

# Analysis, Modeling and Implementation of Incremental Conductance Maximum Power Point Tracking

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## ABSTRACT

Maximum power point tracking must be used in PV systems to get the most of solar energy. A solar cell's property is non-linear. The intensity of solar radiation falling on the earth's surface is affected by a variety of elements including clouds, water vapour, pollution, absorption, scattering, and climate conditions. A PV system without MPPT seldom generates maximum power, which also affects the Maximum Power Point of the PV system with regard to a certain environmental situation, resulting in low power. In order to monitor PV system's MPP Incremental conductance (IC) method gives greater steady-state accuracy with better and efficient output compared to non MPPT system. Several simulation results are shown here.

**KEYWORDS:** Solar energy, Photovoltaic system, DC-DC Boost Converter, Incremental Conductance (IC), Maximum Power Point Tracking (MPPT)

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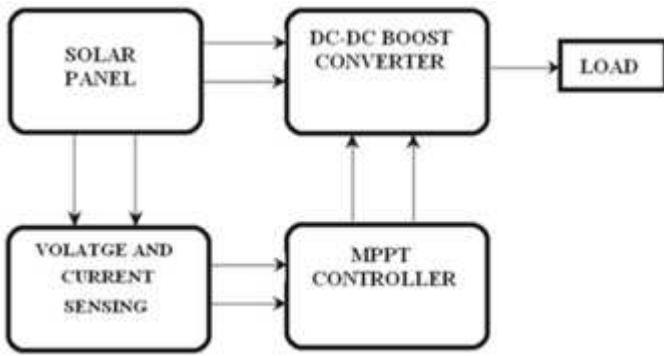
## 1. INTRODUCTION

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.

## 2. PHOTOVOLTAIC SYSTEM:

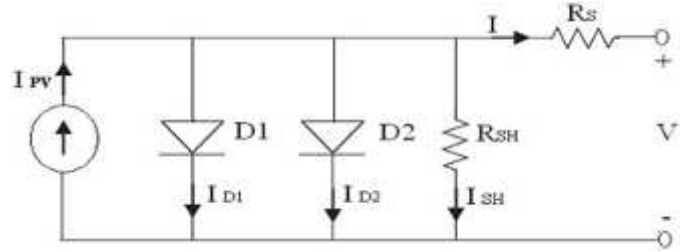
The Photovoltaic system consists of 3 main parts that are: MPPT controller, Solar panel, DC-DC Boost Converter. Solar panel's output voltage is supplied to DC-DC Boost Converter to drive the load. From solar panel, voltage and current are sensed and fed to MPPT Controller. The controller needs voltage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



**Fig. 1. Photovoltaic system block diagram**

**3. 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  $R_S$  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:

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

$$I_{PV} = [I_{SC} + kI(T \pm T_{REF})G] \quad (2)$$

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

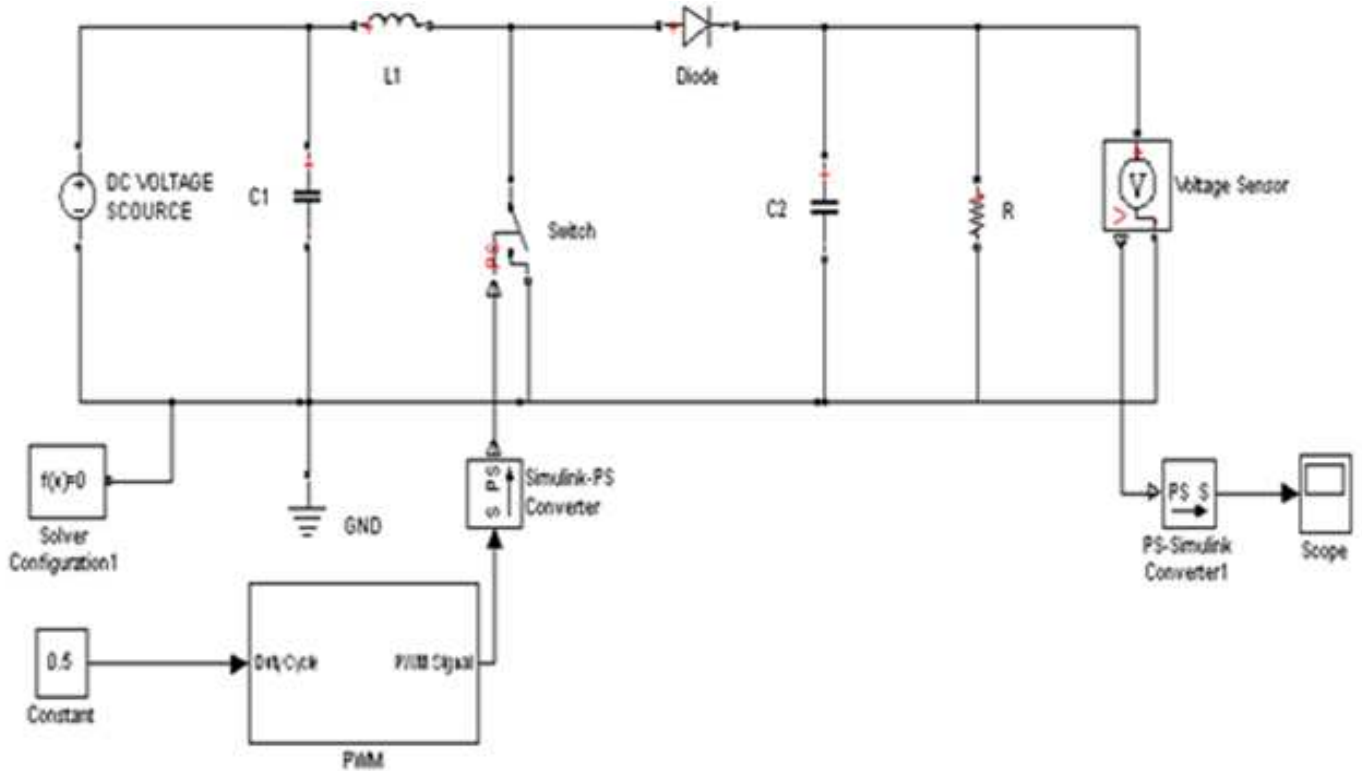
$$I_{D2} = I_{S2} \left[ e^{\frac{q(V + IR_S)}{n2kT}} - 1 \right] \quad (4)$$

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

**TABLE I SOLAR CELL'S PARAMETER TABLE**

PARAMETERS	DESCRIPTION OF PARAMETERES
I	Output current (Ampere)
V	Output voltage (volts)
I	Photo current (Ampere)
$I_{D1}, I_{D2}$	Diode 1 current & Diode 2 current (Ampere)
$I_{SH}$	Shunt resistance current (Ampere)
$T_{REF}$	Reference temperature of cell ( $^{\circ}C$ )
$K_i$	Short circuit temperature coefficient ( $0.003A/^{\circ}C$ )
G	Solar irradiation ( $W/m^2$ )
$I_{S1}, I_{S2}$	Saturation current of diode $D1$ & diode $D2$ (Ampere)
$n1, n2$	Ideality factor of $D1$ & $D2$ ( $n1=n2=1$ )
Q	Electron Charge ( $1.6 \times 10^{-19} C$ )
K	Boltzmann's Constant ( $1.38 \times 10^{-23} J/K$ )
$V_{OC}$	Open circuit voltage of solar panel (21.6Volts)
$I_{SC}$	Short circuit current of solar panel (5Ampere)

**DC/DC Boost Converter:** This section is a prime part of the system. Boost converter is the simplest non-isolation topology. 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. 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. Figure of DC-DC Boost Converter is shown in Fig.4. The values of the components used in converter are  $L1=150\mu H$ ,  $C1=100\mu F$ ,  $C2=470\mu F$ ,  $R=30\Omega$ .



