SIMULINK Model of PV array with MPPT using Cuk converter

Ramyaka Sammangi, Raghunadha Sastry R, Sambasiva Rao N

Abstract— solar energy is most useful for sustainable development. The efficiency of Photovoltaic array will be maximum if it is operated at maximum power point (MPP). The output of Photovoltaic array is depends on temperature and irradiation levels so it is difficult to track MPP.Maximum Power Point Tracker (MPPT) is an algorithmic technique that tracks MPP and force the PV array to operate at its maximum power point. In this paper we focuses on improving Perturb and Observe (P&O) and Incremental Conductance method of MPPT techniques by eliminating its drawbacks like oscillations at maximum power point, complexity . A general model of Photovoltaic system with proposed MPPT controller and Cuk converter is implemented on Matlab and a comparision between proposed P&O and Incremental Conductance MPPT techniques under constant and variable irradiation levels is done, which proves that Incremental Conductance MPPT algorithm is robust and efficient for changing irradiation conditions and P&O is simple and efficient technique for constant irradiation condition.

Index Terms— Cuk converter, Incremental Conductance (IC), Irradiation, Maximum Power Point Tracker (MPPT), Photovoltaic array (PV array), Perturb & Observe (P&O), Photovoltaic array, Temperature.

1 INTRODUCTION

One of the major problems in the power sector is unbalance in supply and demand due to the depletion of conventional energy resources.Usage of fossil fuels causes serious environmental pollution. So focus is increased towards the utilisation of renewable energy. Thus the growing demand on electricity, the limited stock and rising prices of conventional sources such as coal, petroleum etc has led to the use of renewable energy sources.

The solar has advantages like less operational and maintenance cost, bulk availability and ecofriendliness.With all its advantages solar is gaining more attention.

The solar efficiency is increased by tracking its MPP and using MPPT algorithm this can be achieved. A number of algorithms are developed to track the maximum power point efficiently. Among all MPPT methods, Perturb and Observe (P&O) method and Incremental Conductance method are the most used MPPT algorithms.

The proposed topology consists of control strategy of interconnection between photovoltaic array with MMPT and Cuk converter to load as shown in below figure 1. The power Injected from PV panel to load through two stages. In the first stage PV array is connected to Cuk converter in order to improve the dc voltage level of PV panel and it is used to set the PV operating point at maximum through MPPT Controller.

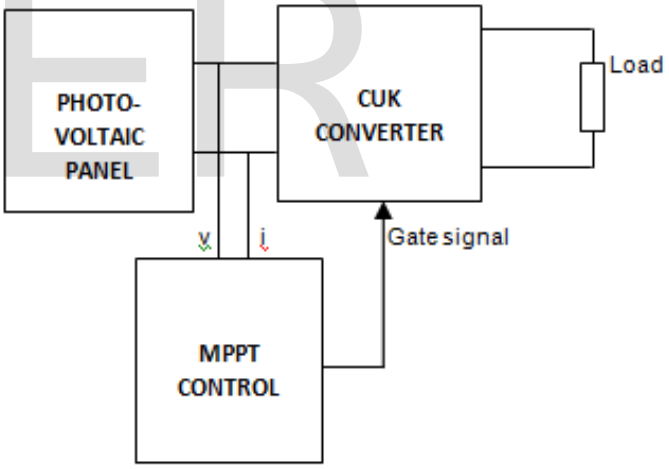

Fig1: Block diagram of PV array connected to load

Finally, in the second stage the dc power from the Cuk converter is connected to load. This proposed topology is simulated in MATLAB/SIMULINK.

2 PV CELL AND ITS CHARACTERISTICS

2.1 PV CELL

PV cell works under the principle of Photovoltaic Effect. Photovoltaic Arrays are formed by combinations of series and parallel connection of PV solar cells. A simple solar cell equivalent circuit model is shown in below figure 2a.

