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Maximum Power Point Tracking In Photovoltaic Cells: Design and Implementation

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Abstract: **Photovoltaic Energy is the most important Energy Resource since it is clean pollution free and inexhaustible. In recent years a large number of techniques have been proposed for tracking the Maximum Power Point. Maximum Power Point Tracking is used in photovoltaic system to maximize the photovoltaic output power irrespective of the temperature & irradiance condition. The P-V & I-V characteristic is obtained for various values of solar irradiance & temperature. The method is based on use of Incremental Conductance of the PV & Beta method to determine a Maximum Output Power. MPPT algorithm plays an important role in increasing the efficiency of system, the purpose of this paper is to study and compared two Maximum Power Point Tracking algorithms in a Photovoltaic System.**

Keywords: **Photovoltaic System, Modeling of PV array, Incremental Conductance Algorithm, Beta method, Simulation result.**

I. INTRODUCTION

In the current global energy scenario, Importance of power generation from renewable energy sources is increasing day by day. In India sector wise consumption of Electrical Energy (utilities) during 2013-2014 in percentage was 22 in Domestic, 17 in Agriculture , 45 in Industry, 9 in Commercial, 2 in Traction and railways, 5 in others. By 2013 total installed capacity of electrical power in India is 2, 25,793.10 MW, in which state sector is contributing 89,092.12 MW, central sector 65,612.94 MW and private sector 71,088.04 MW. Fuel wise power generation capacity varies as Total Thermal power is 153,847.99 MW in which Coal is 132, 288, 39MW,Gas is 20,359.85MW and Oil is 1,199.75MW, Hydro(Renewable) is 39,623.40MW, Nuclear is 4,780.00MW and renewable energy sources is 27,541.71MW.[sourse MNRE 2014]

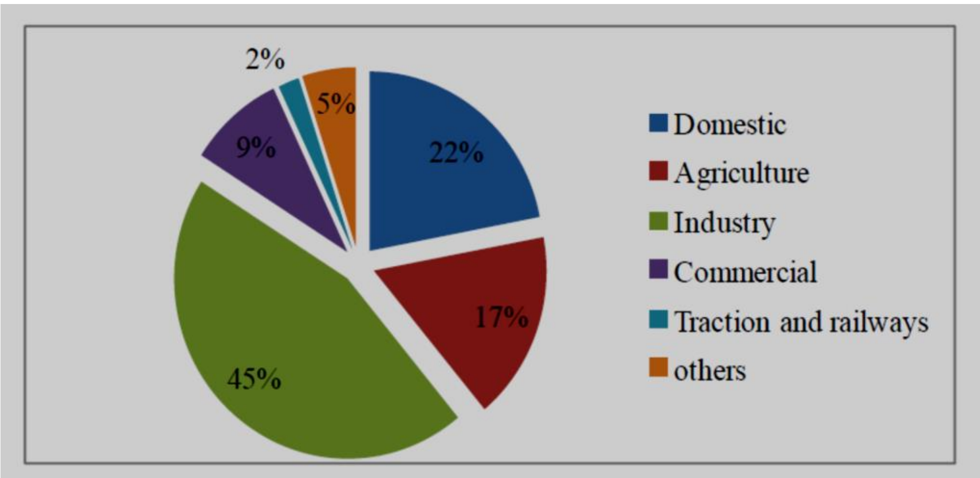

Figure 1: Sector wise consumption of Electrical Energy (utilities) during 2011-2012

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The major power generation is due to fossil fuels but the availability of these fuels are limited and various environmental hazards associated with traditional power generation methods. Out of the various grids connected renewable energy systems, Solar Photo-Voltaic energy systems are most popular. Energy supplied by the sun in one hour is equal to the amount of energy required by the human in one year. Solar power is available during the whole day but the solar irradiance levels change because of the changes in the sun's intensity and shadows caused by many reasons.

