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Modeling and Simulation of Incremental Conductance Maximum Power Point Tracking

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Abstract – **To utilize the maximum amount of solar energy application of maximum power point tracking must be employed in PV systems. The trait of a solar cell is non-linear in nature. The intensity of the solar radiation falling on the earth surface relies on various parameters like clouds, water vapor, pollution, absorption, scattering and in climatic factors. A PV system without MPPT hardly produces maximum power, which also changes the Maximum Power Point of PV system with respect to a particular environmental condition which ultimately leads to low power. In order to track PV system's MPP Incremental conductance (IC) algorithm provides higher steady-state accuracy with better and efficient output compared to the non MPPT system. Various results of simulation are conferred here**.

Keywords- Solar energy, Photovoltaic system, DC-DC Boost Converter, Incremental Conductance(IC), Maximum Power Point Tracking (MPPT).

I. INTRODUCTION

In modern age of technology and its dependency on energy resources is increasing heavily day by day. Looking at the depletion of non-renewable energy resources has made humans to think and understand the importance of utilizing maximum amount of renewable energy resources. Solar energy is absolutely a key to use as renewable energy resources in terms of its availability, abundance around the world and non-polluting factor which makes a concern to use at its maximum possible level. Semiconductor material made solar cell that convert solar energy into electrical energy and are building blocks of solar panel. Partial shading, low solar insolation, dirt deposition, and continuous usage of panels are common non-ideal conditions [1].With frequent irradiation and temperature changing conditions degrades the performance of Photovoltaic system. Hence Solar panel's efficiency of converting it into usable energy is less. Therefore tracking and operating PV system at its maximum power point (MPP) is what MPPT is called. Combining of DC-DC Boost converter with it is used to drive load. Incremental Conductance is one of the methods used to track MPP. Also its simulation results are discussed.

II. PHOTOVOLTAIC SYSTEM

The Photovoltaic system consists of 3 main parts that are: MPPT controller, Solar panel, DC-DC Boost Converter. Solar panel's output voltage is supplied to DC-DC Boost Converter to drive the load. From solar panel, voltage and current are sensed and fed to MPPT Controller. The controller needs voltage and current for computing incremental conductance algorithm. Fig.1 shows Photovoltaic system's block diagram.

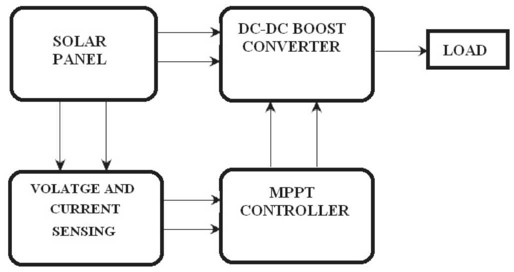

Fig. 1. Photovoltaic system block diagram

Computation is done by MPPT controller and converter's duty cycle is controlled. Continuous monitoring and controlling of duty cycle is done by controller with respect to environmental conditions which maintains the system to work on Maximum Power point. IC method uses voltage, current and conductance values for computing the algorithm.

III. SOLAR PANEL

Solar cell is made from semiconductor material. The solar cell is modeled using double diode with series and shunt resistance model using MATLAB/Simulink using five parameter model only. Series configuration of cells is used to form a PV module in order to obtain acceptable working voltage [2]. Simulation of model can also be formed by using mathematical equations in Simulink library. PV panel holds non-linear characteristic with different considerations, which can be obtained from experimental data analysis [3].Variation of irradiation and temperature affects the current-voltage (I-V) and power-voltage (P-V) characteristics of a solar cell. The solar cell model is shown in Fig.2

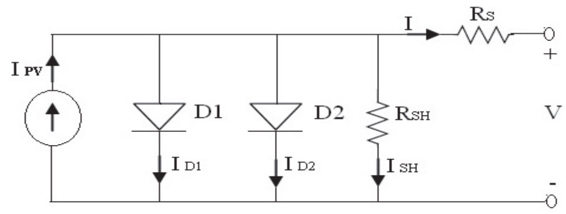

Fig. 2. Model of solar cell circuit

Solar cell model represents series resistance Rs in series with parallel combination of two diodes D1&D2, current source and parallel resistance R_{SH}. The equation for output current I, is given as follows:

$$I = I_{PV} - I_{D1} - I_{D2} - I_{SH} \quad (1)$$

$$I_{PV} = [I_{SC} + ki\,(T - T_{REF})\,G] \quad (2)$$

$$I_{D1} = I_{S1}\,[e^{\frac{q(V+IR_S)}{n1kT}} - 1] \quad (3)$$

$$I_{D2} = I_{S2}\,[e^{\frac{q(V+IR_S)}{n2kT}} - 1] \quad (4)$$

$$I_{SH} = \frac{(V + IR_S)}{R_{SH}} \quad (5)$$

TABLE. I. SOLAR CELL'S PARAMETER TABLE

PARAMETERS	DECRIPTION OF PARAMETERES
I	Output current (Ampere)
V	Output voltage (volts)
I	Photo current (Ampere)
I_{D1} ,I_{D2}	Diode 1 current &Diode2 current (Ampere)
I_{SH}	Shunt resistance current (Ampere)
T_{REF}	Reference temperature of cell (°C)
Ki	Short circuit temperature coefficient(0.003A/°C)
G	Solar irradiation (W/m2)
I_{S1},I_{S2}	Saturation current of diode D1 & diode D2 (Ampere)
n1 ,n2	Ideality factor of D1 & D2(n1=n2=1)
Q	Electron Charge(1.6×10^-19 C)
K	Boltzmann's Constant(1.38×10^-23 J/K)
V_{OC}	Open circuit voltage of solar panel (21.6Volts)
I_{SC}	Short circuit current of solar panel (5Ampere)

IV. EFFECT ON CHARACTERISTICS

There are frequent variations in the irradiation and temperature of environment which affects the overall performance of solar panel. Simulation of solar panel under variation of irradiation and temperature is done. At standard temperature conditions 25°C and 1000W/m² the solar panel's maximum power point is 72W at 16.08V and 4.46A. Solar panel's I-V and P-V characteristics for various conditions are plotted in MATLAB/Simulink.

