IMPLEMENTATION OF INCREMENTAL CONDUCTANCE (MPPT) TECHNIQUE FOR PV SYSTEM

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Abstract: *This project investigates in detail the concept of Maximum Power Point Tracking (MPPT) which significantly increases the efficiency of the solar photovoltaic system. The project proposes a simple MPPT algorithm is called Incremental conductance Method. This method computes the maximum power and controls directly the extracted power from the PV. The proposed method offers different advantages which are: good tracking efficiency, response is high and well control for the extracted power. The resultant system is capable of tracking MPPs accurately and rapidly without steady-state oscillation, and also, its dynamic performance is satisfactory. First the photovoltaic module is analyzed using SIMULINK software. The main aim will be to track the maximum power point of the photovoltaic module so that the maximum possible power can be extracted from the photovoltaic. For the main aim of the project Maximum Power Point Tracking control mechanism is used. Modeling the converter and the solar cell in Simulink and interfacing both with the MPPT algorithm to obtain the maximum power point operation would be of prime importance A MPPT plays a very vital role for extracting the maximum power from the solar PV module and transferring that power to the load. Modeling the converter and the solar cell in Simulink and interfacing both with the MPPT algorithm to obtain the maximum power point operation would be of prime importance.*

Keywords: *maximum power point tracking, photovoltaic cell, cuk converter, buk converter*

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I. INTRODUCTION

Global warming and energy policies have become a hot topic on the international agenda in the last years. Developed countries are trying to reduce their greenhouse gas emissions. For example, the EU has committed to reduce the emissions of greenhouse gas to at least 20% below 1990 levels and to produce no less than 20% of its energy consumption from renewable sources by 2020 [1]. In this context, photovoltaic (PV) power generation has an important role to play due to the fact that it is a green source. The only emissions associated with PV power generation are those from the production of its components. After their installation they generate electricity from the solar irradiation without emitting greenhouse gases.

Tracking the maximum power point (MPP) of a photovoltaic (PV) array is usually an essential part of a PV system. Renewable sources of energy acquire growing importance due to its enormous consumption and exhaustion of fossil fuel. Also, solar energy is the most readily available source of energy and it is free. The rapid increase in the demand for electricity and the recent change in the environmental conditions such as global warming led to a need for a new source of energy that is cheaper and sustainable with less carbon emissions. Solar energy has offered promising results in the quest of finding the solution to the problem. A great deal of research has been done to improve the efficiency of the PV modules. A number of methods of how to track the maximum power point of a PV module have been proposed to solve the problem of efficiency and products using these methods have been manufactured and are now commercially available for consumers [5-7]. A MPPT is used for extracting the maximum power from the solar PV module and transferring that power to the load [2-3].

A dc/dc converter (step up/ step down) serves the purpose of transferring maximum power from the solar PV module to the load. A dc/dc converter acts as an interface between the load [3]. By changing the duty cycle the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power [3]. This manuscript steps through a wide variety of methods with a brief discussion and categorization of each. We have avoided discussing slight modifications of existing methods as distinct methods. Therefore MPPT techniques are needed to maintain the PV array's operating at its MPP [17]. Many MPPT techniques have been proposed in the literature; examples are the Perturb and Observe (P&O) methods, Incremental Conductance (IC) methods, Fuzzy Logic Method etc.

II. PV CELL MODELING

The solar cell is the basic unit of a PV system. An individual solar cell produces direct current and power typically between 1 and 2 W, hardly enough to power most applications. Solar Cell or Photovoltaic (PV) cell is a device that is made up of semiconductor materials such as silicon, gallium arsenide and cadmium telluride, etc. that converts sunlight directly into electricity. The voltage of a solar cell does not depend strongly on the solar irradiance but depends primarily on the cell temperature. PV modules can be designed to operate at different voltages by connecting solar cells in series. When solar cells absorb sunlight, free electrons and holes are created at positive/negative junctions. If the positive and negative junctions of solar cell are connected to DC electrical equipment, current is delivered to operate the electrical equipment.