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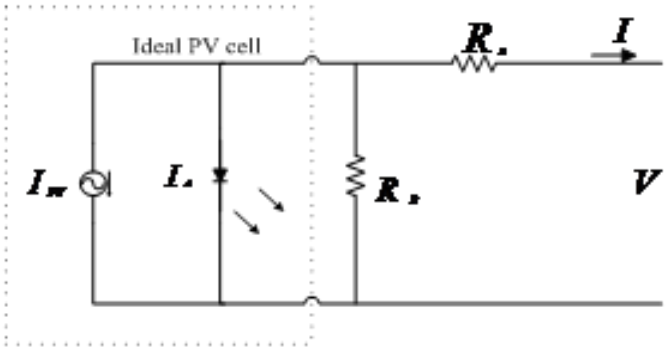


Fig 2a: Equivalent circuit of PV Cell

$$I=n_p I_{ph} - n_p I_{rs} [\exp (k_o(v/n_s))-1]$$

Where I is the PV array output current, V is the PV output voltage, I_{ph} is the cell photocurrent that is proportional to solar irradiation, n_s represents the number of PV cells Connected in series and n_p represents the number of such strings connected in parallel.

$$I_{ph} = [I_{scr} + k_i (T-T_r)] \frac{s}{100}$$

I_{scr} is the cell short-circuit current at reference temperature and radiation,

k_i is short circuit current temperature coefficient,

T is the Nominal Temperature i.e 295.15K (25C)

T_r is the cell reference temperature,

S is solar irradiation in $\frac{W}{cm^2}$

I_{rs} is the cell reverse saturation current that mainly depends on the temperature, K is a constant.

$$I_{rs} = I_{rr} \left[\frac{T}{T_r}\right]^3 \exp\left(\frac{qE_G}{kA}\left[\frac{1}{T_r} - \frac{1}{T}\right]\right)$$

I_{rr} is the reverse saturation at T_r

E_G is the band-gap energy of the semiconductor used in the cell.

A is the area of photovoltaic cell.

k is Bolttzmann constant i.e.

$1.3806503*10^{-23}$jouls/kelvin

q is electron charge i.e. $1.607*10^{-19}$c

2.2 CHARACTERISTICS OF PV CELL

The performance characteristics of a PV Module depend on its basic materials, manufacturing technology and operating conditions. Short circuit point (I_{sc}), Maximum power point (I_{mpp} and V_{mpp}) and Open circuit point (V_{oc}) are the three important points of these curves. The I-V curve is obtained by controlling the load current.. By increasing the load current from zero to its maximum value, the operating point moves from open circuit voltage at zero current to the shot circuit current at zero voltage. The series of all the measured pairs yields the I-V characteristic curve of module.

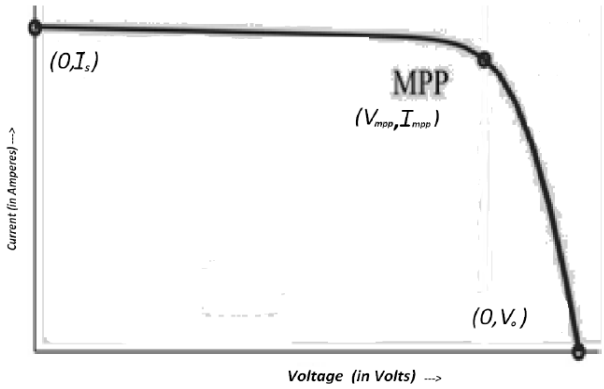


Fig 2b: PV Array Characteristics V (X axis) Vs I (Y axis)

An increase in solar radiation causes the output current to increase and the horizontal part of the curve moves upward.