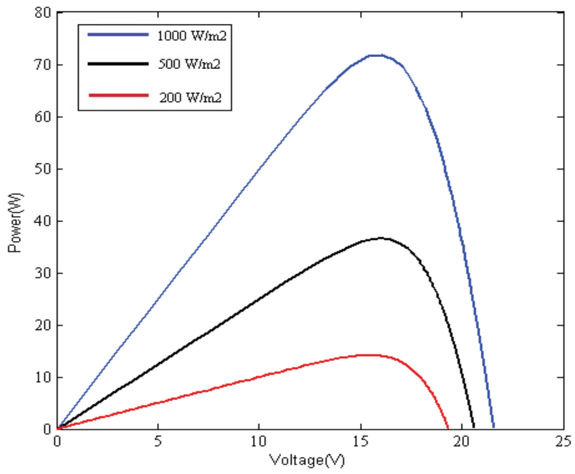

Fig. 3. P-V characteristics under different irradiation conditions

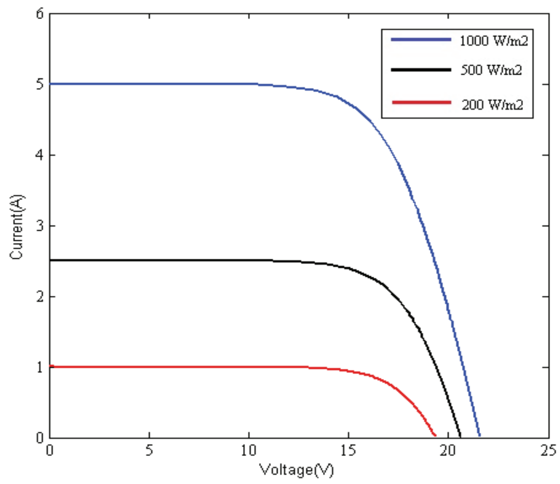

Fig. 4. I-V characteristics under different irradiation conditions

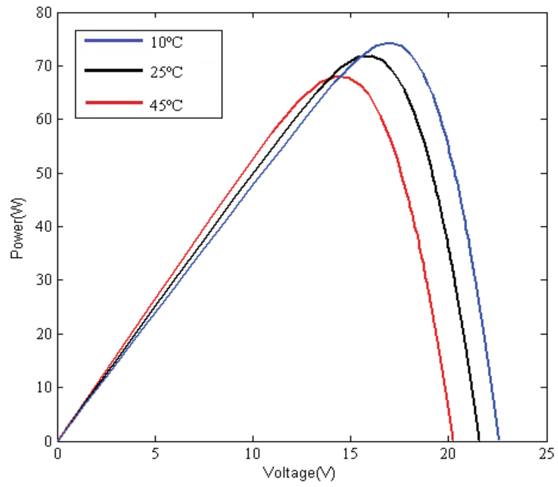

Fig. 5. P-V characteristics under different temperature conditions

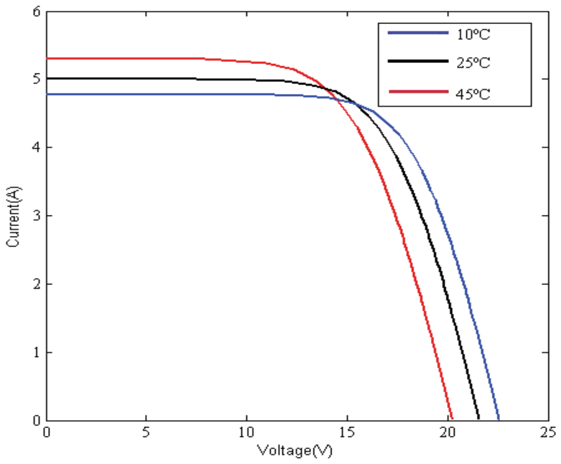

Fig. 6. I-V characteristics under different temperature conditions

The results under varying irradiation conditions shows that at 25ºC as the irradiation increases from 200W/m² to 1000W/m²MPP increases from 14W to 72W respectively as shown in Fig.3. At 1000W/m² as temperature is increased from 10°C to 45ºC MPP decreases from 74W to 68W respectively as shown Fig.5. For obtaining good results of a PV system is to have high irradiation and low temperature conditions.

V. DC-DC BOOST CONVERTER

This section is a prime part of the system. Boost converter is the simplest non-isolation topology [4]. Converter steps up the voltage coming from solar panel. If converter isn't used then the load connected to the panel will have voltage and current independent of MPP. Means the solar panel won't operate on MPP and efficiency is less. Converter is applicable for service when the battery voltage is high and the array voltage is low [5]. Hence the boost converter transfers maximum power from source to load by matching of source and load impedance. MPPT controller adjusts the duty cycle of MOSFET, which keeps on changing according to the climate conditions. Proper MOSFET switching would try to maintain steady output. [6].Figure of DC-DC Boost Converter is shown in Fig.7.The values of the components used in converter are L1=150µH, C1=100µF, C2=470µF, R=30Ω.

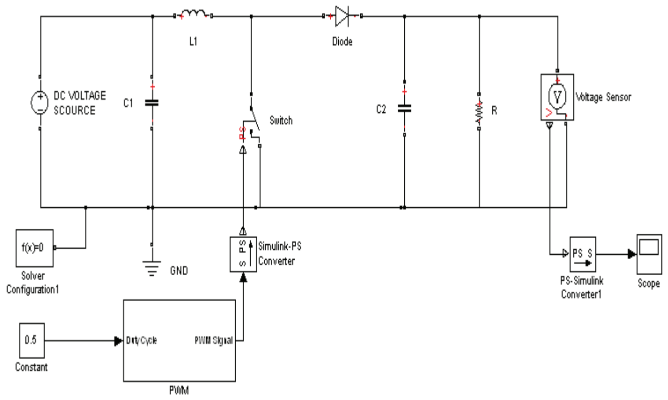

Fig. 7. DC-DC Boost Converter

VI. INCREMENTAL CONDUCTANCE

Using solar panel without MPPT controller will result in wasted power and will demand installation of more panels on the site. Such PV system hardly operates on MPP that would give output according to the need. According to this method extraction of maximum power becomes indispensable in PV systems [7].Incremental conductance is one of the MPPT techniques to track maximum power.Fig.8 shows P-V graph for incremental conductance. In this technique incremental conductance ($\frac{dI}{dV}$) and instantaneous conductance ($\frac{I}{V}$) are compared. The formulas for incremental conductance are given by equation [8] (6), (7), (8). By comparing of formulas the duty ratio is either increased or decreased under varying climate condition to change the output voltage of converter.

