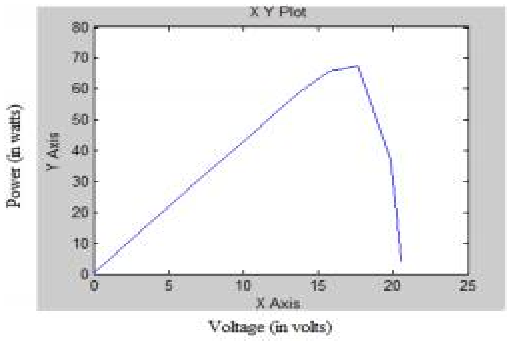
Simulation model of PV module



Simulated I-V and P-V characteristics of PV model





Maximum Power Point Tracking Algorithms

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the Thevenin impedance of the circuit (source 233impedance) matches with the load impedance. Hence our problem of tracking the maximum power point reduces to an impedance matching problem. In the source side we are using a boost convertor connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By changing the duty cycle of the boost converter appropriately we can match the source impedance with that of the load impedance.

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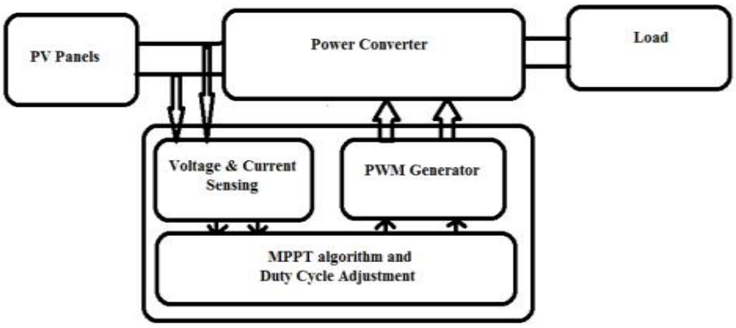

Fig 5.MPPT Control

Different MPPT techniques

There are different techniques used to track the maximum power point. Few of the most popular techniques are
1) Perturb and Observe (hill climbing method)
2) Incremental Conductance method
3) Fractional short circuit current
4) Fractional open circuit voltage
5) Neural networks
6) Fuzzy logic
The choice of the algorithm depends on the time complexity the algorithm takes to track the MPP, implementation cost and the ease of implementation. Because of less complexity, perturb and observe algorithm and incremental conductance algorithm are selected.

Perturb and Observe (P&O) Algorithm

Perturb & Observe (P&O) is the simplest method. Only one sensor is used, that is the voltage sensor, to sense the PV array voltage because of the use of single sensor, the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm. However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP.The perturbation causes the power of the solar module to change continuously. If the power increases due to the perturbation then the perturbation is continued in the same direction. The power at the next instant decreases after the peak power is reached, and after that the perturbation reverses. The algorithm oscillates around the peak point when the steady state is reached. The perturbation size is kept very small in order to keep the power variation small. The algorithm can be easily understood by the following flow chart. To avoid this problem incremental conductance is used.

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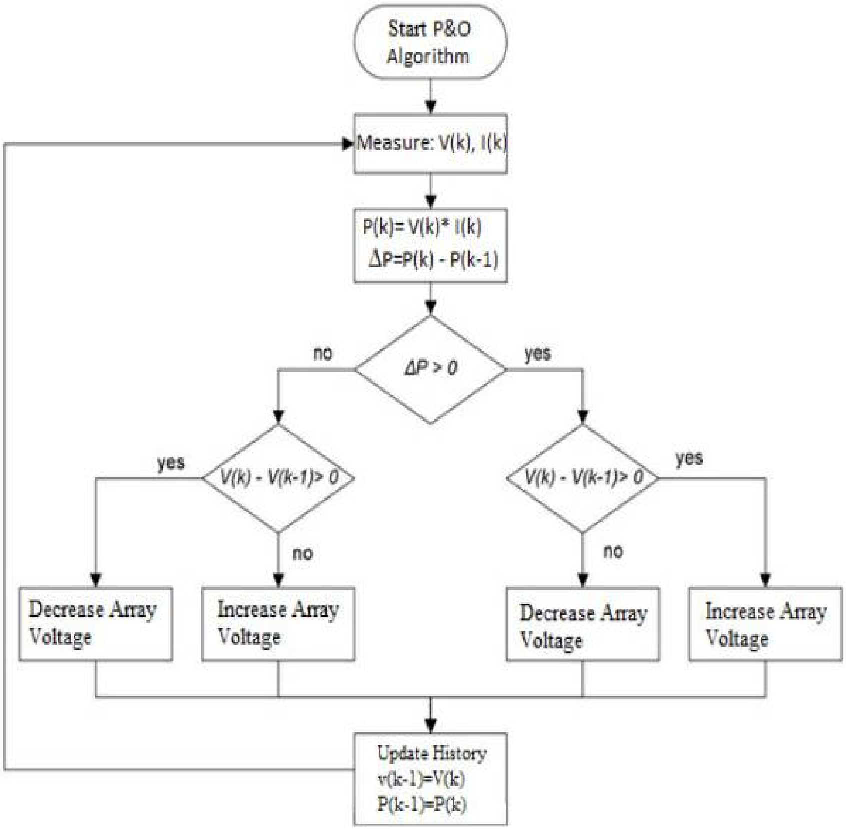