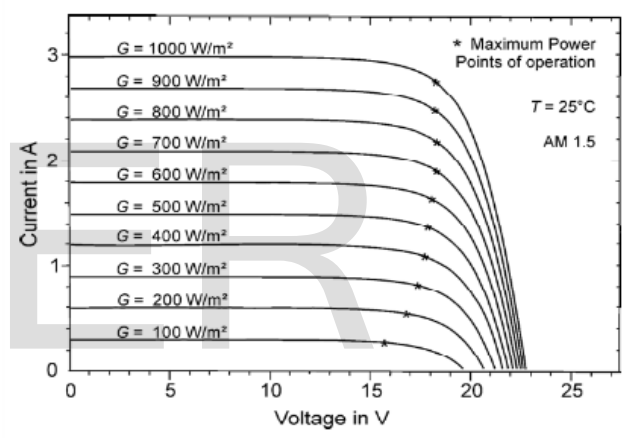


Fig 2c: Characteristics of PV Array with Variation of Insolation

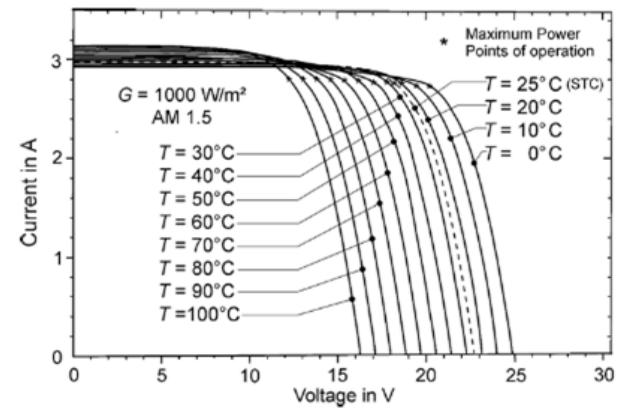


Fig 2d: Characteristics of PV Array incorporating effect of Temperature

An increase in cell temperature causes the voltage to move leftward, while decreasing temperature produces the opposite effect. Thus, the I-V curves display how a photovoltaic module responds to all possible loads under different solar radiation and cell temperature conditions. The maximum power points the line which is positioned at the knees of the I-V curves, has a nearly constant output voltage at varying solar radiation conditions.

3 Maximum Power Point Tracking

Practically the efficiency of solar cell is very less nearly 15%. Maximum power point tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer theorem the power output of a circuit is maximumwhen the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence the problem of tracking the maximum power point reduces to an impedance matching problem. So, for tracking that MPP, MPPT algorithm is using.

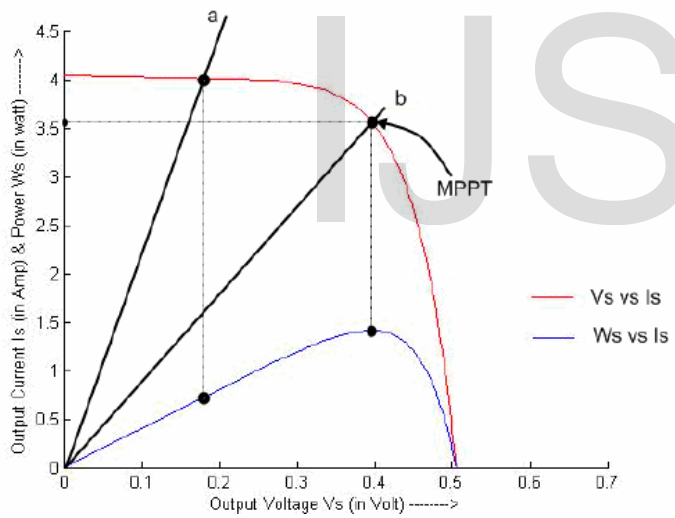


Fig3a: Operating Point of PVA

3.1 Peturb and Observe method

In P&O method, the operating voltage is sampled and the algorithm changes the operating voltage in the required direction. The iteration is continued until the algorithm finally reaches the MPP. This technique is simple to implement but the major drawback is the occasional deviation from th maximum operating point in case of rapidly changing atmospheric conditions.