Alot of MPPT algorithms have been used developed by researchers and industry delegates all over the world. They are Perturbation and Observation methods, Incremental Conductance method, Hill Climbing method, Beta method, Fractional short circuit current method, Open circuit voltage method and so on.[1,2]

II. PV ARRAY CHARACTERISTICS AND MODELING

The equivalent circuit of a PV cell is shown in Fig. An ideal solar cell is modelled by a current source and a diode in parallel with it. However no solar cell is ideal there by series resistance which has a very small value. Rsh is the equivalent shunt resistance whose value is very high.[3]

Applying Kirchoff's current law to the junction where Iph, diode, Rsh and Rs meet, we get,

$$Iph = Id + IRp + I$$

$$I = Iph - (Id + IRp)$$

We get the following equation for the PV cell current

$$I = Iph-(Io[e(V+IRs/VT)-1]+V+IRs/Rp)$$

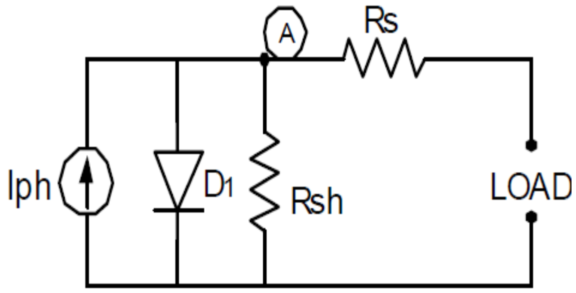

Figure 2: PV module equivalent electrical circuit

Where Iph is Insolation Current, I is the Cell Current, Io is the Reverse Saturation Current, V is the Cell Voltage, Rs is the Series Resistance, Rsh is the Parallel Resistance, and VT is the Thermal Voltage. Equation of cell is derived from the physics of the PN junction and is generally accepted as reflecting the characteristic behaviour of the cell. The building block of PV array is a solar cell, which converts light energy into electricity. The photo current Iph depends on the solar radiation and cell temperature as follows.[1,2]

$$Iph = [Iscr+Ki(T-Tr)]\ S/100$$

Where Iscr is the Cell Short Circuit Current at reference temperature and radiation, Ki is the Short Circuit Current Temperature Coefficient and S is the solar irradiation in W/m2.

III. MPPT TECHNIQUE FOR SOLAR PANEL

Maximum Power Point Tracking (MPPT) techniques are used in Photovoltaic (PV) systems to maximize the PV array output power by tracking continuously the Maximum Power Point (MPP) which depends on panel temperature and irradiance conditions. To make best use of solar PV system,the output is maximize in two ways. The first is mechanically tracking the sun and always orienting the panel in such a direction as to receive maximum solar radiation under changing position of the sun. The second is electrically tracking the operating point by manipulating the load to maximize power output under changing condition of irradiance and temperature.[10]

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Incremental Conductance Mppt Algorithm:

The Incremental Conductance method is based on the slope of the PV array power curve is zero at the MPP, positive on the left of the MPP, and negative on the right, as given by[9].

$dP/dV = 0$, at MPP

$dP/dV > 0$, left of MPP

$dP/dV < 0$, right of MPP.

