ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Modeling and Analysis of Perturb & Observe and Incremental Conductance MPPT Algorithm for PV Array Using CUK Converter

D.Durgabhavani
M.Tech Student Scholar,
Department of Electrical & Electronics Engineering,
Godavari Institute of Engineering and Technology,
Nh-16 Chaitanya Nagar, Rajahmundry-533296,
East Godavari (Dt), Andhra Pradesh, India.

Ms.P.Suguna Ratnamala, M.Tech
Assistant Professor,
Department of Electrical & Electronics Engineering,
Godavari Institute of Engineering and Technology,
Nh-16 Chaitanya Nagar, Rajahmundry-533296,
East Godavari (Dt), Andhra Pradesh, India.

Abstract:

Nowadays, photovoltaic (PV) generation is developing increasingly fast as a renewable energy source. The PV generator is connected to the boost DC-DC converter, the control systems based on the maximum power point tracking (MPPT) with PV array to generate the maximum power to the grid/load with change weather conditions, and then integrated into the AC utility system by DC/AC inverter and control the power active and reactive for achieved unit power factor at connection point. This photovoltaic (PV) system does not require bulk and loss battery and reduces transmission losses. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Even though there are many methods of MPPT techniques, here we use perturb and observe (P&O) type of MPPT. The overall efficiency of grid/load connected photovoltaic power generation systems depends on the efficiency of the DC-into-AC conversion. Finally the proposed converter connected to induction motor drive to update the drive characteristics. The simulation results are obtained by using MATLAB/SIMULINK software.

Keywords:

Photovoltaic array, photovoltaic system, MPPT control, Induction machine Drive.

I.INTRODUCTION:

Large electric drives and utility applications require advanced power electronics converter to meet the high power demands. As a result, power converter structure has been introduced as an alternative in high power and medium voltage situations. As conventional sources of energy are rapidly depleting and the cost of energy is rising, photovoltaic energy becomes a promising alternative source. Among its advantages are that it is: 1) abundant; 2) pollution free; 3) distributed throughout the earth; and 4) clean and noise-free source of electricity. The main drawbacks are that the initial installation cost is considerably high and the energy conversion efficiency is relatively low. To overcome these problems, the following two essential ways can be used: 1) increase the efficiency of conversion for the solar array and 2) maximize the output power from the solar array Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Even though there are many methods of MPPT techniques, here we use perturb and observe (P&O) type of MPPT.

The much concerned with the fossil fuel exhaustion and the environmental problems are caused by the conventional power generation. Nowadays, renewable energy sources, such as photovoltaic (PV) panels and wind-generators, are now widely used. PV systems are the most direct way to convert solar radiation into electricity and are based on the PV effect.It is quite generally defined as the emergence of an electric voltage between two electrodes attached to a solid or liquid system upon shining light onto this system. Practically, all PV devices incorporate a PN junction in a semiconductor across which the photo voltage is developed. These devices are also known as solar cells. Light absorption occurs in a semiconductor material. The semiconductor material has to be able to absorb a large part of the solar spectrum [1].

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The PV generation is gaining increased importance as a renewable source. It is used today in many applications e.g. battery charging; water pumping, home power supply, swimming-pool heating systems, satellite power system.

The PV systems have the advantage of being maintenance and pollution-free but their installation cost is high and, in most applications; they require a power conditioner (DC/DC or DC/AC converter) for load interface.

Since PV modules still have relatively low conversion efficiency. The overall system cost can be reduced using high efficiency power conditioners which, in addition, are designed to extract the maximum possible power from the PV module.

II.PHOTOVOLTAIC SYSTEM:

A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a load by using proper energy conversion devices.

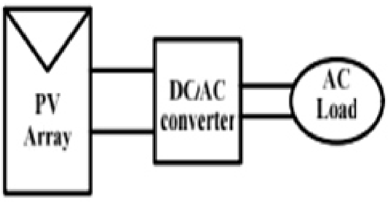

Fig.1. Block diagram representation of Photovoltaic system

This photovoltaic system consists of three main parts which are PV module, balance of system and load. The major balance of system components in this systems are charger, battery and inverter. The Block diagram of the PV system is shown in Fig.1.