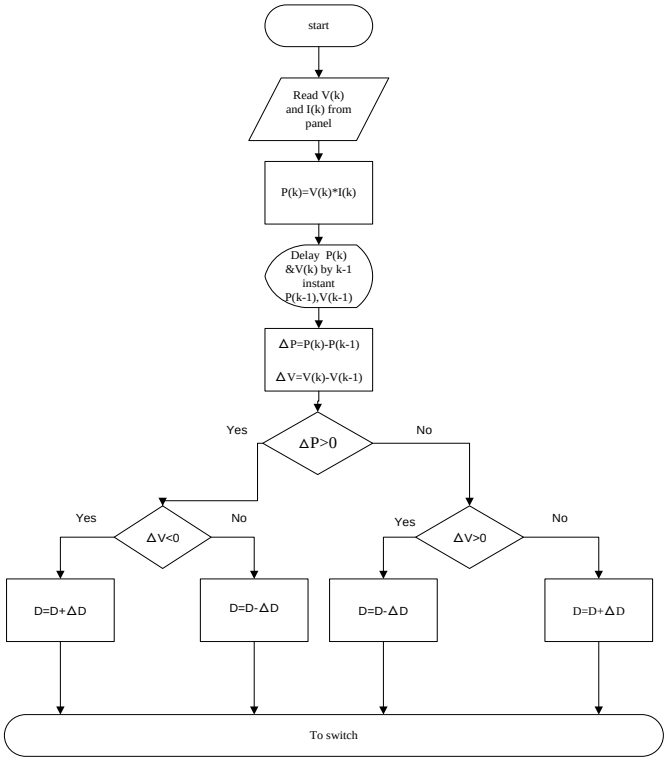


Fig3b: flow chart of P&O Method

3.2 Incremental Conductance method

The Incremental Conductance (Inc-Cond) algorithm is based on the fact that the slope of the curve power vs. Voltage (current) of the PV module is zero at the MPP, positive (negative). on the left of it and negative (positive) on the right. This method tracks rapidly under varying irradiation conditions. It is more accurate than P&O method. It requires complex and costly control circuits.

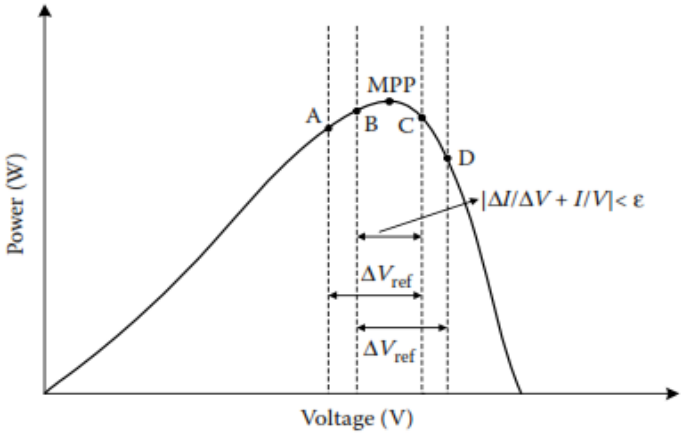


Fig 3c: IC method on a P-V curve of a solar module

From the P –V curve by comparing the conductance at each sampling time, the MPPT will track the maximum power

of the PV module. The flow chart of IC method shown in below figure. It makes use of instantaneous and incremental conductance to generate an error signal which is zero at MPP; however it is not zero at most of the operating points, but it make the error from the MPPs near to zero.