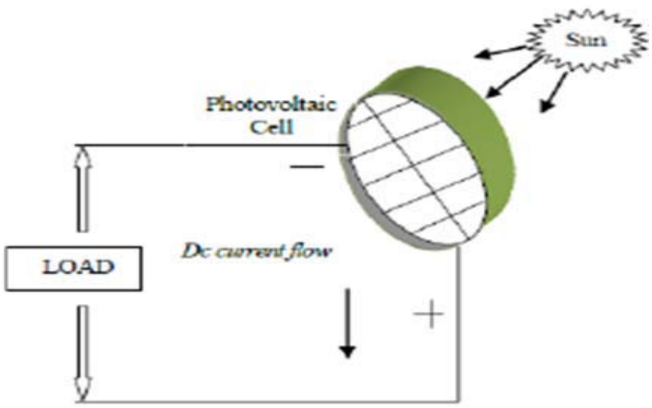

Fig 1: PV Cell

The positive and negative charges created by the absorption of photons are thus encouraged to drift to the front and back of the solar cell. The back is completely covered by a metallic contact to remove the charges to the electric load. The collection of charges from the front of the cell is aided by a fine grid of narrow metallic fingers. [5]The p-n junction provides an electrical field that sweeps the electrons in one direction and the positive holes in the other. If the junction is in thermodynamic equilibrium, then the Fermi energy must be uniform throughout. Since the Fermi level is near the top of the gap of an n-doped material and near the bottom of the p-doped side, an electric field must exist at the junction providing the charge separation function of the cell.

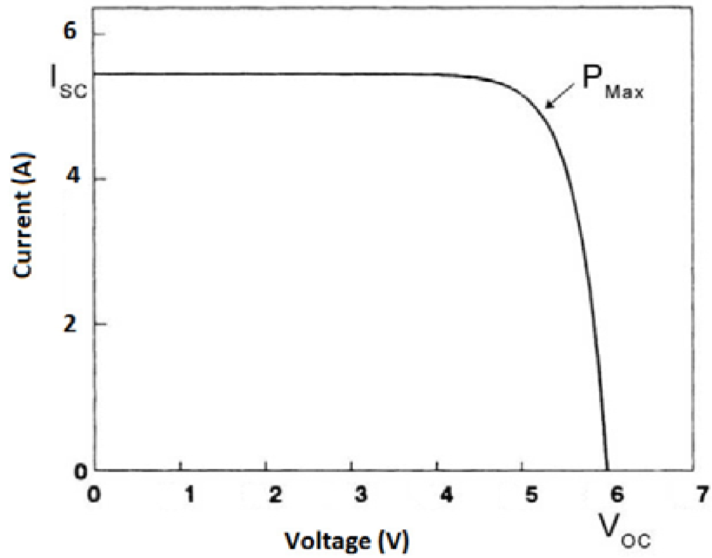

Fig 2: I-V characteristics of a solar panel

Three points in these curves are of particular interest: 1. Short circuit point, where the voltage over the module is zero and the current is at its maximum (short circuit current *Isc*). 2. Maximum power point or MPP, where the product of current and voltage has its maximum (defined by *Impp.Vmpp*). 3. Open circuit point, where the current is zero and the voltage has its maximum (open circuit voltage *Voc*). The measurements taken for obtaining an *I-V* curve is done by controlling the load current. At open circuit, when no load current is generated, a first characteristic value can be measured: the open circuit voltage *Voc*. Increasing the load fed by the photovoltaic module leads to a decreasing voltage *V* with an increasing current *I*. In other words, by increasing the load current from zero to its maximum value, the operating point moves from the open circuit voltage at zero current to the short circuit current *Isc* at zero voltage. The series of all measured pairs (*V*, *I*) yields the characteristic *I-V* curve of the module. From the characteristic curve of the module, it is clear that the open circuit voltage of the photovoltaic module, the point of intersection of the curve with the horizontal axis, varies little with solar radiation changes. It is inversely proportional to temperature, i.e., a rise in temperature produces a decrease in voltage. Short circuit current, the point of intersection of the curve with the vertical axis, is directly proportional to solar radiation and is relatively steady with temperature variations. Actually, the photovoltaic module acts like a constant current source for most parts of its *I-V* curve

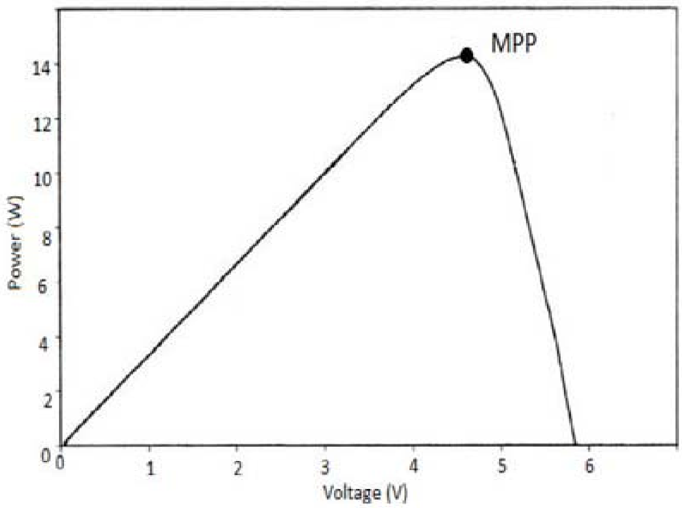

Fig 3: P-V characteristics of a solar panel

This is the P-V characteristics of PV cell. When the voltage and the current characteristics are multiplied we get the P-V characteristics as shown in fig.4 The point indicated as MPP is the point at which the panel power output is maximum.