**Fig. 4. DC-DC Boost Converter**

**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. Incremental conductance is one of the MPPT techniques to track maximum power. Fig.3 shows P-V graph for incremental conductance. In this technique incremental ( $\frac{dI}{dV}$ ) and instantaneous conductance ( $\frac{I}{V}$ ) are compared. The formulas for incremental conductance are given by equation (1), (2), (3). By comparing of formulas the duty ratio is either increased or decreased under varying climate condition to change the output voltage of converter.

$$\frac{dI}{dV} = -\frac{I}{V} \text{ At MPP (1)}$$

$$\frac{dI}{dV} > -\frac{I}{V} \text{ Left of MPP (2)}$$

$$\frac{dI}{dV} < -\frac{I}{V} \text{ Right of MPP (3)}$$

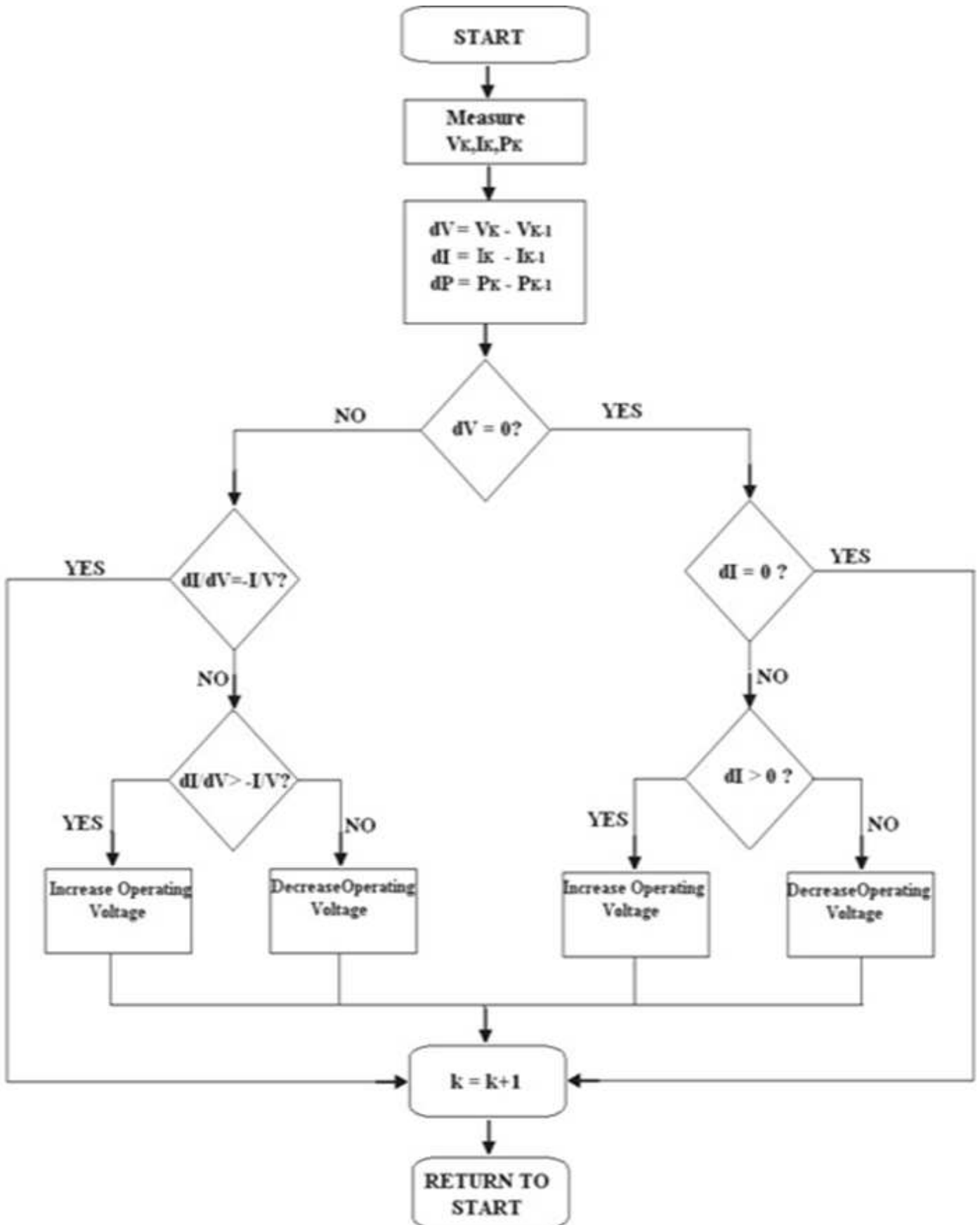
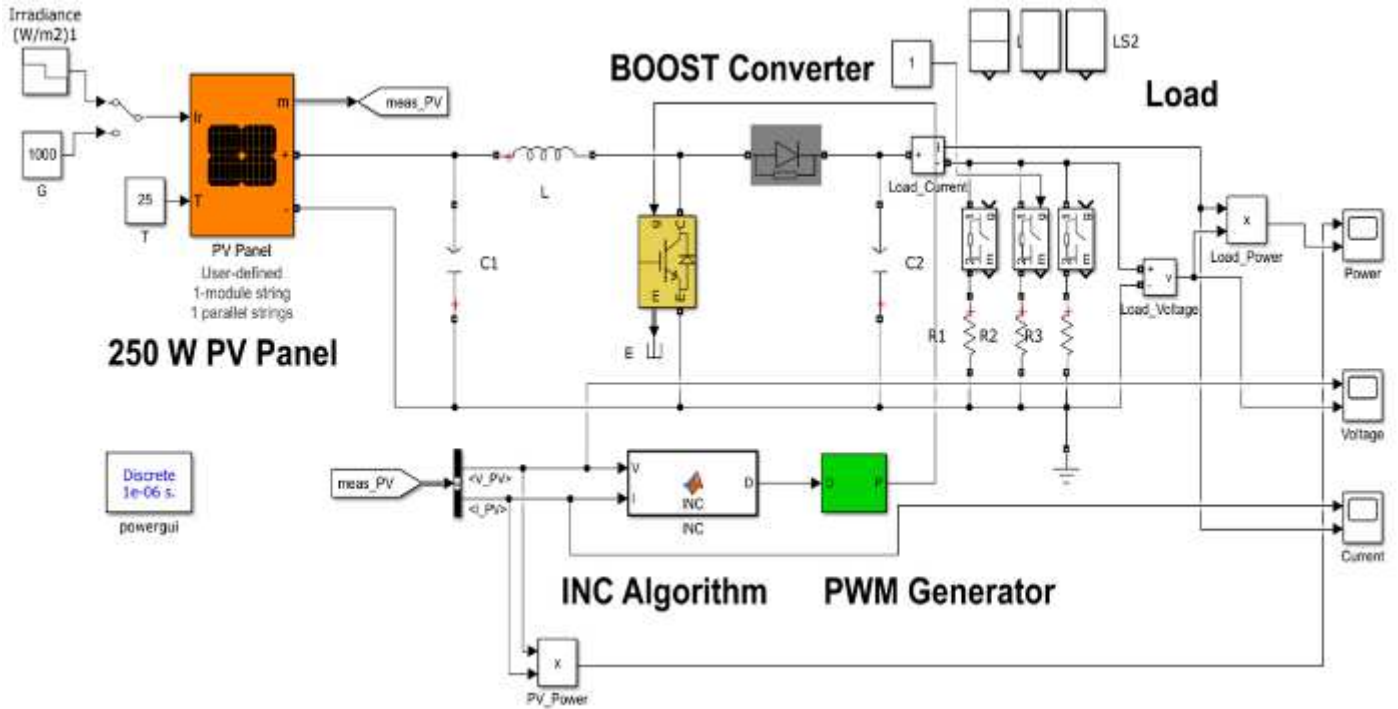