Fig 6. Flow chart of perturb and observe algorithm

The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller is used to move the operating point of the module to that particular voltage level. It is observed that there is some power loss due to this perturbation and it also fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular because of its simplicity.

Incremental Conductance (IC) Algorithm

Incremental Conductance (IC) method overcomes the disadvantage of the perturb and observe method in tracking the peak power under fast varying atmospheric condition. Incremental conductance method uses two voltage and current sensors to sense the output voltage and current of the PV array. This method can determine whether the MPPT has reached the MPP and also stops perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V. This relationship is derived from the fact that dP/dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm determines when the MPPT has reached the MPP, where as P&O oscillates around the MPP. This is clearly an advantage over P&O. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe method .

The disadvantage of this algorithm is that it is more complex when compared to P&O. The algorithm can be easily understood by the following flow chart.

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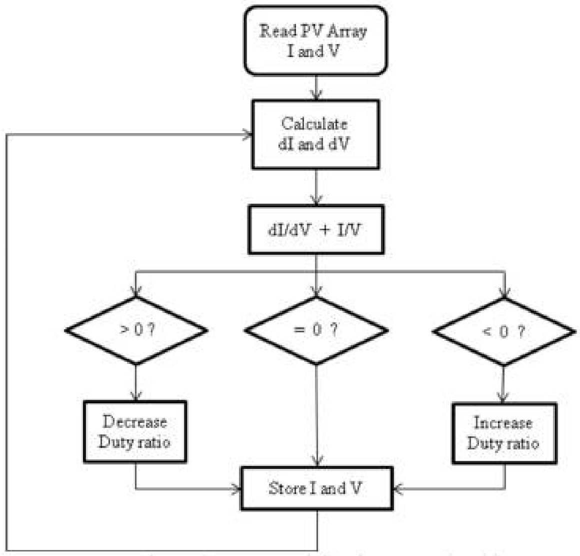

Fig 7. Flowchart for incremental conductance

PV Array Characteristics

The mathematical model of PV array is developed using MATLAB Simulink tool box. Various parameters of the PV array are determined and chosen. Series resistance (Rs) is iteratively chosen by incrementing from zero value. Decreasing the value of parallel resistance (Rp) too much will lead 'Voc' to decrease and increasing the value of series resistance (Rs) too much will lead 'Isc' to drop. 'Io' strongly depends on the temperature and hence the simulation circuit of 'Io' includes Kv and Ki which are the voltage and current coefficients.

PARAMETER SPECIFICATIONS OF 70W PV MODULE

Parameters	Specifications
Open circuit voltage V_{oc}	21.4V
Short circuit current I_{sc}	4.53A
Maximum output power	70W
Voltage at maximum power	17.7V
Current at maximum power	3.96A

The light generated by the PV is modeled as an equivalent current source. The series and parallel resistances are connected and simulated. The various equations describing the PV array characteristics are modeled using suitable blocks from the simulink library.

III. SIMULATION MODEL OF P&O ALGORITHM

The MATLAB subsystem includes the 70W PV array and it also contains the equations required for modelling it. DC voltage source of the dc-dc boost converter is replaced by the MATLAB subsystem integrated with PV array. Perturbing the duty ratio of dc-dc boost converter perturbs the PV array current and consequently perturbs the PV array voltage. To compute the power at various duty cycles and to compare it with the power of the current operating point, the MPPT subsystem is used. The duty cycle either increases or decreases or remains the same. Figure 10 shows the simulation model of PV array with dc-dc boost converter and P&O MPPT