A. Photovoltaic cell is basically a semiconductor diode whose p–n junction is exposed to light. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. The incidence of light on the cell generates charge carriers that originate an electric current if the cell is short circuited1

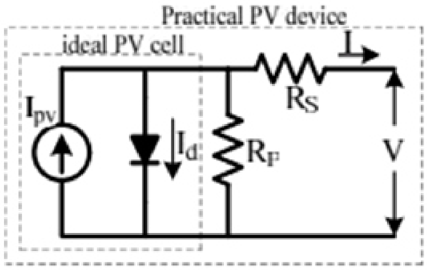

Fig.2. Practical PV device

The equivalent circuit of PV cell is shown in the fig.3. In the above figure the PV cell is represented by a current source in parallel with diode. Rs and Rp represent series and parallel resistance respectively. The output current and voltage form PV cell are represented by I and V. The I-V characteristics of PV cell are shown in fig.3. The net cell current I is composed of the light generated current IPV and the diode current ID.

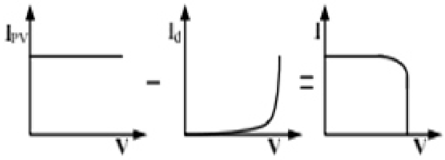

Fig.3. Characteristics I-V curve of the PV cell

III.PV MAXIMUM POINT POWER TRACKING (MPPT):

Typical solar panel can only convert 30% to 40% of the incident solar irradiation into electrical energy. However, usually solar panel delivers less than that, because according to the MPT theorem, the actual power output of a circuit reaches its maximum when the source impedance matches with the load impedance, a match which is usually not guaranteed. MPPT algorithms are used to ensure impedance match to improve the efficiency of the solar panel in delivering its maximum power. In the source side a boost converter is connected to a solar panel in order to enhance the output voltage. By changing the duty cycle of the boost converter appropriately the source impedance is matched with that of the load impedance. As we have reviewed in Section III, several approaches have been proposed for tracking the MPP. One of the most widely used algorithms is the P&O algorithm.The P&O algorithm is used due to its simplicity and easy implementation. The operation of P&O consists in periodically perturbing the panel operating voltage incrementally,

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so that the power output can be observed and compared at consecutive perturbing cycles. If the power difference is positive, further perturbation is added to the operating voltage with the same increment, and again the output power is observed. This perturbing process is continued until the power difference becomes negative. Thus, the direction of perturbation in operating voltage must be reversed.When the OP is located on the left of MPP (Fig. 4), the P&O works by increasing V, which results in an increase in the power output. When the OP is on the right of the MPP, P&O will work in the opposite direction by decreasing V; this results in an increase in power output. If a perturbation produces an increase of power (dP/dV> 0), it means that the OP is moved closely towards the MPP. The subsequent perturbation must be kept in the same direction to bring the OP closer towards the MPP until it is reached.

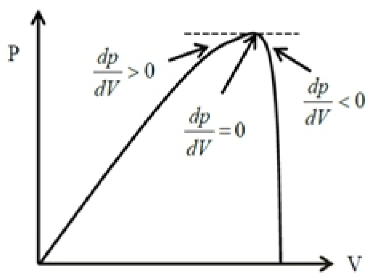

Fig. 4 The PV- characteristics of a PV module

Conversely, if a perturbation results in decrease of power (dP/dV<0), meaning that the OP has moved away from the MPP, the direction of the perturbation must be reversed. The P&O algorithm regulates the PV panel's voltage to the voltage corresponding to MPP. This MPP is tracked and updated to satisfy the mathematical equation of the power slope dP/dV=0. The slope dP/dV can be calculated digitally by sampling the PV panel output I and V at previous and current time intervals (n-1) and (n), as follows:

$$\frac{dP(n)}{dV(n)} = \frac{P(n)-P(n-1)}{V(n)-V(n-1)}$$

here P(n) is the power product of voltage V(n) and current I(n) measurements. The P&O algorithm works with only two sensors for measuring the panel's operating V and I.