Fig. 5. Incremental conductance algorithm

**SIMULATION MODEL & RESULTS:**

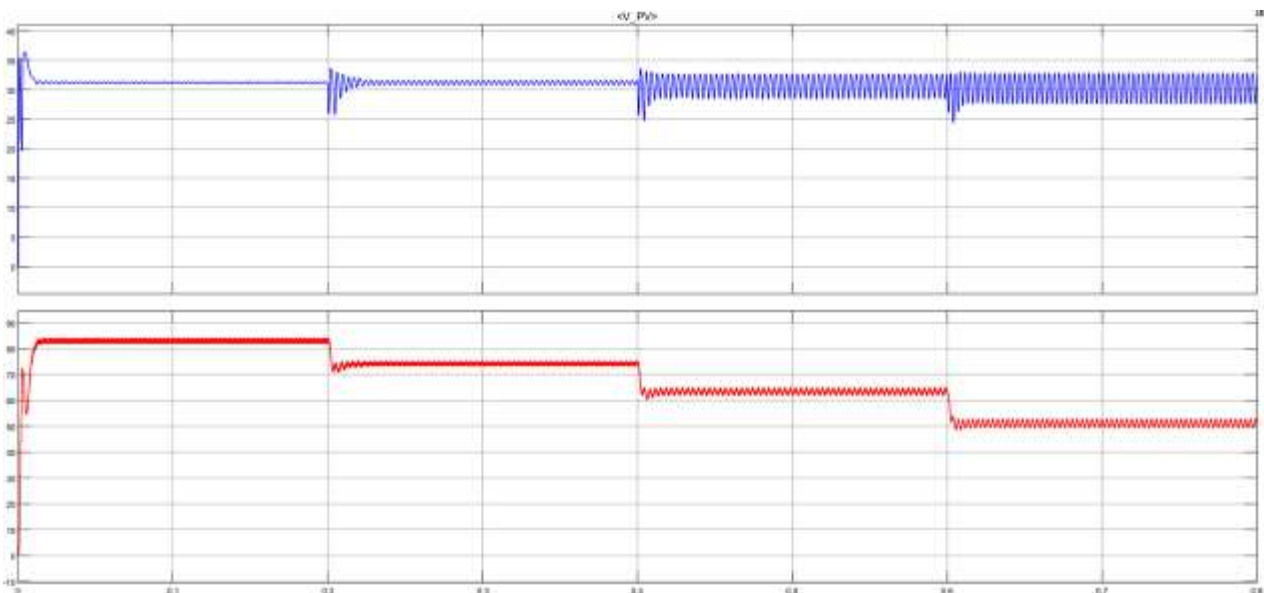


**Fig. 6. SOLAR MPPT INC SIMULINK MODEL**

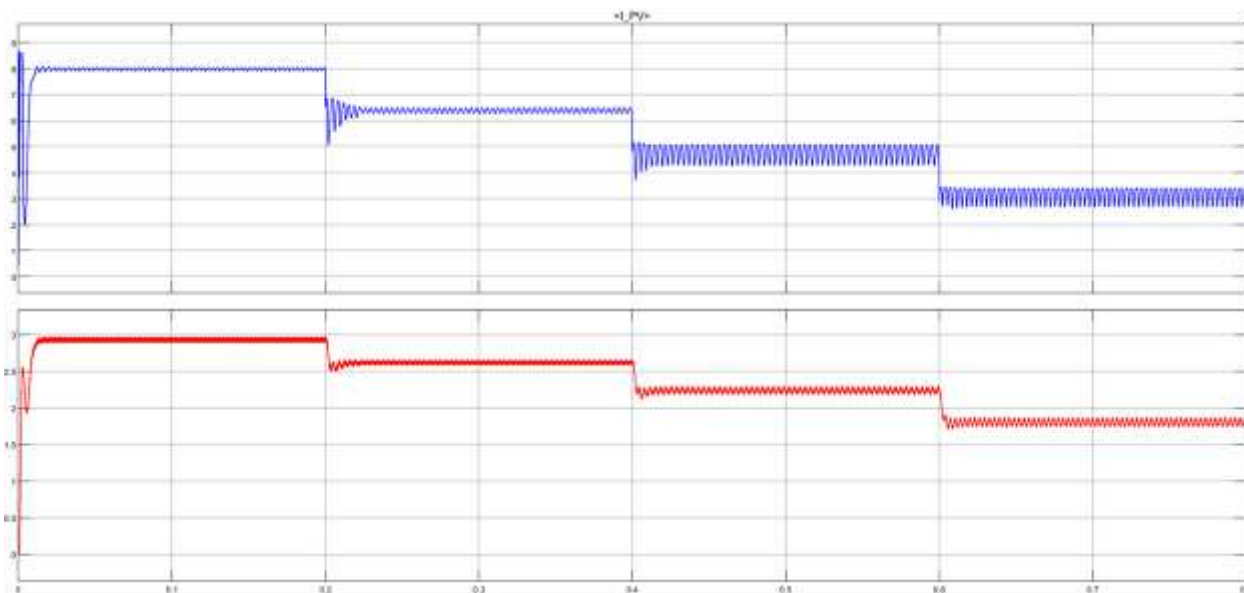
**TABLE II: PV PARAMETERS**

Parameters	Specifications
Maximum power, $P_m$	250 W
Series-connected modules per string	1 nos
Parallel strings	1 nos
Cells per module (Ncell)	60
Maximum power voltage, $V_{pm}$	30.7 V
Maximum power current, $I_{pm}$	8.15 A
Open circuit voltage, $V_{oc}$	37.3V
Short circuit current, $I_{se}$	8.66 A

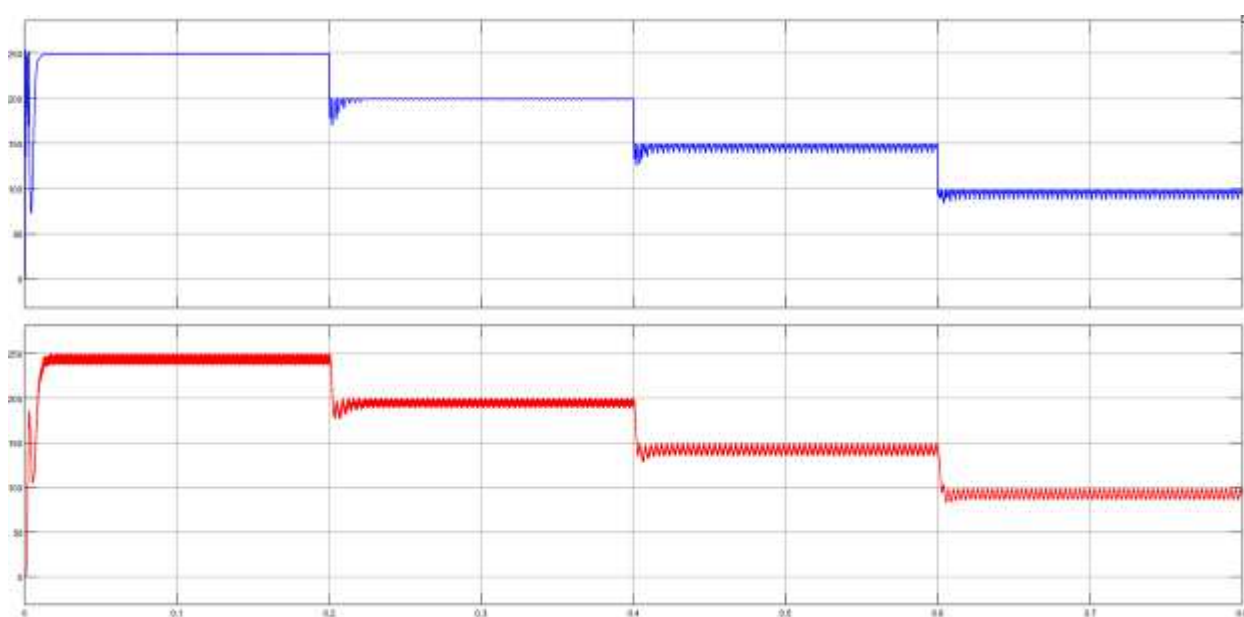
**SIMULATION RESULTS:** Simulation results are obtained after simulating the PV system with MPPT and INC. The output power changes with respect to different irradiances starting from 1000W/m<sup>2</sup> and reducing the step change values up to 200W/m<sup>2</sup>. The output power decreases as the irradiation reduces. Change in power, voltage, current can be observed in Fig.7, Fig.8 and Fig.9 respectively.



**Fig 7. PV Output Voltage vs Time in (S)**



**Fig 8. PV Output Current vs Time in (S)**



**Fig 9 PV Output Power vs Time in (S)**

**CONCLUSION & FUTURE SCOPE:**

**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.

**FUTURE SCOPE:**

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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