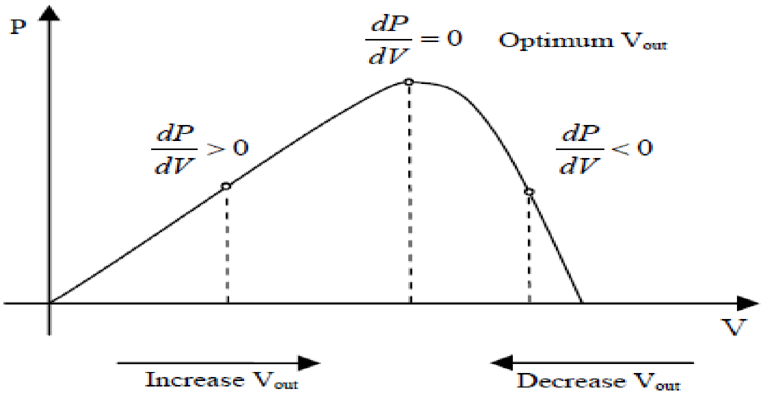

Figure 3: Incremental Conductance power slope

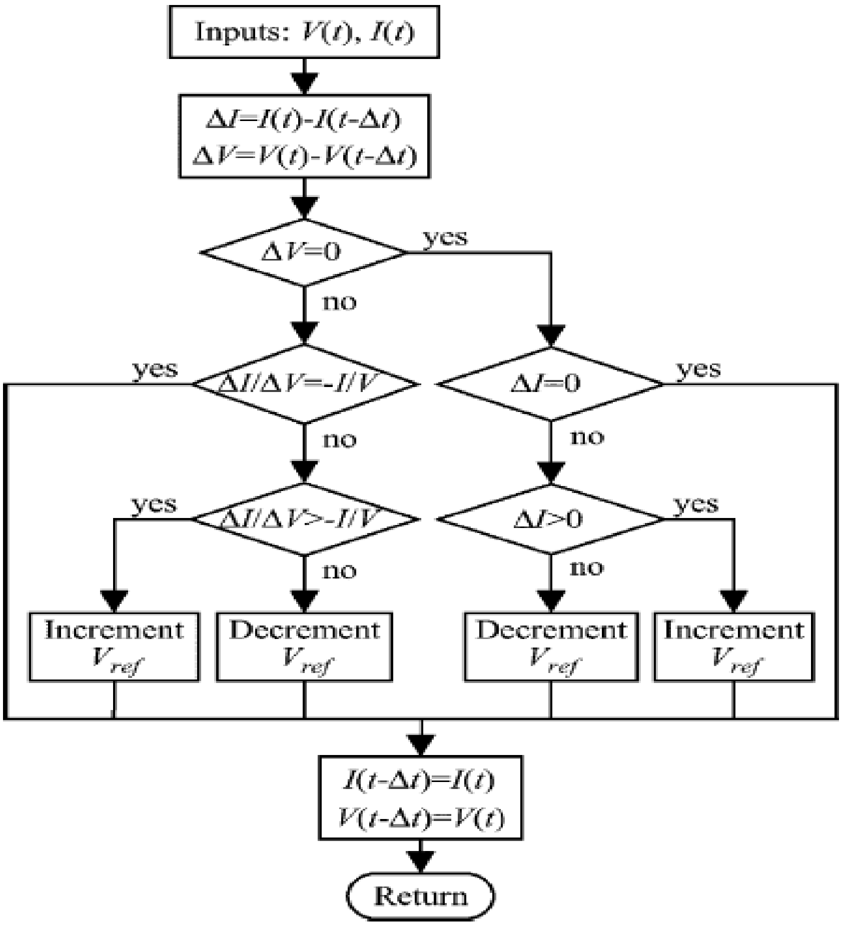

Figure 4: Flowchart of the IC Algorithm

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Since

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} \cong I + V\frac{\Delta I}{\Delta V} \quad \ldots\ldots\ldots\ldots (1)$$

Eqn. (1) can be written as

$$\begin{cases} \Delta I/\Delta V = -I/V, & \text{at MPP} \\ \Delta I/\Delta V > -I/V, & \text{left of MPP} \\ \Delta I/\Delta V < -I/V, & \text{right of MPP.} \end{cases}$$

Beta Method:

This algorithm works in two stages. The first stage takes the operating point (OP) quickly within a close range of the actual MPP. The second stage consisting of a conventional scheme (such as the ones mentioned above) is then used to bring the OP to the exact MPP. The proposed scheme offers the following advantages over the existing schemes.

1) In the first stage, the scheme tracks an intermediate variable, β that appears in the analysis, rather than tracking power. This overcomes the limitation of the conventional schemes where there is no way to predict the iteration step size and the duty cycle needed to track the MPP. It will be shown subsequently that tracking β facilitates fast tracking, β with a relatively larger and variable iteration step size. Thus the proposed algorithm is more efficient, as losses due to small steps, when the operating point is away from MPP, are eliminated.

2) The fast tracking of the first stage does not compromise the accuracy of the tracking because it is followed by a conventional scheme in the second stage, which tracks power with fine steps. But since the first stage brings the OP within a close proximity of MPP, the second stage does not require a long time.[9,10]

3) In view of (1) and (2), The proposed algorithm is especially suitable for fast-changing environmental conditions.

The derivative of P_{PV} with respect to V_{PV}, we get

$$\frac{dPpv}{dVpv} = i_{pv} + V_{pv} \times \frac{dipv}{dVpv}$$

Where P_{PV} ,V_{PV} , i_{PV} are the PV array output power, output voltage, and output current, respectively. It is known that

$$i_{pv} = I_{ph} - Io \times (e^{c \times (I_{pv} \times Rs + V_{pv})} - 1)$$

Where I_{Ph} is photo generated current, I_O is reverse saturation current, C= q/ (k×T×η), where q is electronic charge, k is Boltzmann's constant, η is diode quality factor, T is ambient temperature in Kelvin and R_S is the cell series resistance in Ohms. Differentiating (2) with respect to, solving and substituting in (1), and applying the MPP condition yields

$$\frac{dPpv}{dVpv} = o = i_{pv} + V_{pv} \times \frac{-Io \times \left(ec \times (ipv \times Rs \times Vpv)\right) \times c}{1 + Io \times \left(ec \times (ipv \times Ra \times Vpv)\right) \times Rs \times c}$$