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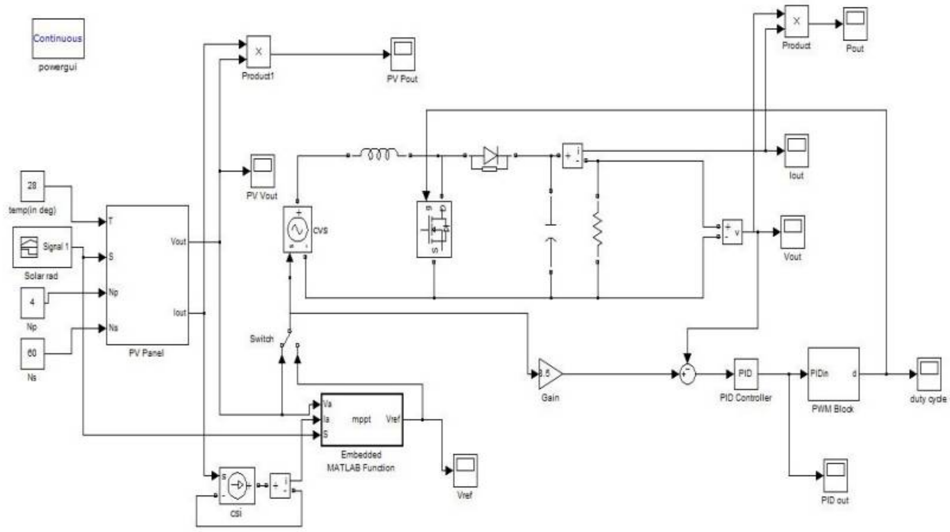

Fig 8. Simulation model of P&O MPPT with DC to DC converter.

Simulation Model of Incremental Conductance Algorithm

The simulation model of PV array with dc-dc boost converter and InC MPPT algorithm is shown in figure 12, under the same conditions as the P & O algorithm is simulated.

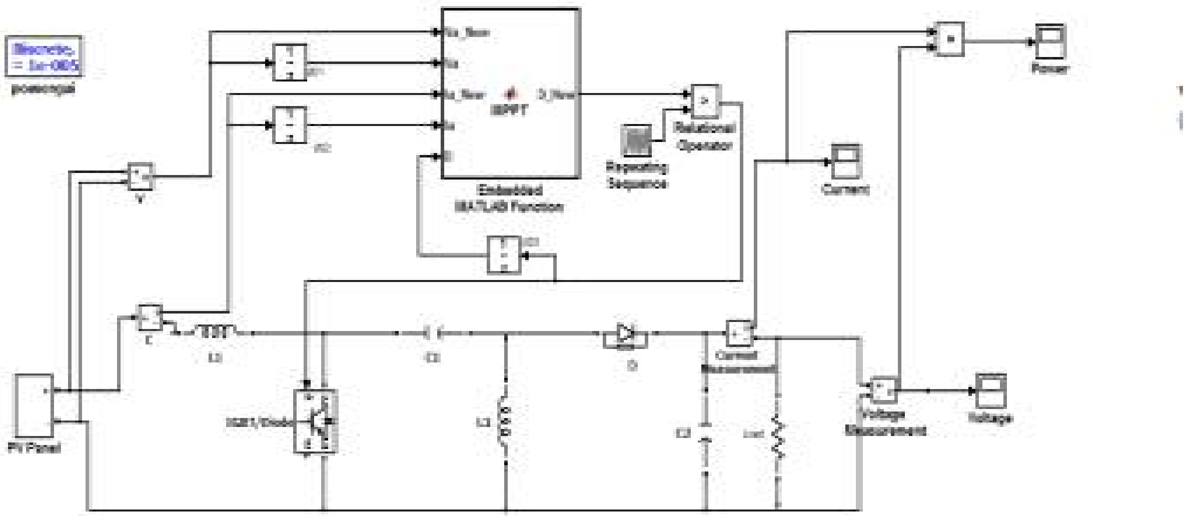

Fig 9. Simulink model of Incremental inductance with DC to DC converter.

Comparison between P&O and InC MPPT Algorithms

The P & O and InC MPPT algorithms are simulated and compared using the same conditions. When atmospheric conditions are constant or change slowly, the P&O MPPT oscillates closetoMPP but InC finds the MPP accurately at changing atmospheric conditions also.

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MPPT	Output Current	Output Voltage	Output Power	Time Response	Accuracy
P&O MPPT	0.073A	36V	2.6W	0.0175 sec	Less
InC MPPT	0.087-0.093A	43-47V	3.7-4.7W	0.1 sec	Accurate

IV. CONCLUSIONS

In this paper a mathematical model of a 70W photovoltaic panel has been developed using MATLAB Simulation. This model is used for the maximum power point tracking algorithms. The P&O and Incremental conductance MPPT algorithms are discussed and their simulation results are presented. It is proved that Incremental conductance method has better performance than P&O algorithm. These algorithms improve the dynamics and steady state performance of the photovoltaic system as well as it improves the efficiency of the dc-dc converter system.

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