III. MAXIMUM POWER POINT TRACKING

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[17] . 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. Additional power harvested from the modules is then made available as increased battery charge current. MPPT can be used in conjunction with a mechani cal tracking system, but the two systems are completely different.

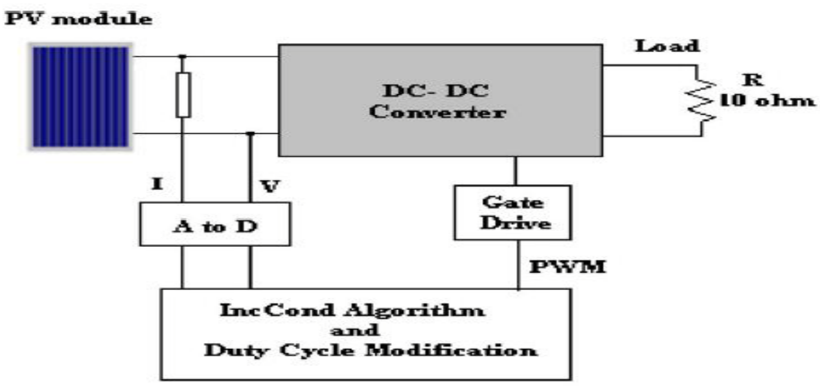

Fig 4: Block diagram of typical MPPT system

Solar panel is used as energy source. DC-DC Converter is used for transferring maximum power from the solar PV module to the load. MPPT Controller track maximum power.

Incremental conductance

The time complexity of perturb & observe algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm. [5] However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP. To avoid this problem we can use incremental conductance method.

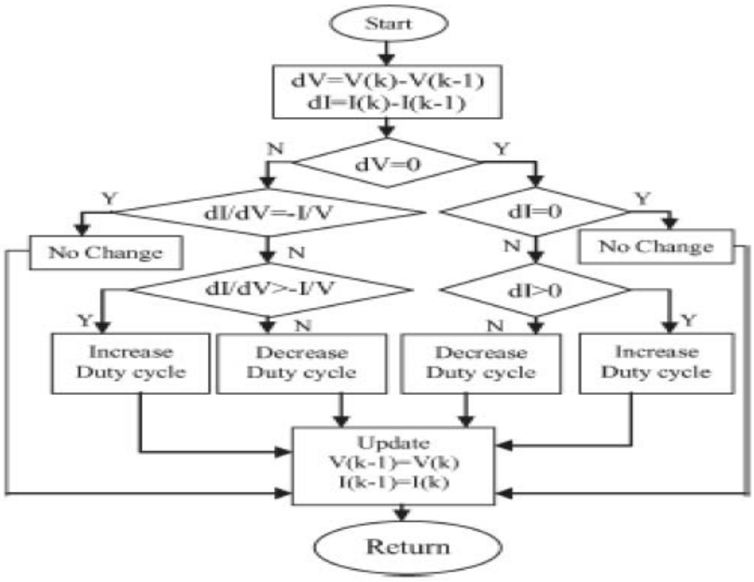

Fig 5: Algorithm for Incremental Conductance Method

The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by IC method . The IC can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V This relationship is derived from the fact that dP/dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm has advantages over P&O in that it can determine when the MPPT has reached the MPP, where P&O oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than P and O.[7,8]

This relationship is derived from the fact that

$$\frac{dI}{dV} = -\frac{I}{V}, \quad \text{at MPP}$$
$$\frac{dI}{dV} > -\frac{I}{V}, \quad \text{left of MPP}$$
$$\frac{dI}{dV} < -\frac{I}{V}, \quad \text{right of MPP}$$

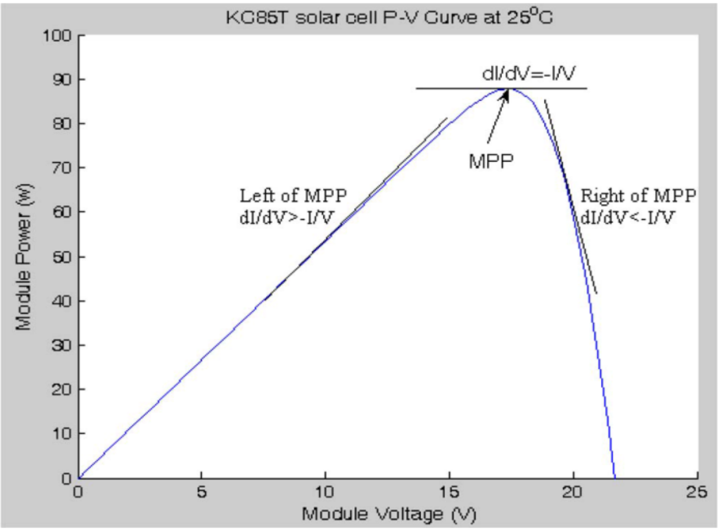

Fig 6: P-V characteristics for Incremental Conductance Algorithm

VI. CUK CONVERTER

The Cuk converter is obtained by using the duality principle on the circuit of a buck-boost converter. Similar to the buck-boost converter, the Cuk converter provides a negative polarity regulated output voltage with respect to the common terminal of the input voltage. The output voltage magnitude can be same, larger or smaller than the input, depending on the duty cycle. The inductor on the input acts as a filter for the dc supply, to prevent large harmonic content. Here, the capacitor C1 acts as the primary means storing and transferring energy from the input to the output.