$$\frac{dI}{dV} = -\frac{I}{V} \qquad \text{At MPP} \qquad (6)$$

$$\frac{dI}{dV} > -\frac{I}{V} \qquad \text{Left of MPP} \qquad (7)$$

$$\frac{dI}{dV} < -\frac{I}{V} \qquad \text{Right of MPP} \qquad (8)$$

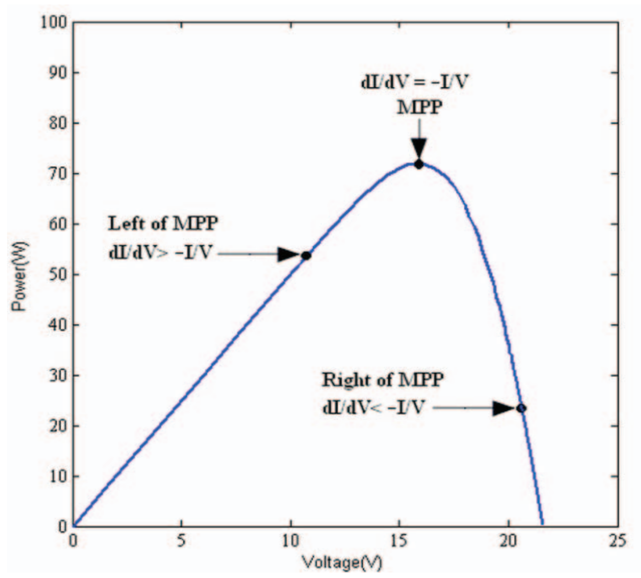

Fig. 8. P-V graph on incremental conductance of solar panel

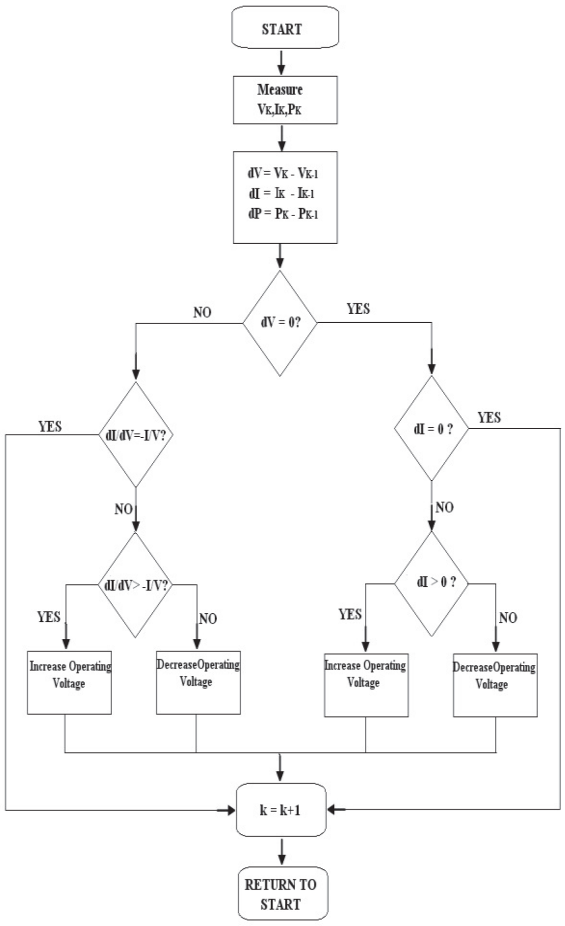

Fig. 9. Incremental conductance algorithm

This method has satisfying tracking performance for environment changing conditions [9]. Fig.9 shows incremental conductance flow chart. When incremental conductance is equal to instantaneous conductance then the system is operating at MPP. If the incremental conductance is greater than instantaneous conductance then it is left of MPP hence must increase the operating voltage to attain MPP else it is right of MPP which must decrease the operating voltage until MPP is reached. At MPP incremental conductance and instantaneous conductance must be equal in magnitude but opposite in polarity given equation (6). Also at point other than MPP inequalities are developed and must be opposite in polarities given in equation (7) and (8). This algorithm can be programmed in MATLAB/Simulink.

