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ANALYSIS OF MAXIMUM POWER POINT TRACKING FOR PHOTOVOLTAIC POWER SYSTEM USING CUK CONVERTER

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ABSTRACT
The maximum power point tracking algorithum is used to track maximum power from PV cell. The incremental conductance algorithm is easy method and works better than other maximum power point tracking algorithm. The cuk converter gives good performance among various types of DC to DC converters for a PV system. It can also provide a better output current characteristic due to the inductor on the output stage. A fixed-step-size incremental conductance MPPT with direct control method is employed and necessity of another control loop is eliminated. MATLAB and simulink will be employed for simulation and analysis of the DC-DC converter for PV power system using incremental conductance technique.

KEYWORDS: Photovoltanic module, Incremental conductance (IncCond), Maximum Power Point Tracking (MPPT),cuk converter.

INTRODUCTION
One of the major concerns in the power sector is the day to day increasing power demand but the unavailability of enough resources to meet the power demand using the conventional energy sources. Demand has increased for renewable sources of energy to be utilized along with conventional systems to meet the energy demand. Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike dwindling conventional fossil fuels. The continuous use of fossil fuels has caused the fossil fuel deposit to be reduced and has drastically affected the environment depleting the biosphere and cumulatively adding to global warming.
Solar energy is abundantly available that has made it possible to harvest it and utilize it properly. Solar energy can be a standalone generating unit or can be a grid connected generating unit depending on the availability of a grid nearby. Thus it can be used to power rural areas where the availability of grids is very low. Another advantage of using solar energy is the portable operation whenever wherever necessary.
In order to tackle the present energy crisis one has to develop an efficient manner in which power has to be extracted from the incoming solar radiation. The power conversion mechanisms have been greatly reduced in size in the past few years. The development in power electronics and material science has helped engineers to come up very small but powerful systems to withstand the high power demand. But the disadvantage of these systems is the increased power density. The use of the newest power control mechanisms called the Maximum Power Point Tracking (MPPT) algorithms has led to the increase in the efficiency of operation of the solar modules and thus is effective in the field of utilization of renewable sources of energy.
Maximum power point tracking technique is used to improve the efficiency of the solar panel. A MPPT is used for extracting the maximum power from the solar photovoltaic (PV) module and transferring that power to the load. MPPT is an electronic system that operates the 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. The Power point tracker is a looks at the output of the panels, and compares it to the battery voltage. It then figures out what is the

best power that the panel can put out to charge the battery. Most modern MPPT's are around 93-97% efficient in the conversion.

MATERIALS AND METHODS

Photovoltaic Module

The basic structural unit of a photovoltaic module is the PV cells. A PV cell is a semiconductor device that converts light energy to electrical energy by photovoltaic effect. If the energy of photon (light) is greater than the band gap then the electron is emitted and the flow of electrons creates current. However a PV cell is different from a photo-diode. In a photodiode light falls on the n-channel of the semiconductor junction and it gets converted into current or voltage signal but a PV cell is always forward biased. Usually a number of PV modules are arranged in series and parallel to meet the requirements of energy. PV modules of different sizes are commercially available (mostly sized from 60W to 170W).

PV Modeling

A PV array consists of several PV cells in series and parallel connections. It is the combination of many PV modules. Parallel connections are responsible for increasing the current of the module whereas the series connection is responsible for increasing the voltage in the array. A solar cell can be modeled by a current source and an diode which is inverted is connected in parallel to it. It has its allowable series and parallel resistance. Series resistance is due to the blocking in the path of flow of electrons from n junction to p junction and parallel resistance is due to the leakage current.

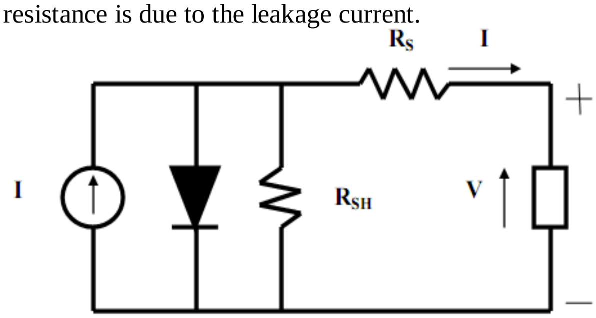

Fig 1: Single diode model of a PV cell

The output current from the PV array is

$$I = I_{sc} - I_d \quad (1)$$

$$I_d = I_o\,(eqV_d/kT - 1) \quad (2)$$

Where, I_o is the reverse saturation current of the diode, q is the electron charge, V_d is the voltage across the diode, k is Boltzmann constant (1.38 * 10-19 J/K) and T is the junction temperature in Kelvin (K).

From equation 1 and equation 2

$$I = I_{sc} - I_o\,(eqV_d/kT - 1) \quad (3)$$

By suitable approximations,

$$I = I_{sc} - I_o\,(eq((V+IR_s)/nkT) - 1) \quad (4)$$

Where, I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature (in Kelvin) and n is the diode ideality factor.

