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# Maximum Power Point Tracking Using Modified Incremental Conductance for Solar Photovoltaic System

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***Abstract— —. This paper discusses the concept of Maximum Power Point Tracking (MPPT) which significantly increases the efficiency of the solar photovoltaic System. In order to get maximum power from the solar panels, they have to operate at their maximum power point (MPP) despite the changes in the environment conditions. The objective of MPPT is to ensure that the system can always utilize the maximum power generated by the Photovoltaic (PV) arrays. Solar panels have a nonlinear voltage-current characteristic, which depends on the environmental factors, such as temperature and insolation. This paper proposes an improved maximum power point tracking for solar photovoltaic system using modified Incremental Conductance algorithm. The MPPT is simulated and studied using MATLAB software.***

***Index Terms*—Maximum Power Point Tracking (MPPT), Photovoltaic (PV) System, Incremental conductance (IncCond), Particle Swarm Optimization (PSO).**

## I. INTRODUCTION

Solar Photovoltaic (SPV) system converts sunlight into electricity with no pollution, no maintenance and no depletion of natural resources. The output power induced in a PV module depends on solar insolation and temperature of the solar cells [1]. In order to get maximum power from the solar panels, they have to operate at their maximum power point despite the changes in the environmental conditions. To operate the PV array at its maximum power point, the PV system can implement a maximum-power point tracking (MPPT) controller. MPPT algorithms are necessary because PV arrays have a non linear voltage-current characteristic. These voltage-current characteristics have a unique point, where the power produced is maximum. This point depends on the varying environmental conditions. These conditions change during the day and are also different depending on the seasons. Also, insolation can change rapidly due to changing atmospheric conditions such as clouds. It is very important to track the MPP under all possible conditions so that the maximum power is always obtained.

## II. MPPT METHODS

In the past years numerous MPP tracking methods have been proposed. They differ in many aspects such as complexity, accuracy, sensors required, cost or efficiency, and speed. Based on the control variable it uses, each method can be categorized. There are different MPPT techniques such as Perturb and Observe, Hill climbing method, Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Fuzzy Control, and Neural Network Control etc. Among all these methods Perturb and observe (P&O) and Incremental conductance are most commonly used because of their simplicity.

### *A. Perturb and Observe*

Perturb and observe is the simplest method. In this we use only one sensor that is either voltage sensor or current sensor, to sense the PV array voltage or current and so the cost of implementation is less. In this method the sign of last perturbation and last increment in power are used to decide what the next perturbation should be. If there is an increase in the power, the perturbation should be kept in the same direction and if the power decreases, then the perturbation should be in the opposite direction [2]. The process is repeated until the MPP is reached. Then the operating point oscillates around the MPP. Also this method does not take account of the rapid change of insolation level and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP [4]. To avoid this problem we can use incremental conductance method.

### *B. Incremental Conductance*

Incremental conductance method uses two sensors, that is voltage and current sensors to sense the output voltage and current of the PV array. Algorithm works by comparing the ratio of derivative of conductance with the instantaneous conductance [3]. When this instantaneous conductance equals the conductance of the solar then MPP is reached. The basic equations of this method are as follows

$$\frac{dI}{dV} = -\frac{I}{V} \quad ,at\ MPP \qquad (1)$$

$$\frac{dI}{dV} > -\frac{I}{V} \quad ,left\ of\ MPP \qquad (2)$$

$$\frac{dI}{dV} < -\frac{I}{V} \quad ,right\ of\ MPP \qquad (3)$$

Where I and V are the PV array current and voltage respectively. The left-hand side of the equations represents the IncCond of the PV module, and the right-hand side represents the instantaneous conductance. From (1)–(3), it is obvious that when the ratio of change in the output conductance is equal to the negative output conductance, the solar array will operate at the MPP. In other words, by comparing the conductance at each sampling time, the MPPT

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Will track the maximum power of the PV module [5]. Here we are sensing both the voltage and current simultaneously. Hence the error due to change in insolation is eliminated. However the complexity and the cost of implementation increase. The drawbacks of these techniques are mainly two. The first and main one is that they can easily lose track of the MPP if the solar insolation level changes rapidly. The other one is the oscillations of the voltage and current around the MPP in the steady state. This is due to the fact that the control is discrete and the voltage and current are not constantly at the MPP but oscillating around it.

## III. SOLAR PV ARRAY MODELLING

The basic unit of a solar photovoltaic system is the PV cell, which converts sunlight into electricity by means of photoelectric phenomenon. A single PV cell cannot produce a large amount of power, for this PV cells are connected in series and parallel to form PV modules. Equivalent circuit of a solar PV module is shown in fig.1.