IV.PROPOSED PV GENERATION SYSTEM:

The PV generators exhibit non-linear I-V characteristics. . On the other hand, the optimum operating point changes with the solar irradiation, and cell temperature [2].Therefore, online tracking of the maximum power point of a PV array is an essential part of any successful PV system. A variety of maximum power point tracking (MPPT) methods is developed in literature. For example, in [3] a MPPT is implemented with a boost converter the Incremental Conductance algorithm, is based on the principle that the slope of the PV array power curve is zero at the maximum power point. Dual boost converter based MPPT using fuzzy logic has been reported [4]. In order to extract the maximum amount of power from the PV generator, 'Perturb and observe' control method for the MPPT of a PV system under variable temperature and insulation conditions, is generally considered.

This method compares the PV output power before and after and adjusts the duty cycle of the switch control waveform for MPPT as a function of the evolution of the power input at the DC/DC boost converter. In this control system, it is necessary to measure the PV array output power and to change the duty cycle of the DC/DC converter control signal. This paper presents the analysis, modeling and control model of the electric part of a PV generation system connected to the induction drive system by a boost converter and DC/AC inverter.

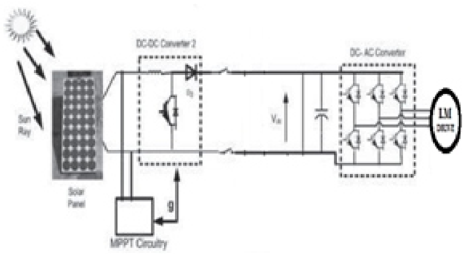

Fig. 5 Configuration of the grid-connected PV generation system

The penetration of renewable sources (particularly, solar power) in to the power system network has been increasing in the recent years. Load connected PV generator systems always a connection to the electrical network via a suitable inverter because a PV module delivers only DC power. Figure 6 is the configuration of the I.M drive-connected PV generation system. PV array is connected to the DC bus via a DC/DC boost converter, and then to the AC machine via a DC/AC inverter. The inverter has its independent control objective (boost inverter control PV generator to generate the maximum power and inverter control the active and reactive at AC bus to be constant).

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V Simulation Result of P V Module:

The simulation results of i-v curve and p-v curve of PV model for different solar irradiation and constant temperature (T=25°C) are shown in Fig.3.

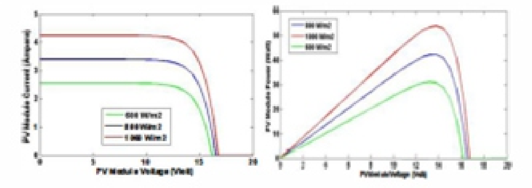

Fig 6. i-v Curve and p-v Curve for Different Solar Irradiance

From the above current & power curve for different solar irradiation and constant temperature, it can be observe that current & power of the PV module increases with increasing the solar irradiation from equation (1).The simulation results of i-v curve and p-v curve of PV model for constant solar irradiation (P = 800 W/m2) and different temperature are shown in Fig.4.

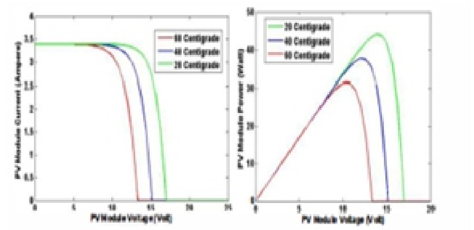

Fig 7. i-v Curve and p-v Curve for Different Cell Temperature

From the above it can be observe that voltage and power of the PV module decreases with increasing the cell temperature. Solar cell is a semiconductor device [8], if temperature increases voltage of the semiconductor device decreases, so voltage and power of the solar cell decreases.