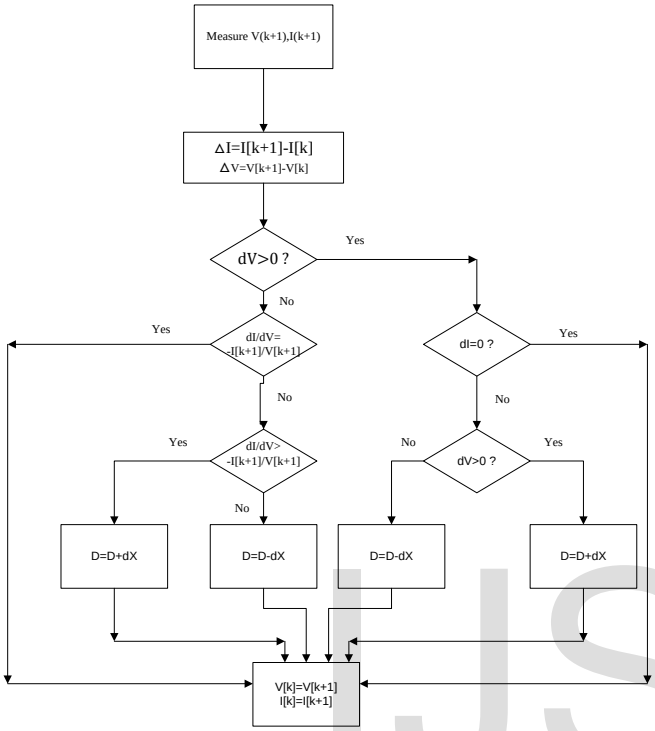


Fig 3d: Flow chart of IC method

The IC method is more efficient and accurate than PO method. Also, it is good and adjusts the module voltage automatically without any oscillations to rapidly changing atmospheric conditions and esy lo locate the maximum power point. But, the IC method is more complex and costly when compared to P&O method. These are the main differences between IC and P&O methods.

4 CUK CONVERTER

The fundamental power conversion unit of Photovoltaic system is solar cell. The basic operation of a solar cell is characterized by its I-V curve.Through this experimental measurement precision of electrical parameters of a PV cell, module or array can be made. This measure gives information for the design, installation and maintenance of photovoltaic systems. The experimental measure of the I-V characteristic curve can be performed using DC-DC converters in Continuous Conduction Mode (CCM). The switching power of DC-DC converters are widely used in photovoltaic systems to transform DC power from a voltage level to another, and for tracking the maximum power point (MPPT).

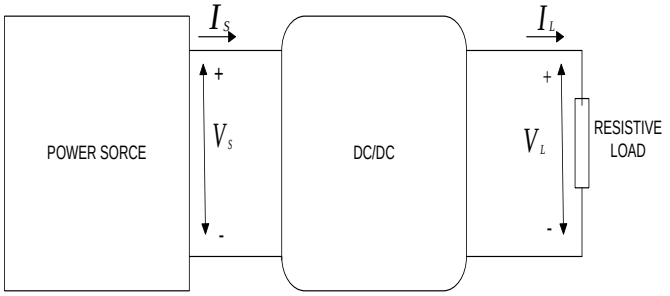


Fig 4: Converter acting as maximum power point tracker

When proposing an MPPT choosing a converter with high efficiency is the main thing as its output voltage is also one of the factor that helps to note the efficiency of PV system.

Converter in the MPPT system is to maximize the input of DC voltage. In term of maximized the output voltage by step up or step down the input voltage the cuk converter is ideally to be choose in the MPPT design compared to the Buck converter, Boost converter because cuk converter has low switching losses and highest efficiency among non-isolated DC-DC converters. It also can provide a better input and output current characteristic due to the inductor on the both input and output stage.

5 SIMULATION RESULTS

Fig gives the detailed simulink model of PV system and accepts irradiance and temperature as variable parameters and outputs the I-V characteristic and P-V characteristic