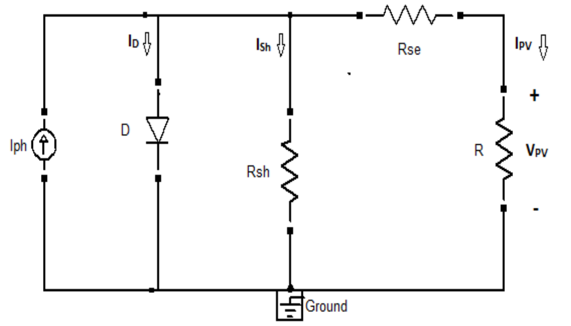


**Fig.1 Equivalent Circuit Mod El Of A Solar PV Module.**

The PV module can be modeled mathematically by the following equations [6].

Module photo-current:

$$I_{ph} = [I_{scr} + K_i(T - 298)]*\lambda/1000 \qquad (4)$$

Module reverses saturation current:

$$I_{sh} = I_{scr}/[\exp(qV_{oc}/N_s kAT) - 1] \qquad (5)$$

Module saturation current:

$$I_D = I_{rs}\left[\frac{T}{T_r}\right]^3 exp\left[\frac{q*E_{go}}{Bk}\left\{\frac{1}{T_r} - \frac{1}{T}\right\}\right] \qquad (6)$$

The current output of PV module:

$$I_{PV} = N_P * I_{Ph} - N_P * I_D\left[\exp\left\{\frac{q*(V_{PV} + I_{PV}R_{se})}{N_S AKT}\right\} - 1\right]$$

(7)

Where $V_{pv} = V_{oc}$, $N_s$=36, Np=1

Terms used:

**λ:** PV module illumination (1000W/$m^2$)

$T_r$: reference temperature (298 K)

T: module operating temperature in Kelvin

A: ideality factor (1.6)

k: Boltzman constant (1.3805 × $10^{-23}$ J/K)

q: Electron charge (1.6 × $10^{-19}$ C)

$E_{go}$: band gap for silicon (1.1 eV)

$N_s$: number of cells connected in series

$N_p$: number of cells connected in parallel

$R_{se}$: series resistance of a PV module

$I_{scr}$: PV module short-circuit current at 25 °C and 1000W/$m^2$ (2.55A)

$K_i$: short-circuit current temperature co-efficient (0.0017A / °C)

***Reference Model***

Solkar make 36 W PV module is taken as the reference module for simulation studies and the name-plate details are given below.

- Maximum power = 37.08 W
- Voltage at maximum power = 16.56 V
- Current at maximum power = 2.25 A
- Open circuit voltage = 21.24 V
- Short circuit current = 2.5 A
- No. of series cells = 36
- Series resistance, Rse = 0.47Ω
- Shunt resistance, Rsh = 145.6Ω
- Ideality factor, n = 1.5

Matlab Simulink model of solar PV module is shown in fig.2.

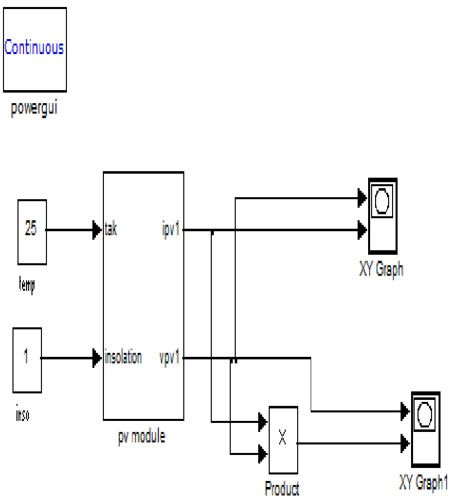


**Fig 2. Matlab Simulink model of solar PV module**

I-V and P-V characteristics at a temperature of 25°c and insolation of 1000 w/m² are shown in fig.3 and fig.4.

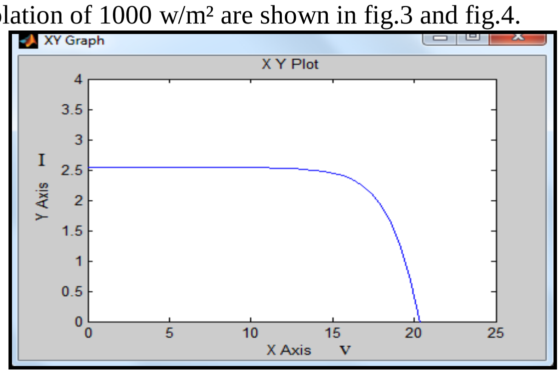


**Fig 3. I-V characteristics of solar PV module**

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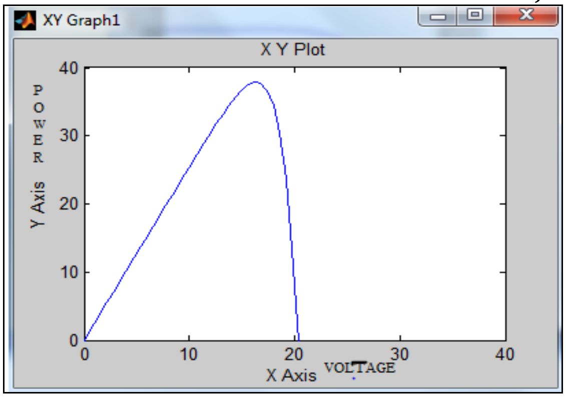