The analysis begins with these assumptions:

1. Both inductors are very large and the currents in them are constant.
2. Both capacitors are very large and the voltages across them are constant.
3. The circuit is operating in the steady state, meaning the voltage and current waveforms are periodic.
4. For the duty ratio of D, the switch is closed for time DT and open for (1-D) T.

5. The switch and the diode are ideal.

In steady state, the average inductor voltages VL1 and VL2 are zero. Therefore by Figure 7

V_{C1}=Vs+V_0------------------------- (1)

Therefore, VC1 is larger than both Vs and Vo. Assuming C1 to be sufficiently large, in steady state the variation in vC1 from its average value VC1 can be assumed to be negligibly small (VC1≈vC1), even though it stores and transfers energy from the input to the output.

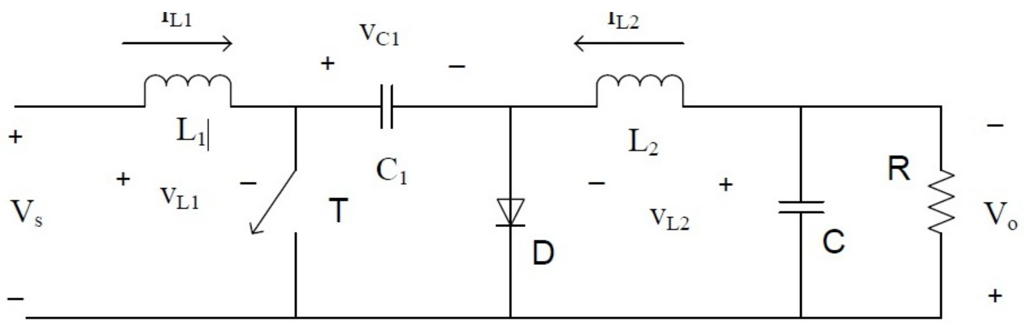

Fig 7: Circuit diagram of a Cuk converter

When the switch is off, the inductor currents iL1 and iL2 flow through the diode. Capacitor C1 is charged through the diode. The circuit is shown in Figure 7, Capacitor C1 is charged through the diode by energy from both the input and L1. Current iL1 decreases because VC1 is larger than Vs. Energy stored in feeds the output. Therefore iL2 also decreases.

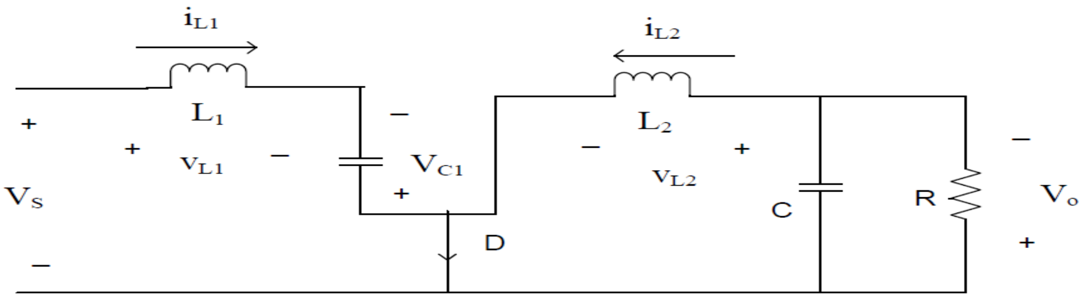

Fig 8: Voltage and Current in a Cuk converter with Switch Off

When the switch is on, VC1 reverse biases the diode. The inductor currents iL1 and iL2 flow through the switch as shown in Figure 8. Since VC1 >Vo, C1 discharges through the switch, transferring energy to the output and L2. Therefore iL2 increases the input feeds energy to L1 causing iL1 to increase.