VI.MODELING OF DC-DC CUK CONVERTER:

PV A generated voltage is fed to the converter and CUk converter output connected to the load. By varying the duty cycle the voltage gain of both Buck-Boost and CUk converters can be set higher or lesser than unity. Although the buck boost configuration is cheaper than the CUk but it has some limitations such as high peak and discontinuous input current, poor transient response and efficiency.

The Cuk converter has low switching losses and the highest efficiency among no isolated DC-DC converters. It can also provide a better output current characteristic due to the inductor on the output stage [3] [5]. The practical circuit of Cuk converter using diode and MOSFET are shown in Fig.5 [14] [15]. The Fig.6 represents the SIMULINK model of Cuk converter and its connection port is connected to PV A. The conversion ratio (M) is the relation between input and output voltage of CUk converter which is the function of Duty cycle as shown below:

$$M(\delta) = \frac{V_2}{V_g} = -\left(\frac{\delta}{1-\delta}\right) = -\left(\frac{T_{on}}{T_{off}}\right) \qquad (5)$$

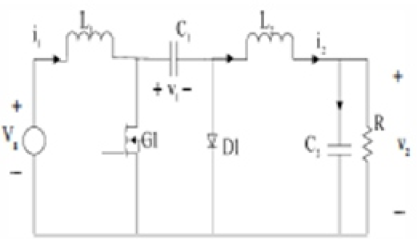

Fig 8. Cuk Converter Using Diode and MOSFET Switch

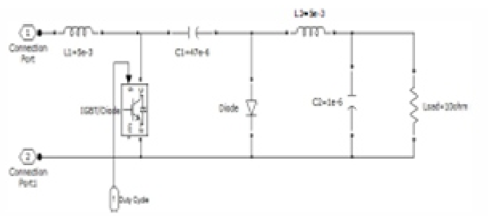

Fig 9. Simulation Circuit Diagram of Cuk Converter

$$\left.\begin{aligned} <v_{L1}> &= \delta V_g + \delta'(V_g - V_1) = 0 \\ <v_{L2}> &= \delta(V_1 - V_2) + \delta'(V_2) = 0 \\ <i_{C1}> &= \delta i_2 + \delta' i_1 = 0 \\ <i_{C2}> &= i_2 - \frac{V_2}{R} = 0 \end{aligned}\right\} \qquad (6)$$

Where $\delta' = \delta - 1$

VII. MAXIMUM POWER POINT ALGORITHM:

To improve the efficiency of the solar panel MPPT is used. According to maximum power point theorem, output power of any circuit can be maximize by adjusting source impedance equal to the load impedance, so the MPPT algorithm is equivalent to the problem of impedance matching. In present work, the Cuk Converter is used as impedance matching device between input and output by changing the duty cycle of the converter circuit.

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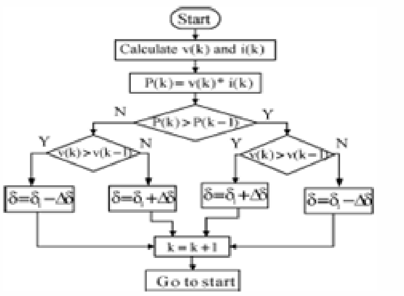
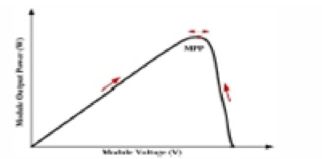
A major advantage of Cuk converter is that high or low voltage obtained from the available voltage according to the application. Output voltage of the converter is depend on the duty cycle, so MPPT is used to calculate the Duty cycle for obtain the maximum output voltage because if output voltage increases than power also increases. In this paper Perturb and Observe (P&O) and constant duty cycle techniques are used, because these require less hardware complexity and low-cost implementations.