**Fig 4. P-V characteristics of solar PV module**

## IV. PROPOSED METHOD

In this paper, a modified incremental conductance method is proposed. The PI control loop is eliminated, and also duty cycle is adjusted directly in the algorithm. Perturbation done based on the concept of particle swarm optimization. The flowchart of the proposed MPPT scheme is shown in the Fig.5. In this scheme incremental conductance with Particle Swarm Optimization MPPT Controller is used to find out the maximum power point.

### *A. PSO-Based MPPT for PV Systems*

PSO was introduced by James Kennedy and Russell C Eberhart in the year 1995. The algorithm maintains a swarm of individuals called particles [7]. Particles follow a simple behavior, it follows the success of neighboring particles and its own achieved successes. The best solution that has achieved so far by that particle is called personal best $P_{best}$. The best value obtained so far by any particle in the neighborhood of that particle is called $G_{best}$. The basic

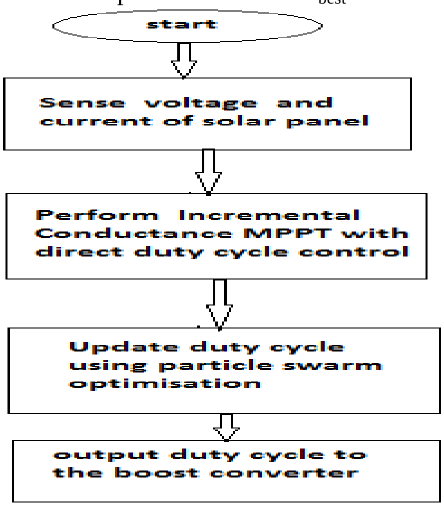


**Fig 5. Proposed MPPT scheme**

Concept of PSO lies in accelerating each particle toward its $P_{best}$ and the $G_{best}$ locations [10]. Particle position xi can be adjusted using the below equation

$$xi^{k+1} = xi^k + \Phi i^{k+1} \qquad (8)$$

Φi represents the velocity component.

The velocity of the particle is calculated using the following equation.

$$\Phi i^{k+1} = \omega\, \Phi i^{k} + c_1 r_1\{P_{besti} - xi^k\} + c_2 r_2\{G_{best} - xi^k\} \qquad (9)$$

Where w is the inertia weight, r1 and r2 are random variables uniformly distributed within [0, 1], and c1, c2 are the acceleration coefficients. If position is defined as the actual duty cycle and velocity defines the perturbation in the present duty cycle then equation (8) can be rewritten as follows.

$$di^{k+1} = di^k + \Phi i^{k+1} \qquad (10)$$

In the perturbation in the duty cycle is not fixed but it varies according to the position of the particles. With proper selection of control parameters, a MPPT controller using PSO can be easily implemented.

Modified PSO Algorithm for MPPT [9]

Step 1: PSO Initialization:- The particle position is defined as the duty cycle d of the boost converter and the fitness value function is chosen as the PV generated power. Duty cycles are initialized, which cover the search space [Dmin, Dmax] .where Dmin is the minimum duty cycle of boost converter and Dmax is the maximum duty cycle of boost converter.

Step 2:Fitness Evaluation:- The objective of MPPT algorithm is to generate maximum panel power. The voltage and current of the panel can be directly measured and using this power can be calculated.

Step3:Update Pbest and Gbest Data:- Pbest and Gbest values are updated by comparing the new power against the previous ones. If the present power is better than previous Pbest, then set this present power as the new Pbest value. The best Pbest value is chosen as the Gbest value.

Step 4: Update duty cycle:- using the Pbest and Gbest values the duty cycle is updated using (9) and (10).

Step5:Convergence Determination:- If the maximum number of iterations is met, the algorithm will stop and output the Gbest solution.

### *B. Incremental conductance with direct duty cycle control*

In this paper a modified incremental conductance with direct control is selected. Instead of reference voltage, the duty cycle is adjusted directly in the algorithm. The flowchart of this direct control method is shown in fig 6. The algorithm starts its cycle by obtaining present and previous values of voltage and current. Main check is carried out by comparing $(\frac{dI}{dV})$ against $(-\frac{I}{V})$.According to the result of this check duty

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cycle is adjusted in order to obtain maximum power from the solar PV module.