In this paper PV model is built and implemented using MATLAB/SIMULINK to verify the output characteristics of the PV module. In this model, the inputs are the solar irradiation and cell temperature; the outputs are the photovoltaic voltage and current.

MPPT Technique

According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence the maximum power point tracking reduces to an impedance matching problem. In the source side we are using a boost convertor connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By changing the duty cycle of the boost converter appropriately we can match the source impedance with that of the load impedance.

Incremental Conductance Method

The incremental conductance 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.

The method is based on the principle that the slope of the PV array power curve is zero at the maximum power point. (dP/dV) = 0. Since (P = VI), it yields:

$$\Delta I/\Delta V = -I/V \text{, at MPP} \quad (5)$$

$$\Delta I/\Delta V > -I/V \text{, left of MPP} \quad (6)$$

$$\Delta I/\Delta V < -I/V \text{, right of MPP} \quad (7)$$

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The MPP can be tracked by comparing the instantaneous conductance (I/V) to the incremental conductance (ΔI/ΔV). The algorithm increments or decrement the array reference voltage until the condition of equation (5) is satisfied. Once the Maximum power is reached, the operation of the PV array is maintained at this point. This method requires high sampling rates and fast calculations of the power slope.

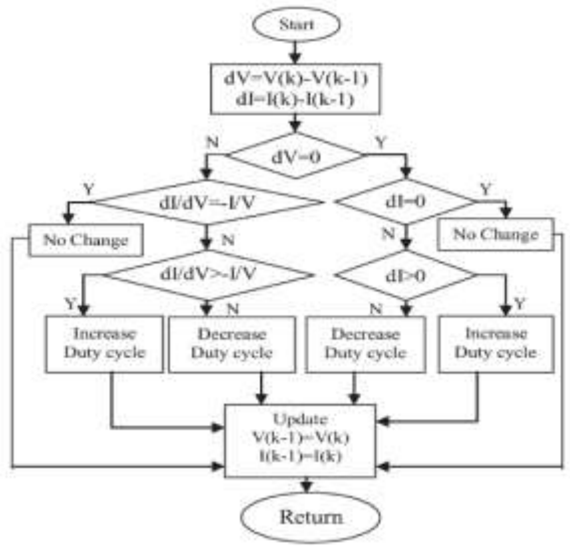

Fig. 2 Flow chart of Incremental Conductance technique

CUK CONVERTER

The maximum power point tracking is basically a load matching problem. In order to change the input resistance of the panel to match the load resistance (by varying the duty cycle), a DC to DC converter is required.

The main applications of this circuit are in regulated dc power supplies, where a negative polarity output may be desired with respect to the common terminals of the input voltage and the average output is either higher or lower than the dc input voltage. The typical schematic circuit for the Cuk Converter is as shown in Fig. 6. The capacitor C1 acts as a primary means to store and transfer the power from input to output. The voltage vc1 is always greater than either input or output voltage. The average output to input relations are similar to that of a buck-boost converter circuit.

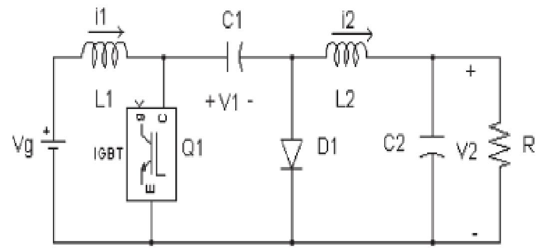

Fig.3 Circuit Diagram of a Cuk Converter

The output voltage is controlled by controlling the switch-duty cycle. The ratio of output voltage to input voltage is given by:

$$V_0 = (D / 1\text{-}D)\ V_s \text{ Volts} \qquad (8)$$

where, V_0 = Converter Output Voltage, Volts
V_s = Converter input voltage, volts
D = Duty Cycle (t_{on} / T)

RESULTS AND DISCUSSION

The Simulink model used for the implementation of the required solar cell and cuk converter systems. From the analysis of different MPPT algorithms it was clear that incremental conductance method is easy method and works better than other maximum power point tracking algorithm.

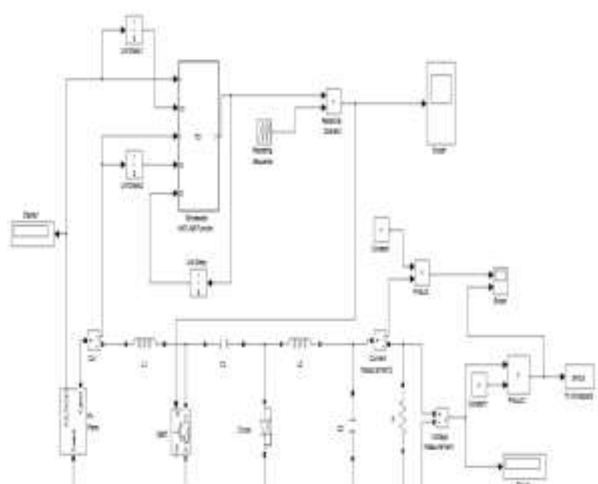

Fig.4 PV System with Incremental Conductance Method

The PV panel output current and voltage curve and power vs voltage curve given in figure 5.