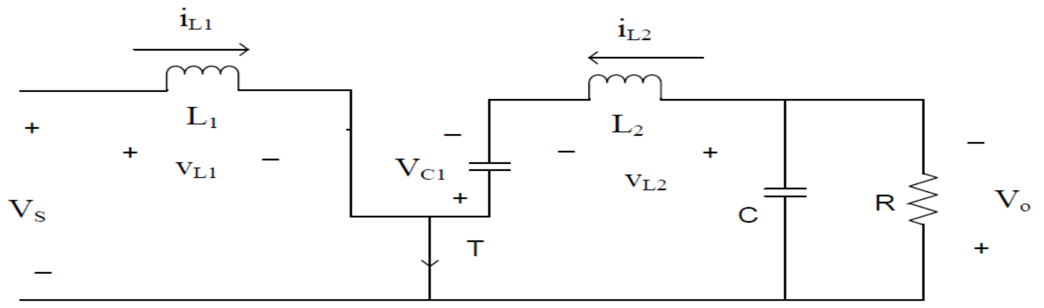

Fig 9: Voltage and Current in a Cuk converter with Switch On

The inductor currents iL1 and iL2 are assumed to be continuous. The voltage and the current expressions in steady state can be obtained in two different ways. If we assume the capacitor voltage VC1 to be constant, then equating the integral of the voltages across L1 and L2 over one time period to zero yields

L1: V_sDT_s-(V_s-V_{c1}) (1-D) T_s=0------------------------- (2)

L2: (V_{c1}-V_0) DT_s + (-V_0) (1-D) T_s = 0------------------- (3)

V_{c1}= (1/1-D)*V_s--- (4)

V_{c1} = (1/D)*V_0-- (5)

From equation (4) and (5) we get,

V_0/V_s= (D/1-D) -- (6)

Next, the average power supplied by the source must be same as the average power absorbed by the load.

$P_s = P_0$

$V_sI_{L1} = V_0I_{L2}$--- (7)

$I_{L1}/I_{L2} = V_0/V_s$ -- (8)

I_0/I_s = (1-D)/ D-- (9)

Benefits:

1. An advantage of this circuit is that both the input current and the current feeding the output stage are reasonably ripple free. It is possible to simultaneously eliminate the ripples in iL1 and iL1 completely, leading to lower external filtering requirements.
2. This converter is also able to step up and down the voltage. It uses a capacitor as the main energy storage. As a result, the input current is continuous.
3. This circuit has low switching losses and high efficiency.
4 This converter does not allow electromagnetic interference like others.

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Drawbacks:

1. A significant disadvantage is the requirement of a capacitor C1 with a large ripple current- carrying capability.
2. In practical circuits, the assumption of a nearly constant is reasonably valid.
3. Its relationship to the duty cycle (*D*) is:

   If 0 < *D* < 0.5 the output is smaller than the input.

   If *D* = 0.5 the output is the same as the input.

   If 0.5 < *D* < 1 the output is larger than the input.