Solving (3) for i_{PV}/V_{PV} and taking the natural log on both sides of the resulting equation

$$\ln\left(\frac{ipv}{Vpv}\right) - c \times Vpv = \ln (Io \times c) + Rs \times c \times i_{pv} - \ln (1 + I_O \times (e^{c \times (i_{pv} \times Rs + V_{pv})}) \times R_s \times c$$

The crux of the proposed scheme lies in the fact that instead of tracking power which does not have an injective relationship with the duty cycle of the boost converter (e.g., two different values of the duty cycle may yield the same power), we track β, which offers a monotonically increasing and injective relationship with the duty cycle shown in fig. Hence, tracking β is simpler and faster than tracking power.

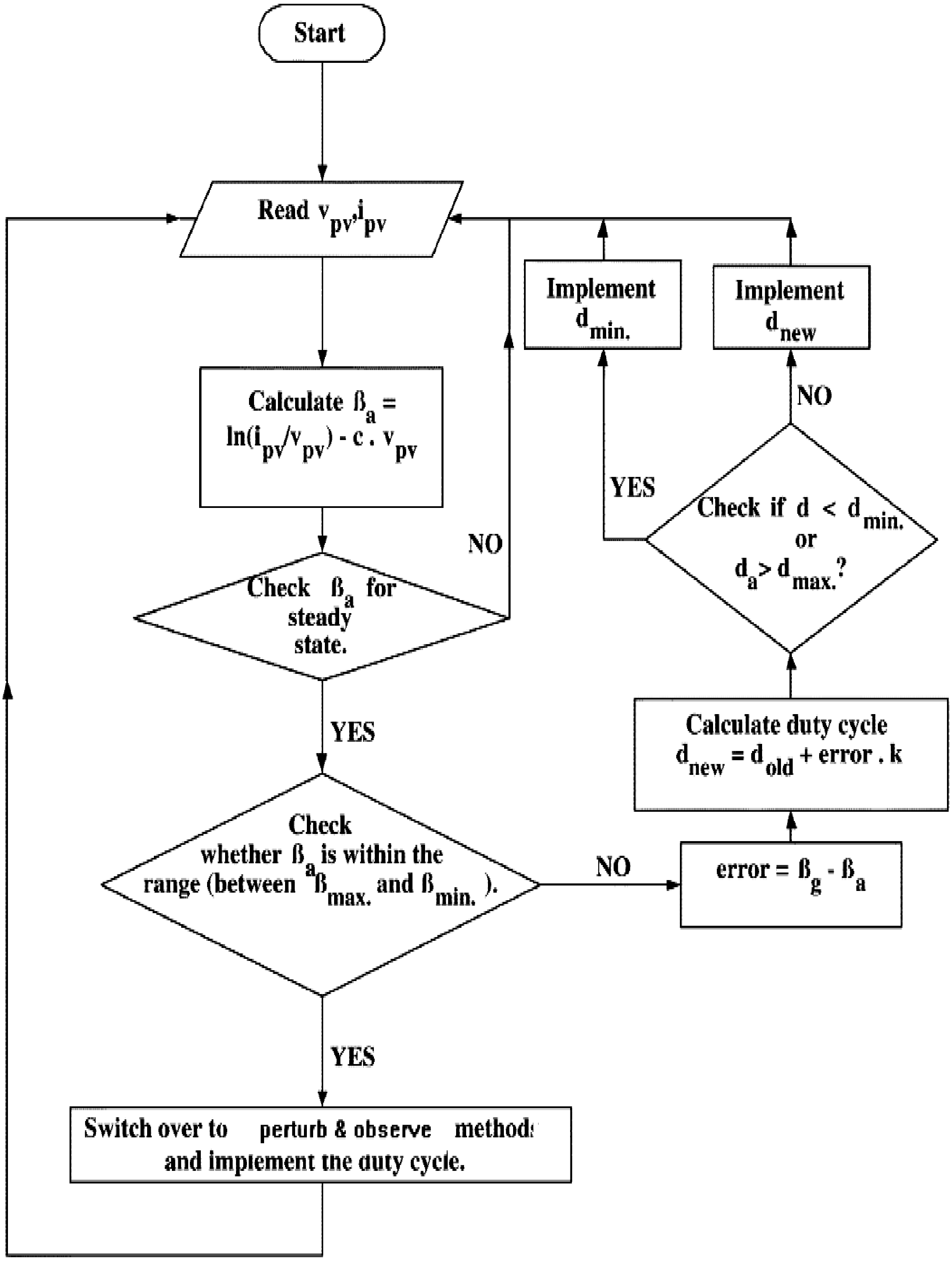