1. Perturb & Observe MPPT Algorithm



Perturb & Observe (P & 0) MPPT Curve It is the simplest method of MPPT to implement. In this method only voltage is sensed, so it is easy to implement. In this method power output of system is checked by varying the supplied voltage. If on increasing the voltage, power is also increases then further 'b' is increased otherwise start decreasing the 'b'. Similarly, while decreasing voltage if power increases the duty cycle is decreased. These steps continue till maximum power point is reached. The corresponding voltage at which MPP is reached is known as reference point (Vrec)' The entire process P&O algorithm A PV A fed Cuk converter's duty cycle is generated through P&O algorithm in embedded system function block. The simulation results of output power of the PV A (input power to CUk converter) and CUk converter for different solar irradiance and constant temperature (T=30°C). for different temperature and constant solar irradiance (□=1000W/m2)

$$\frac{dp}{dv}=\frac{d(vi)}{dv}=0 \quad (7)$$

$$i+v\frac{di}{dv}=0 \quad (8)$$

Left hand side of MPPT

$$i+v\frac{di}{dv}>0 \quad (9)$$

Right hand side of MPPT:

$$i+v\frac{di}{dv}<0 \quad (10)$$

Flow chart for the IC MPPT algorithm and MPPT Curve is given below:

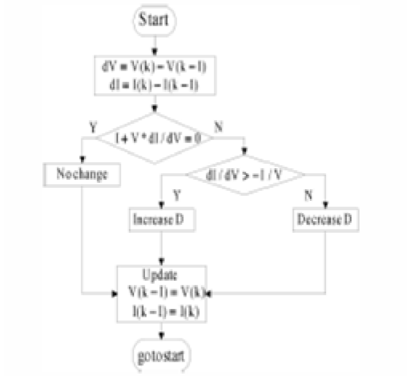


Figure12. Flow Chart ofTC MPPT Algorithm

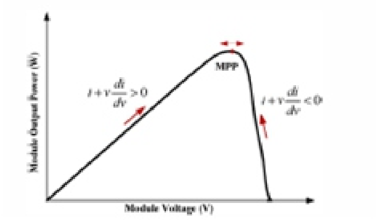


Fig 13. Incremental Conductance (IC) MPPT Curve

Figure H. Output Power Curve of the PV Module and Cuk Converter for Different temperature (T) using P&O MPPT Algorithm From the various simulation results for constant solar irradiance and different cell temperature it is clear that output power of the PV module and Cuk converter decreases with increasing temperature.

Incremental Conductance Algorithm:

In this method the slope of power curve is checked, if slope is positive with increase in voltage then duty cycle is continuously increased. Otherwise, i.e. if slope is negative duty cycle value that result reduction in voltage. In this method both current and voltage are required to be sensed.

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Hence the number of sensors is increased as well as this algorithm is based on mathematical equations. Therefore, IC algorithm for MPPT is more complex than P&O method.

VIII MATLAB/SIMULINK RESULTS:

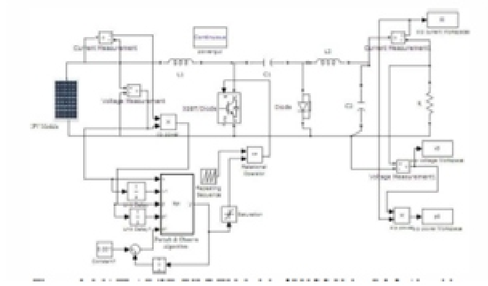

Figure 14. MATLAB/SIMULINK Model of PVCC Using P&O Algorithm 3. Simulation Result of PVCC Using Perturb & Observe (P&O) MPPT Algorithm

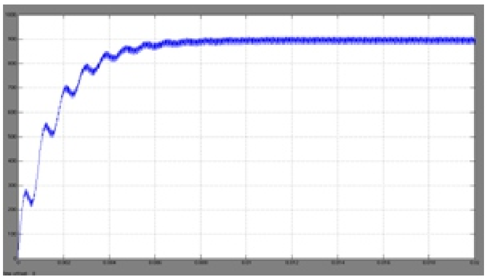

Fig15 : PV module power for 900 W/m^2 Solar Irradiance.