V. SIMULINK MODEL

Simulink model for Cuk Converter Circuit

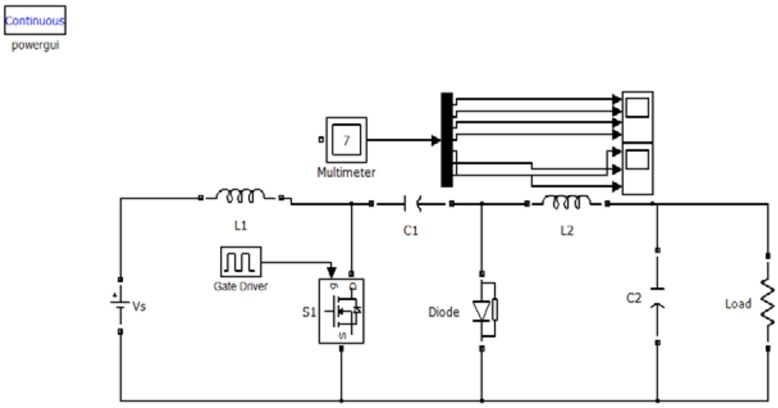

Fig 10: Cuk Converter

Simulink model for PV System Circuit

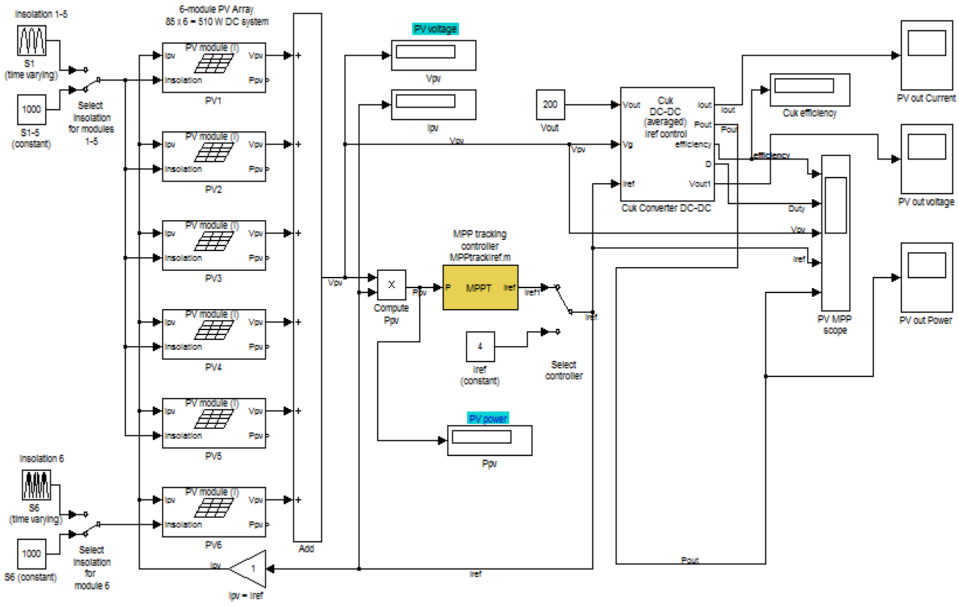

Fig 11: Simulink model for PV System Circuit

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RESULTS

O/P of Cuk Converter

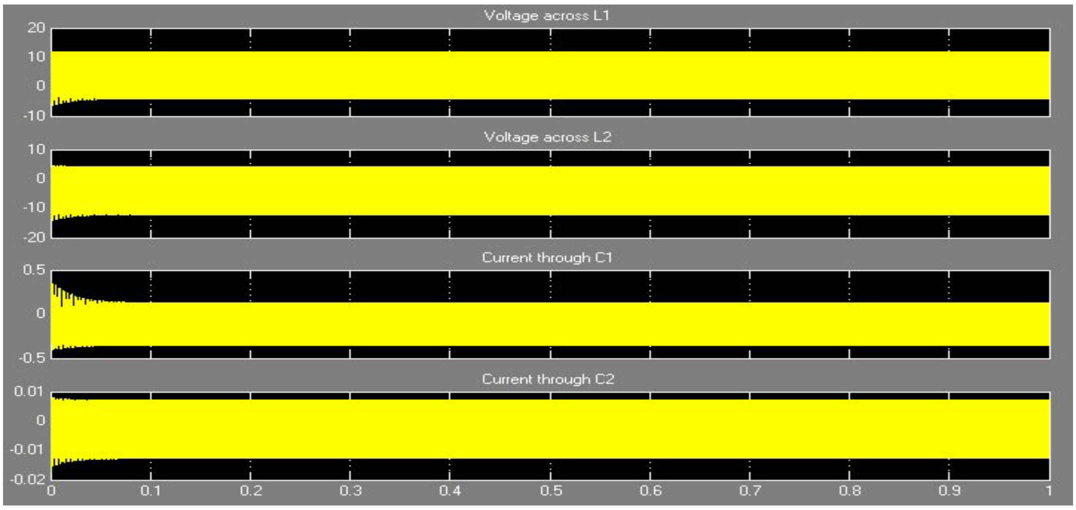

Fig 12 : O/P of Cuk Converter 1 with 25% duty cycle

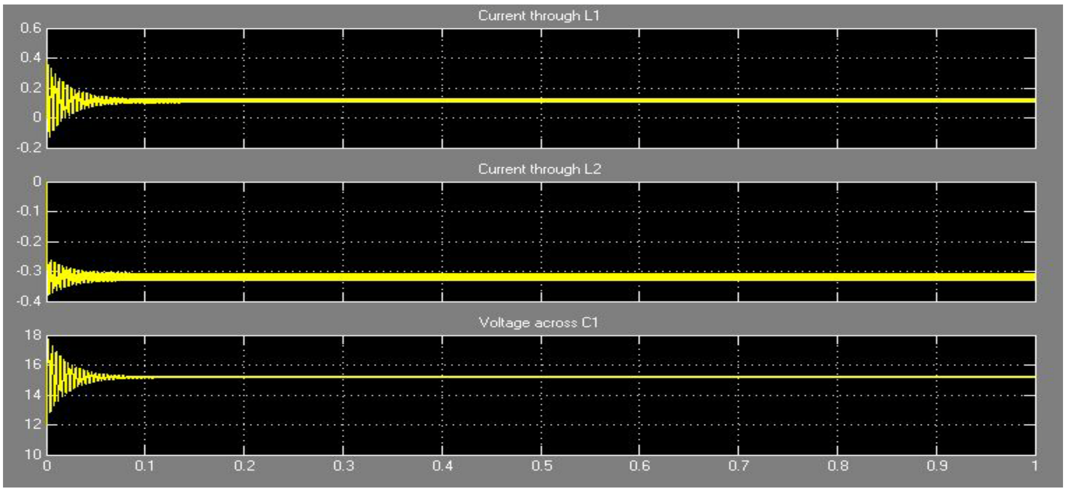

Fig 13: O/P of Cuk Converter 2 with 25% duty cycle

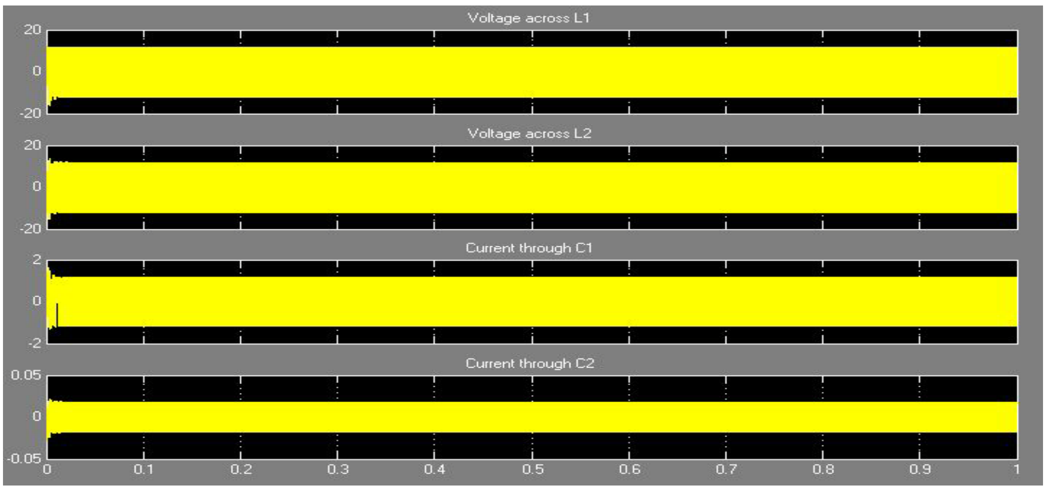