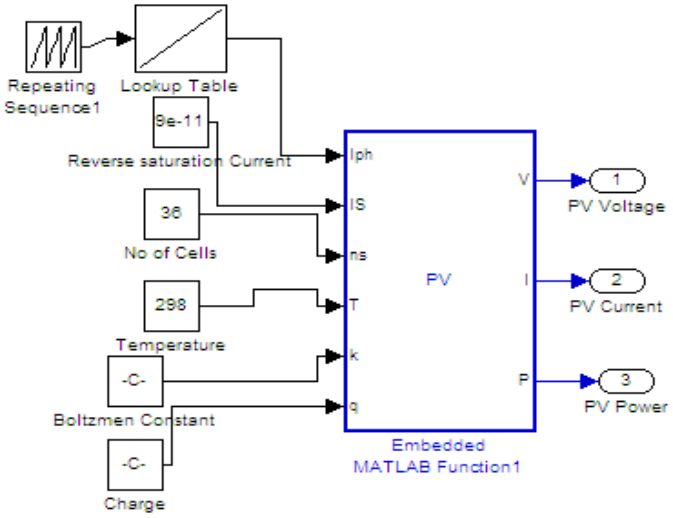


Fig 5a: Simulink model of PV module for change in irradiation

The I-V characteristisc of photo voltaic sysytem strongly depends on irradiation nd temperature. The beloe figure shows the simulation results of PV array for different values of irradiation and temperature.