VII. RESULTS

Simulation results are obtained after simulating the PV system with MPPT and without MPPT (Non-MPPT).The output power changes with respect to different irradiations starting from 1000W/m² and reducing the step change values up to 200W/m². The output power decreases as the irradiation reduces. Change in power, voltage, current can be observed in Fig.10, Fig.11 and Fig.12 respectively.

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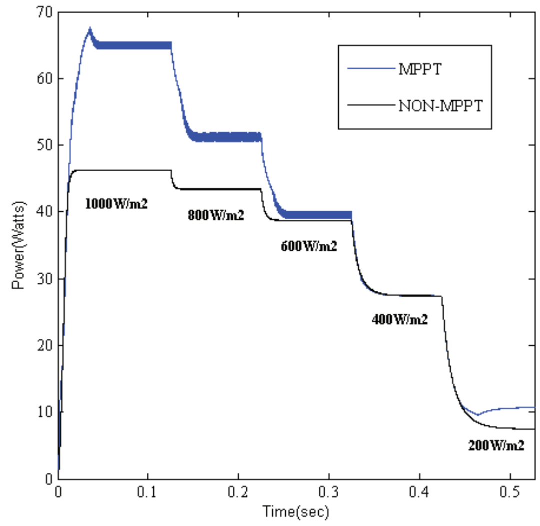

Fig. 10. Change in power with step changes in irradiation

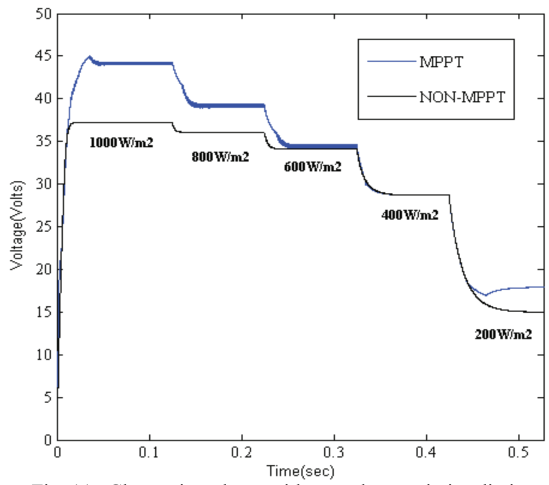

Fig. 11. Change in voltage with step changes in irradiation

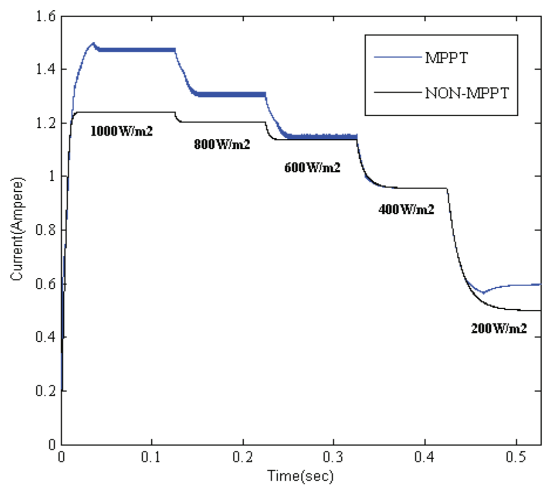

Fig. 12. Change in current with step changes in irradiation

From simulation of the system the actual values of output power in *(Watts)* for different irradiations in *(W/m2)* at 25°C is shown in the table II:

TABLE. II. TABLE OF OUTPUT POWER

Irradiation	PV system without MPPT	PV system with MPPT
(W/m2)	*Power (Watts)*	*Power (Watts)*
1000	46.23	64.97
800	43.37	51.23
600	38.75	41.89
400	27.04	27.82
200	7.45	13.04

From above table it can be inferred that PV system with MPPT yields better output than PV system without MPPT.

VIII. CONCLUSION

The Incremental Conductance MPPT method is simulated by MATLAB/Simulink which is easy and simple to implement. Characteristics of PV module are verified under different irradiation and temperature condition. Effect of step change in irradiation on PV system is observed. The MPPT controller makes a closed loop system which achieves and maintains MPP in distinct temperature and irradiation levels. One of the major drawbacks of incremental conductance technique is that it takes quite large time to settle down and achieve a steady state value.

Real time testing of the advanced control algorithm and minimization of output power ripples in existing algorithm will be the future work.

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