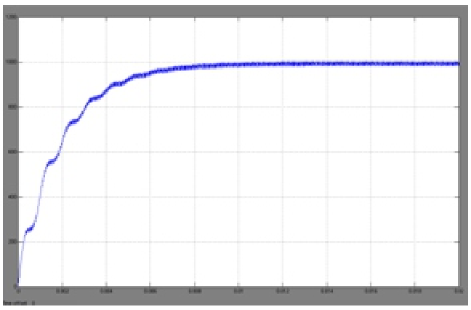

Fig 16: PV module power for 1000 W/m^2 Solar Irradiance.

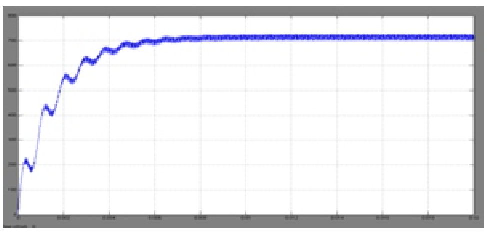

Fig 17 : PV module power for 700 W/m^2 Solar Irradiance. PV module power for Different Solar Irradiance.

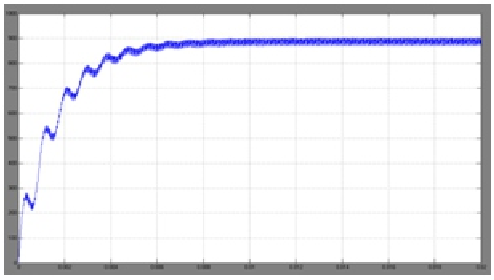

Fig. 18: pv module Curve for Cell Temperature T=20.

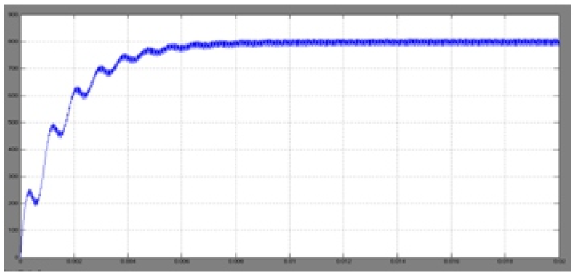

Fig. 19: pv module Curve for Cell Temperature T= 40.

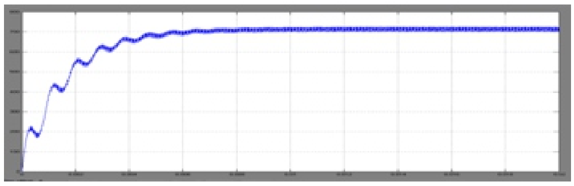

Fig.20: pv module Curve for Cell Temperature T= 60.

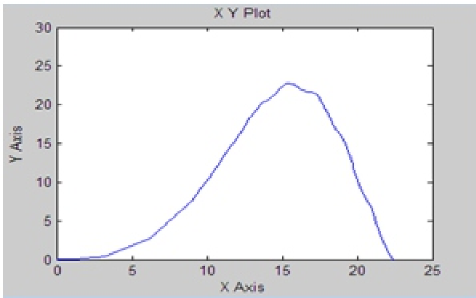

Fig 21: i- Curve 600 W/m^2 Solar Irradiance.

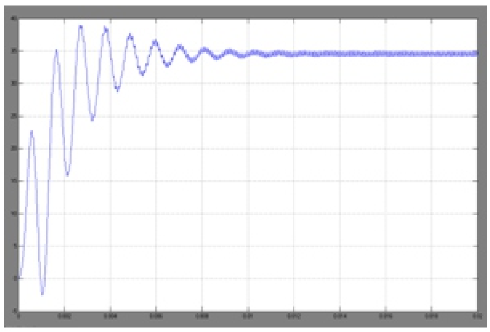

Fig 22: Output Power Curve of the PV Module for Constant δ = 0.6 and β=34.6.