Fig 14: O/P of Cuk Converter 1 with 50% duty cycle

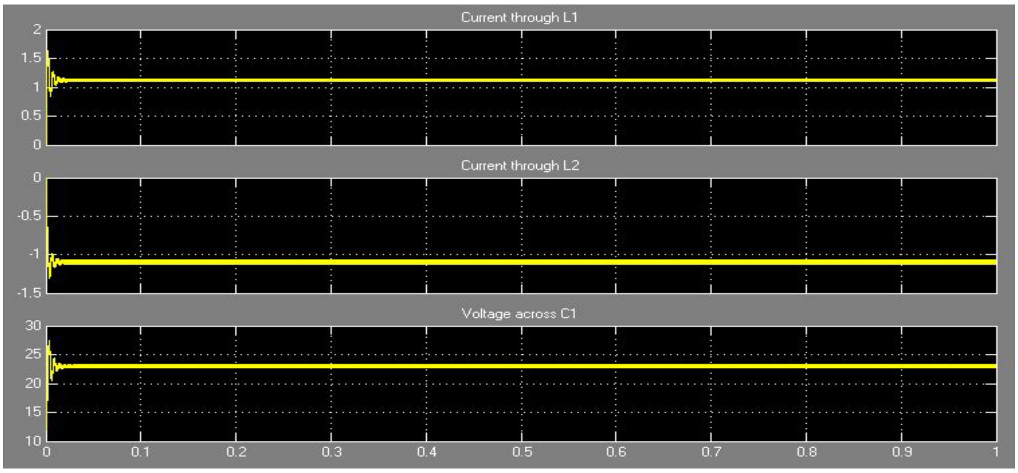

Fig 15: O/P of Cuk Converter 2 with 50% duty cycle

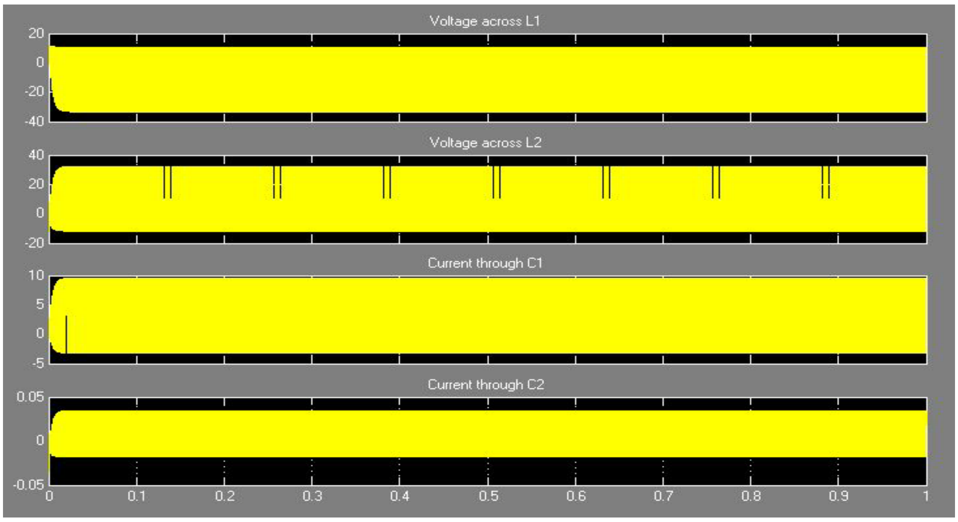

Fig 16 : O/P of Cuk Converter 1 with 75% duty cycle

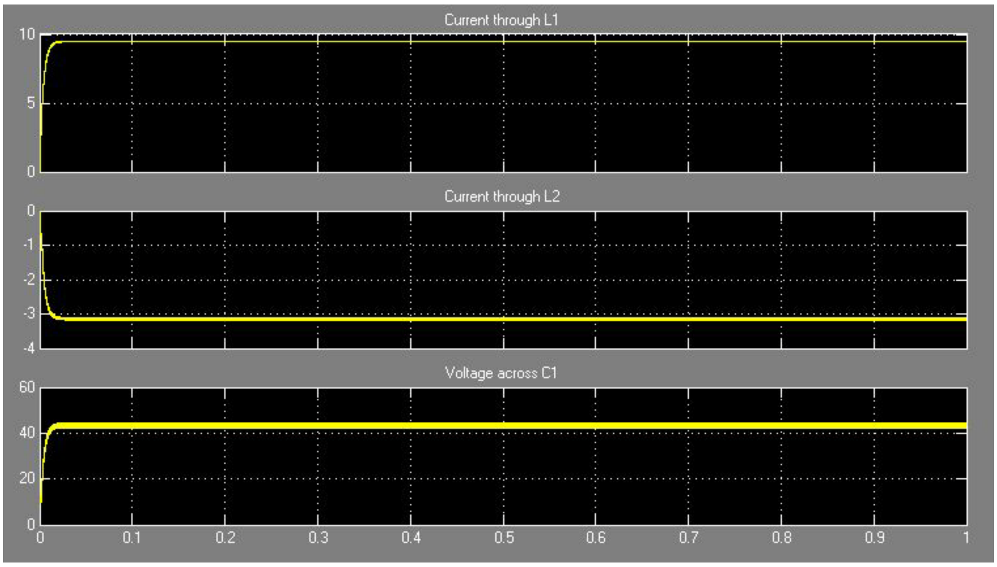

Fig 17: O/P of Cuk Converter 2 with 75% duty cycle O/P of PV System with MPPT

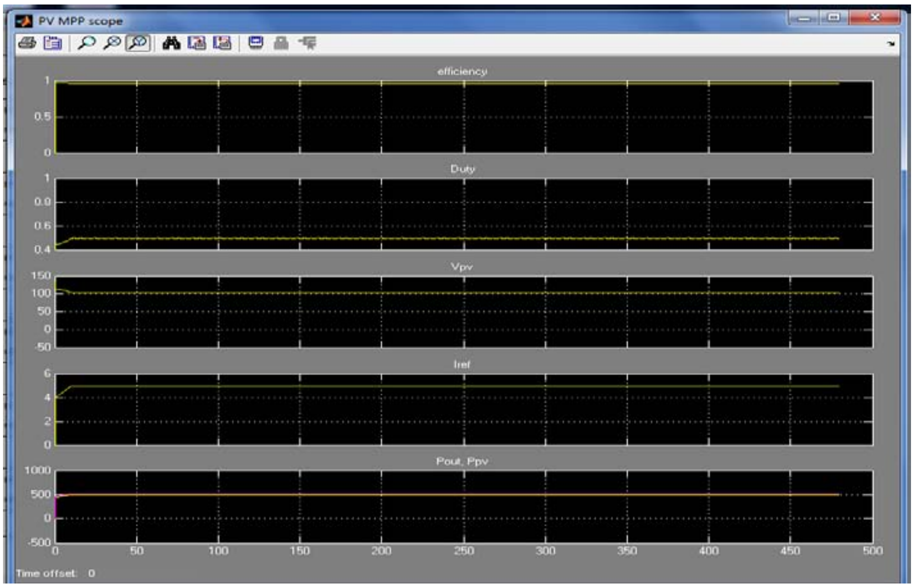

Fig 18: O/P of PV System

VI. CONCLUSION

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 of the PV modules. From the comparison of 3 most popular MPPT technique -Incremental Conductance best MPPT technique. The outputs obtained from Incremental Conductance method were found to eliminate the limitations of Perturb & Observe Method. Cuk converter has many advantages as compared to other converter. It is found that at 50% duty cycle, the performance of convertor is better than other values of duty cycle. At this duty cycle, the input power is nearly equal to output power of Cuk converter. The proposed method offers different advantages which are: good tracking efficiency, response is high and well control for the extracted power.

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