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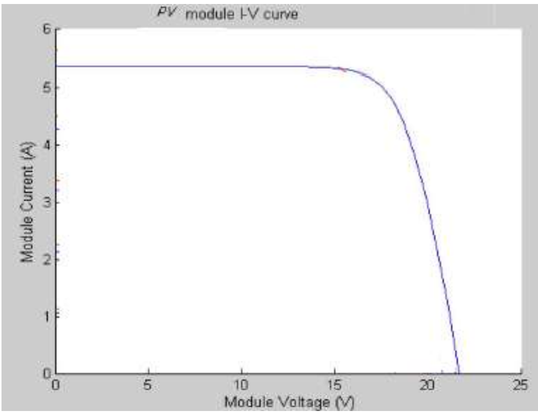
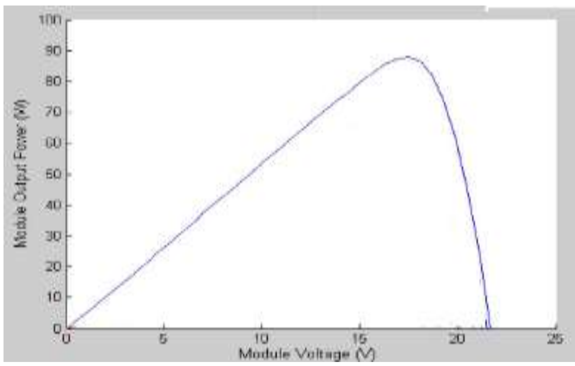


(a)



(b)

Fig.5(a) I-V Characteristics (b)PV Curve of PV Module

Table 1. Electrical Parameter of PV Module

Parameter	Symbol	Value
Maximum Power	*Pmax*	87W
Voltage at MPP	Vmax	17.4V
Current at MPP	Imax	5.02A
Short Circuit Voltage	Vsc	21.7V
Open Circuit Current	Ioc	5.34A

The output from PV system is DC. The DC output is given to the Cuk Converter. The outputs obtained from Incremental Conductance Method eliminate the limitations of Perturb & Observe Method.

The components for the Cuk converter used in simulation were selected as follows:
1) Input inductor L1 = 5 mH;
2) Capacitor C1 (PV side) = 47 μf;
3) Filter inductor L2 = 5 mH;
4) Switch: insulated-gate bipolar transistor [(IGBT)];
5) Freewheeling diode;
6) Capacitor C2 (filter side) = 1 μF;
7) Resistive load = 10 Ω;
8) Switching frequency = 10 kHz;

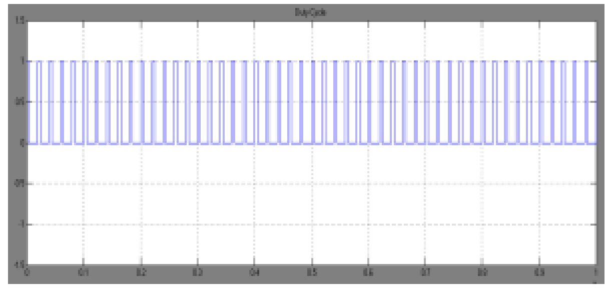


Fig.6. Output Waveform of Duty Cycle

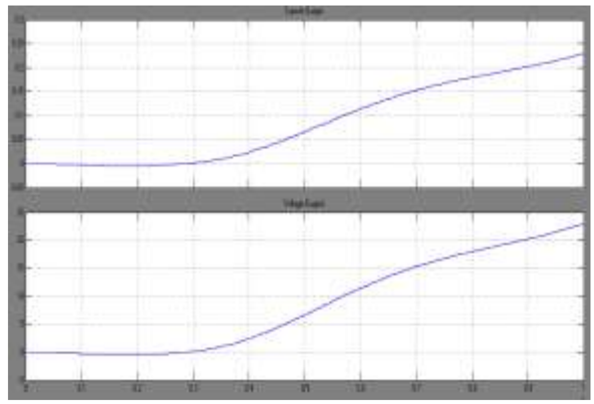


Fig.7 Output Current and Votage Waveform of Cuk Converter

The output from PV system is DC. The DC output is given to the Cuk Converter. The DC output voltage from solar and cuk is having a magnitude of 24.7V.

CONCLUSION

In this paper, a fixed step size Incremental Conductance MPPT with direct control method was employed, and the necessity of another control loop was eliminated. The entire energy conversion system has been designed in MATLB Simulink environment. From the results acquired during the simulations, it was confirmed that, with a well-designed system including a proper converter and selecting an efficient and proven algorithm, the implementation of MPPT is simple and can be easily constructed to achieve an acceptable efficiency level around 93-97% of the PV modules.

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