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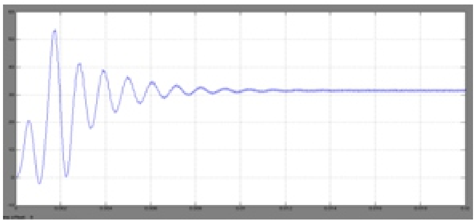

Fig 23: Output Power Curve of the PV Module for Constant δ = 0.6 and β=31.3.

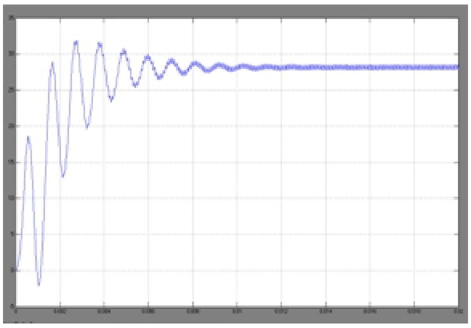

Fig 24: Output Power Curve of the PV Module for Constant δ = 0.6 and β=27.3.

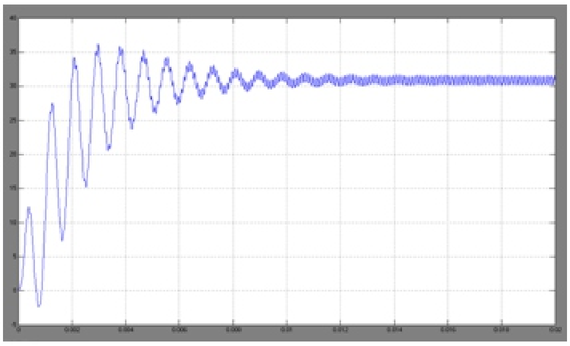

Fig 25: Output Power Curve of the PV Module and for Constant δ = 0.6 and T=31.3

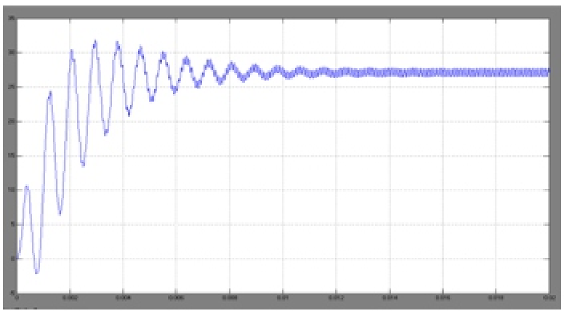

Fig 26: Output Power Curve of the PV Module for Constant δ = 0.6 and T=25.2

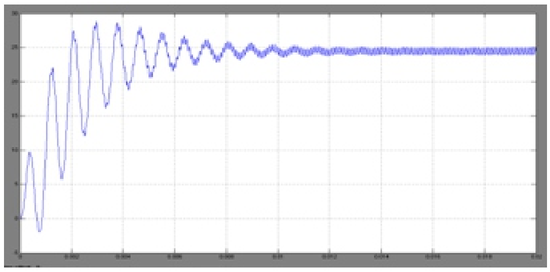

Fig 27: Output Power Curve of the PV Module for Constant δ = 0.6 and T=23.1

IX CONCLUSION;

In this paper, P&O and IC algorithm of MPPT is implemented using Cuk converter. The model is simulated with MA TLAB/SlMULINK. It is shown that PV system output power increases with rise in solar irradiance and fall in cell temperature. Therefore, solar cell performance better in winter season than summer. Implementation of P&O MPPT is easier, its tracking system is easy to implement whereas the IC gives more accurate value of power but its implementation is sometimes more complex. Therefore, exact tracking of MPP IC method is used.

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