Figure 5: Flow-chart of Beta MPPT technique.

β_{min} at MPP corresponds to minimum isolation and minimum temperature. While implementing the first stage of the algorithm, βg, the value of β corresponding to the most probable array temperature is used as the guiding value for calculating the duty correction as given as follows:

error = β_g - β_a and d_{new}= d_{old} + error× k

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Simulation of Solar PV model using MPPT INC algorithm:

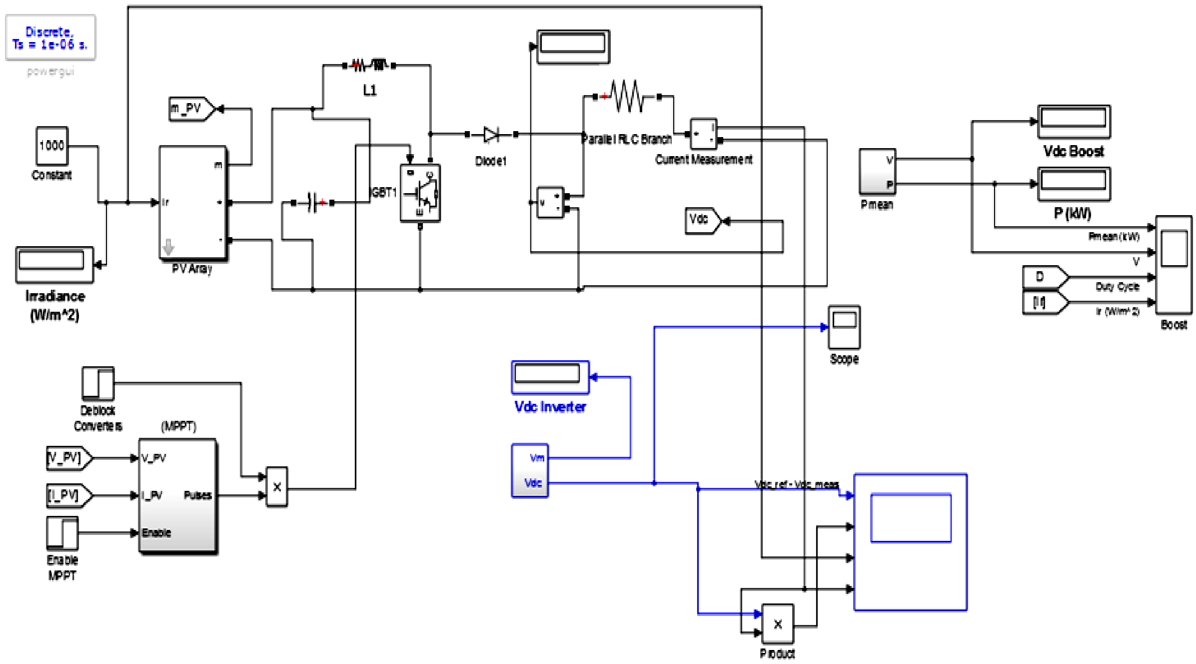

Figure 6: Simulink of solar module using MPPT INC algorithm

The output of the solar PV system is given to the MPPT system, which track the maximum power using INC algorithm, which is used as firing pulse of IGBT switch.