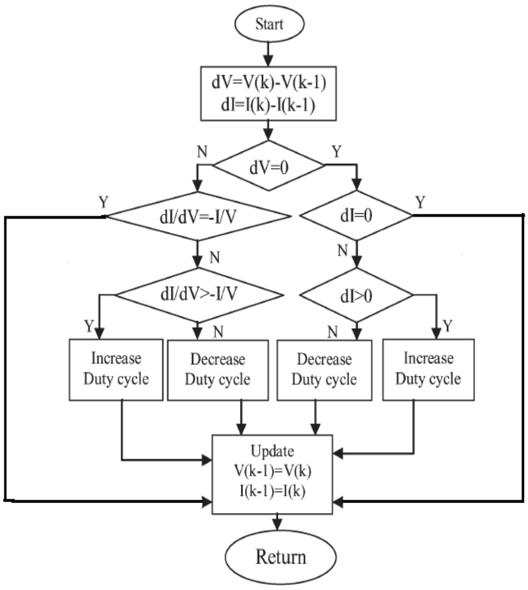


**Fig 6. Flowchart of the IncCond method with direct control [8]**

## V. SIMULATION MODEL AND RESULTS

The diagram of the proposed method designed in MATLAB and Simulink is shown in Fig.7, which includes the PV module, the boost converter, and the MPPT algorithm. Boost converters are used to step up the low module voltage to high voltage levels required by the loads. The PV module current and voltage are fed to the boost converter and the MPPT controller simultaneously.

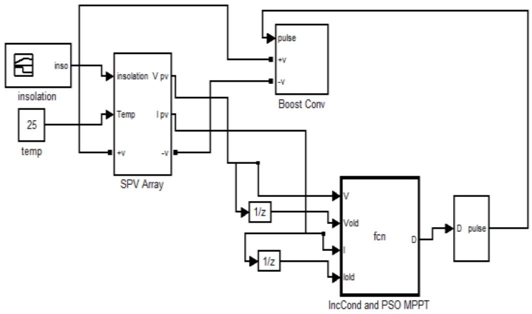


**Fig.7 Simulation Model of the Complete System**

To test the system operation, the condition of changing solar insolation was modeled. The temperature is constant at 25$^{O}$C, and the illumination level is varying between two levels. The first illumination level is 1000 W/m2; at *t* = 0.8s, the illumination level suddenly changes to 750 W/m2. PV output power using modified incremental conductance MPPT is shown in Fig.8 and using incremental conductance MPPT is in fig.9.The results in Fig.8 shows that the output power at *G* =1000 W/m$^2$ and 750 W/m$^2$ are 36 and 29 W, respectively, which are absolutely the desired output power. The results in Fig.9 shows that the output power at *G* =1000 W/m$^2$ and 750 W/m$^2$ are 29 and 23 W, respectively. It also shows that the modified incremental conductance MPPT provides the best desirable results.

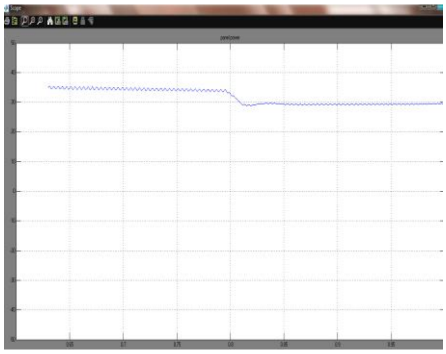

**Fig.8 Panel Power Using Modified Incremental Conductance MPPT**

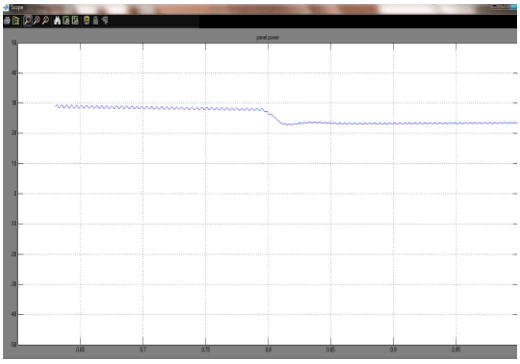

**Fig.9 Panel Power Using Incremental Conductance MPPT**

## VI. CONCLUSION

The conventional MPPTs are incapable to detect the maximum power point under rapidly changing insolation conditions. Hence these algorithms cannot be employed in PV system to extract maximum available PV power. In this paper, a hybrid algorithm of incremental conductance with direct control and particle swarm optimization was employed. The proposed system was simulated and from the results acquired during the simulation, it was confirmed that proposed controller outperforms incremental conductance and Perturb and Observe methods. The results also indicate that the proposed method is capable of tracking maximum panel power under varying insolation conditions.

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