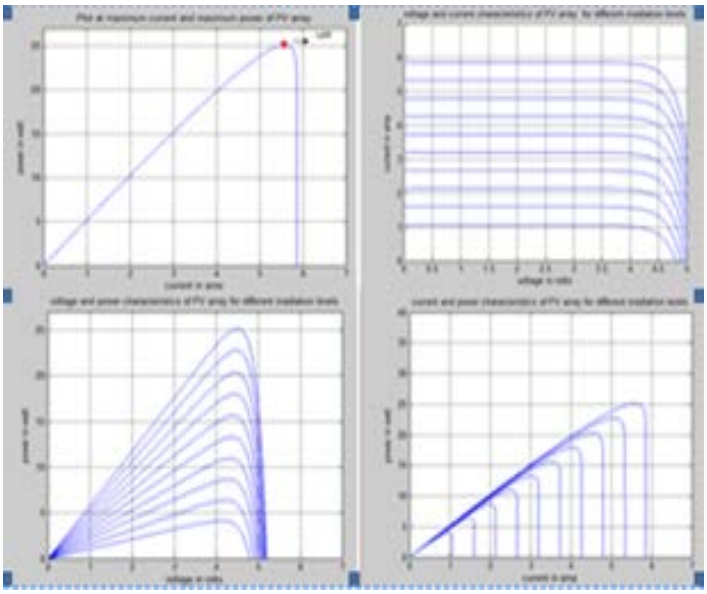


Fig 5b: PV Array characteristics

5.1 MODIFIED P&O AND IC METHODCUK CONVERTER

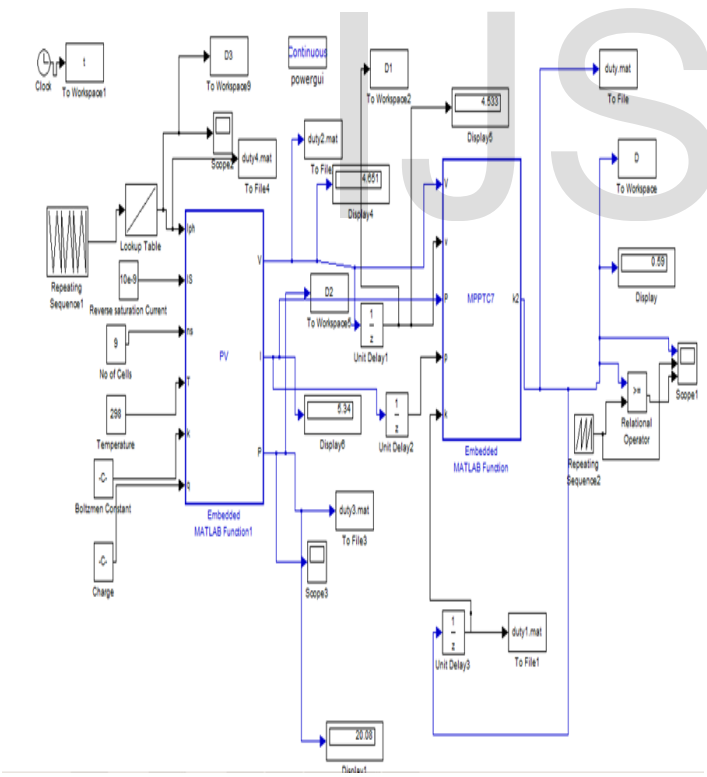


Fig 5c: Simulink model of MPPT

First irradiation level is 1000w/m²; at t=0.1s second irradiation level suddenly changes to 600w/m² and then back to 1000w/m² at t=0.3s. The step size of duty cycle is chosen to be 0.02 so the converter can smoothly track the MPP.

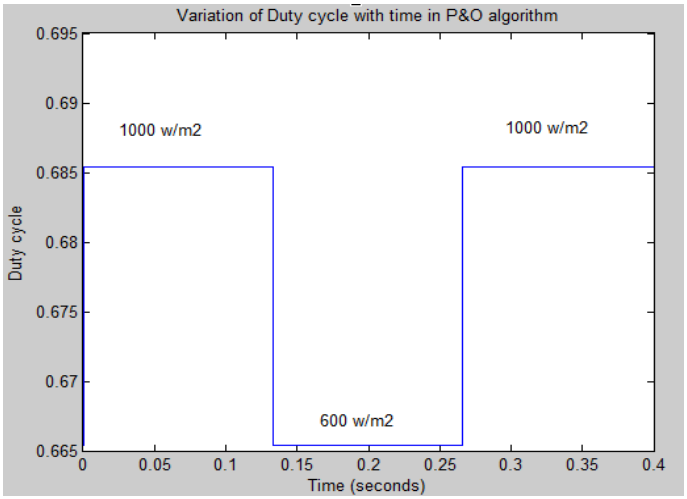
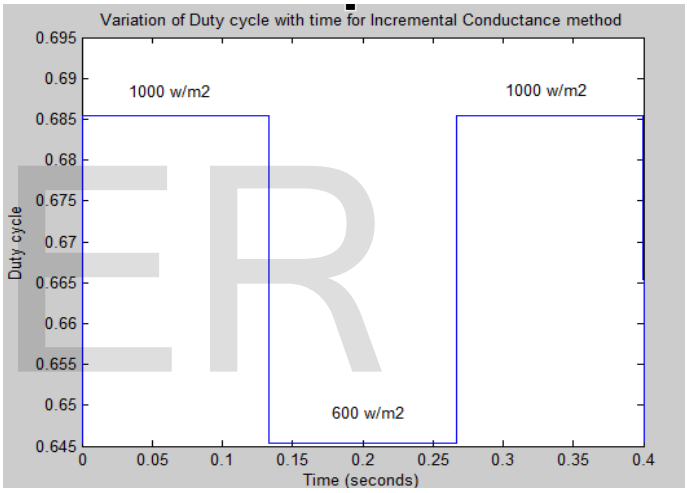


Fig 5d: Plot showing the varying duty ratio with time for Perturb and Observe MPPT algorithm



Fi 5e:. Plot showing the varying duty ratio with time for Incremental Conductance MPPT algorithm

The above figure shows the change in duty cycle adjusted by MPPT Controller to extract maximum power from the module for P&O and Incremental Conductance MPPT techniques.

5.2 P&O AND IC WITH CUK CONVERTER

The duty ratio is adjusted by MPPT controller so that PV system will always work near MPP (Maximum Power Point) and the adjusted ratio is given to the Cuk converter. Initially duty ratio D = 0.6654. Simulation of the modified P&O and Incremental Conductance method in combination with Cuk converter under stable environmental conditions was done. The MPPT manages to adjust the duty ratio D very quickly such that a stable power output is reached. After this point the output power does not change any further since the solar panel operates under constant conditions.