The output voltage, current & power after boosting is 300V, 40 A and 12000 W, respectively shown in figure 7

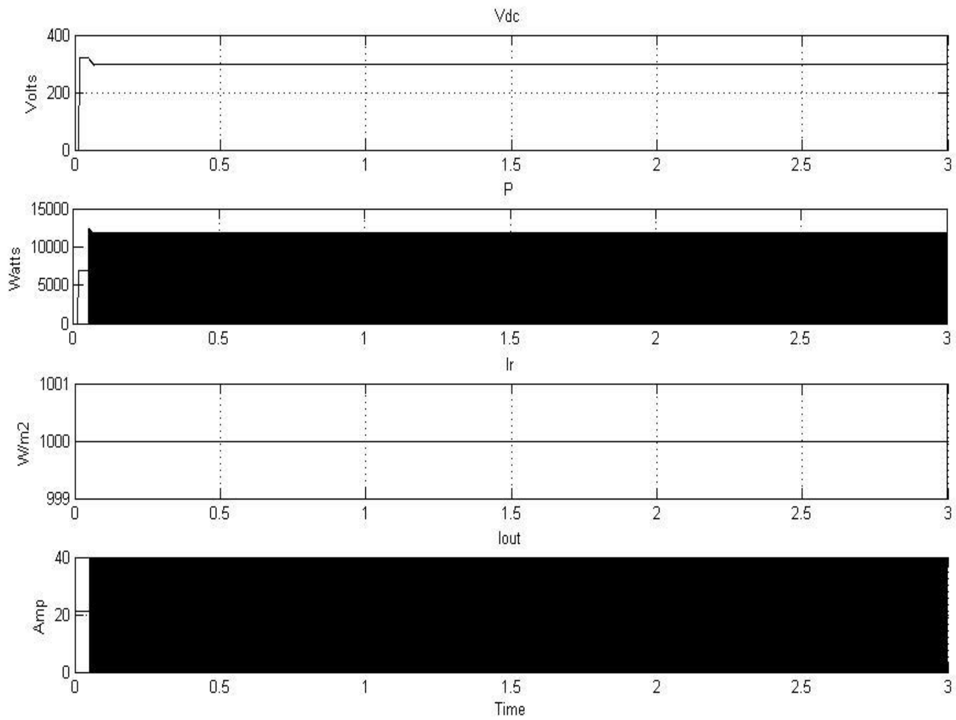

Figure 7: Voltage, power, current, irradiance of Solar PV system

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Simulation of Solar PV model using MPPT Beta algorithm:

It is new algorithm for tracking maximum power point in photovoltaic systems. This gives improved results.

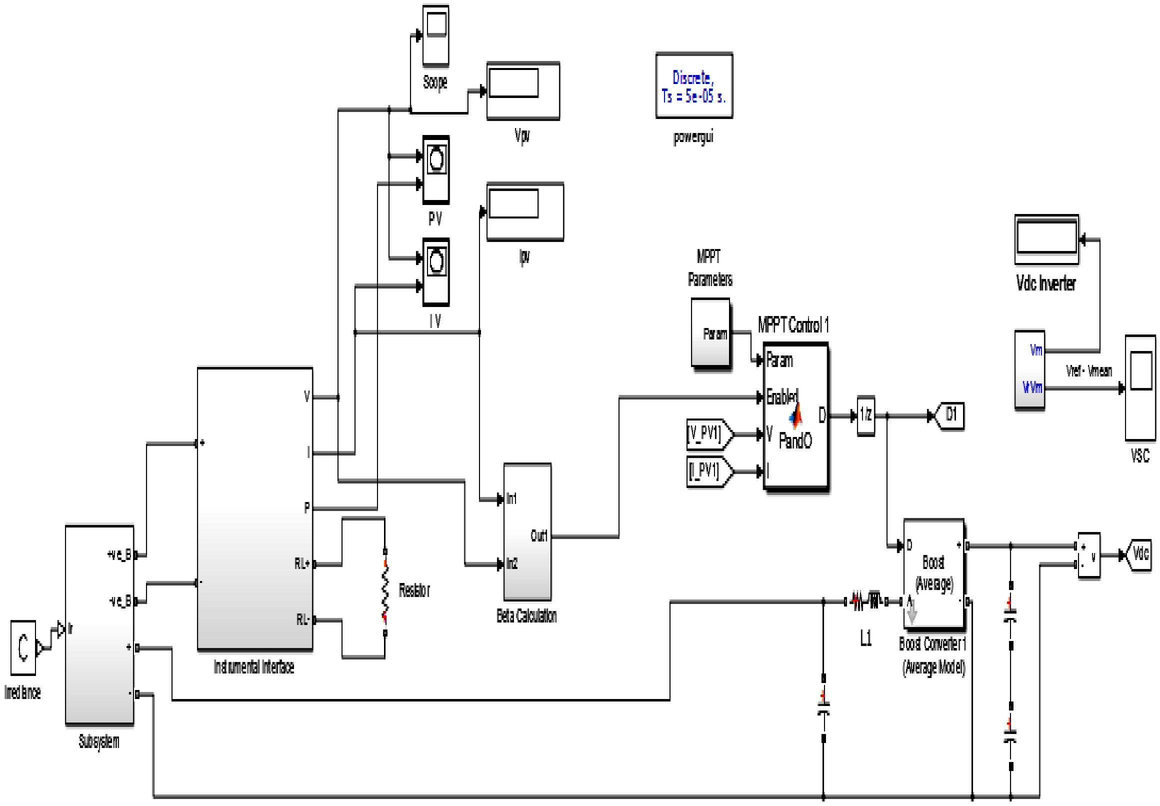

Figure 8: Simulink of solar module using MPPT Beta algorithm

The output of solar PV system is calculated by Beta method. The output voltage after boosting is above 3000Vdc. It is shown in Fig.9 which gives good result as compare to INC method.

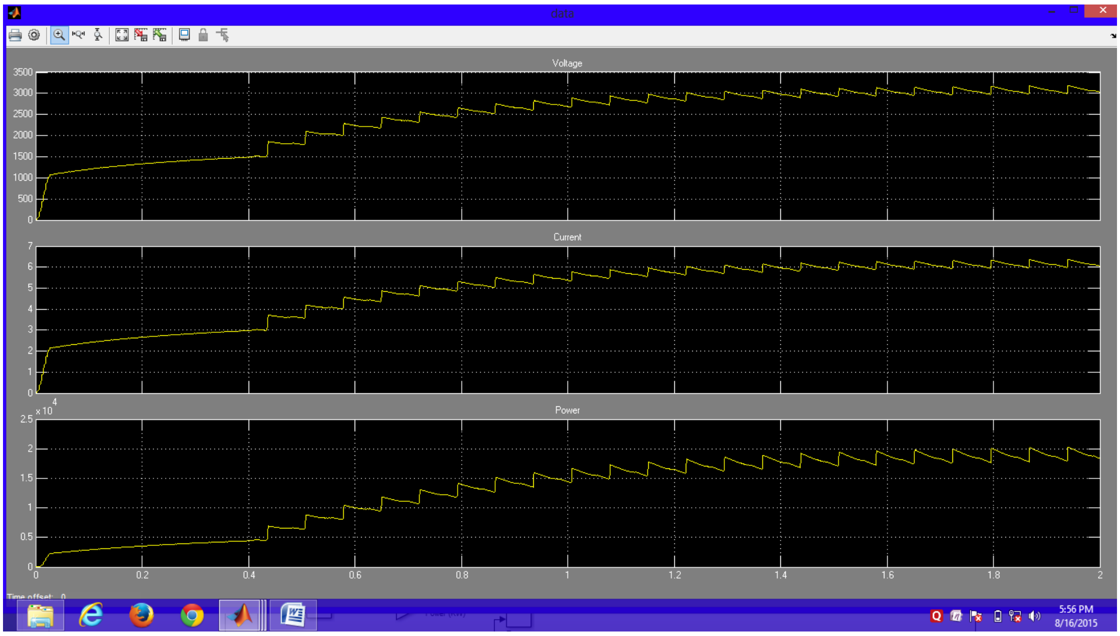

Figure 9: Voltage waveform of Solar PV system using Beta Method

TABLE NO.1

SKY CONDITION	INCREMENTAL METHOD	EFFICIENCY	BETA METHOD	EFFICIENCY
	NO OF DAYS		NO OF DAYS	
CLEAR	20	97.4		98.7

IV. CONCLUSION

A MATLAB/Simulink model for the solar PV cell module was developed. This model is based on the fundamental circuit equations of a solar PV cell taking into account the effects of physical and environmental parameters such as the solar radiation and cell temperature. The module model was simulated in MATLAB 2012a.

The model of MPPT Incremental Conductance (INC) & Beta method has been design in simulink. Comparing both the techniques in respect of output voltage V_{dc} it is found that Beta method with boost converter provides higher and stable output (without oscillation) then INC method. Though Beta method is more efficient with INC & other MPPT methods; in the presented model Beta method shows good result in terms of efficiency.

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