Fig 5f: SIMULINK diagram of Cuk converter

The MPPT, however, continues to readjust the duty ratio D and herefore prevents a deviation from the optimum operating point.

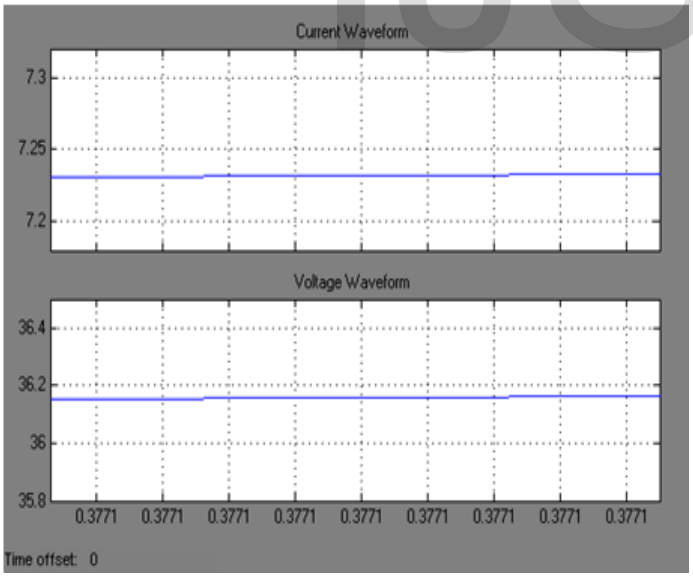


Fig 5g: Current and Voltage waveforms of Cuk converter for Perturb &Observe MPPT Controller

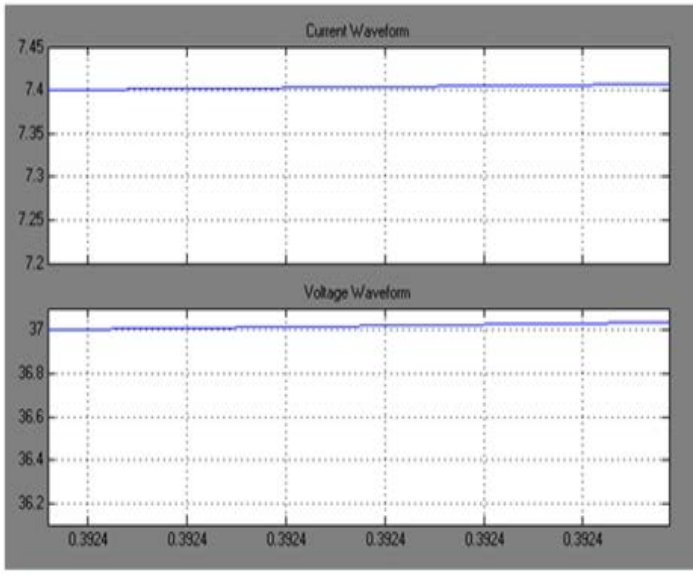


Fig 5h: Current and Voltage waveforms of Cuk converter for Incremental Conductance MPPT Controller

The above two figures represents the output voltage and current waveforms of Cuk converter with modified P&O and Incremental Conductance MPPT controllers.

6 Conclusion

Finally we conclude that the system developed is capable of extracting maximum power from the photovoltaic module at the same time providing a regulated DC supply. The proposed PV system and MPPT was simulated. The Incremental Conductance method is more efficient compare to all MPPT methods because panel terminal voltage is changed according to its value relative to the MPP voltage and it offers good performance under rapidly changing atmospheric conditions. On the other hand, cuk converter has low switching losses and highest efficiency among all non-isolated DC-DC converters. It also provides a better input and output current characteristic due to the inductor on both input and output stage. Thus cuk converter configuration is a proper choice to be employed in designing the MPPT. MPPT techniques are applied on various PV applications such as space satellite, solar vehicles and solar water pumping etc.

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