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LITERATURE SURVEY ON MAXIMUM POWER POINT TRACKING (MPPT) TECHNIQUE FOR PHOTOVOLTAIC (PV) SYSTEM

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Abstract: *Photovoltaic (PV) energy is the most important energy resource since it is clean, pollution free, and inexhaustible. Due to rapid growth in the semiconductor and power electronics techniques, PV energy is of increasing interest in electrical power applications. It is important to operate PV energy conversion systems near the maximum power point to increase the output efficiency of PV arrays. A MPPT plays a very vital role for extracting the maximum power from the solar PV module and transferring that power to the load. In this paper a survey of recent Maximum Power Point Tracking (MPPT) Technique for Photovoltaic (PV) System is presented.*

A comparative study included in this paper with focusing on different MPPT technique, research advantages and drawbacks are provided as well. These techniques vary in many aspects as simplicity, digital or analogical implementation, sensor required, convergence speed, range of effectiveness, implementation hardware, popularity, cost and in other aspects. Multi changes in irradiance, temperature by keeping voltage and current as main sensed parameter been done in the simulation. Matlab simulink tools have been used for performance evaluation on energy point. Simulation will consider different solar irradiance and temperature variations.

Three different converter buck, boost and cuk converter used in different method. 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. 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, Direct current, buck converter, fuzzy logic, neural network*

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I. INTRODUCTION

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; example are the Perturb and Observe (P&O) methods, Incremental Conductance (IC) methods, Fuzzy Logic Method etc.

II. PV CELL

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.

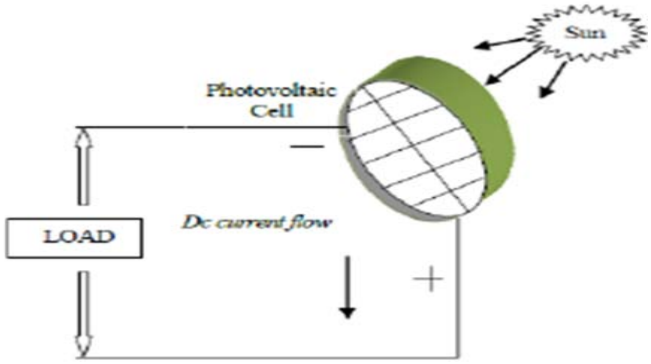

Fig.1 PV Cell

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.

A. PV- Module

Usually a number of PV modules are arranged in series and parallel to meet the energy requirements. PV modules of different sizes are commercially available (generally sized from 60W to 170W). For example, a typical small scale desalination plant requires a few thousand watts of power. PV energy is of increasing interest in electrical power applications. Photovoltaic (PV) energy is clean, pollution free, and inexhaustible.

A PV cell is connected in series and parallel. Series connection is responsible for increasing the voltage of module whereas the parallel connection is responsible for increasing the current. Solar cell can be modeled by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n to p junction and parallel resistance is due to the leakage current. PV energy is of increasing interest in electrical power applications. Photovoltaic (PV) energy is clean, pollution free, and inexhaustible.

It is important to operate PV energy conversion systems near the maximum power point to increase the output efficiency of PV arrays. The output power of PV arrays is always changing with solar irradiation and atmospheric temperature.

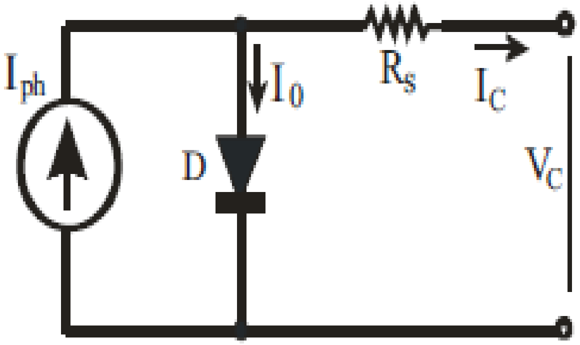

Fig.2 Single diode model of solar cell

I_c = cell output current

V_c = cell output voltage

I_{ph} = light generated current

I_o = reverse saturation current

R_s = series resistance of the cell

The performance characteristics of a photovoltaic module depend on its basic materials, manufacturing technology and operating conditions.

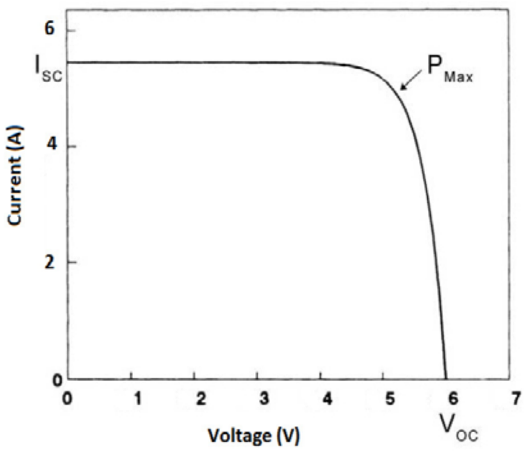

Fig.3 I-V characteristics of a solar panel

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

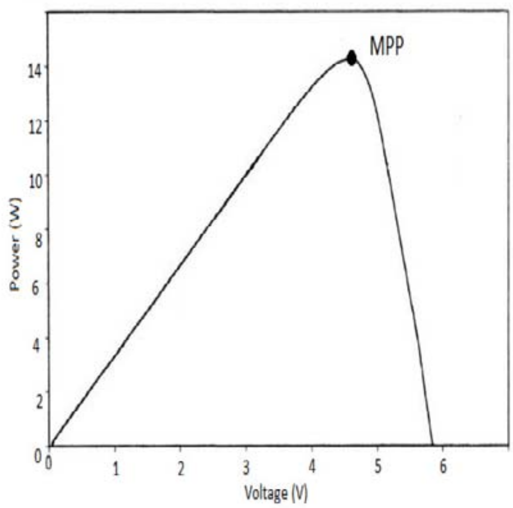

Fig.4 I-V characteristics of a solar panel

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.

B.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 mechanical tracking system, but the two systems are completely different.

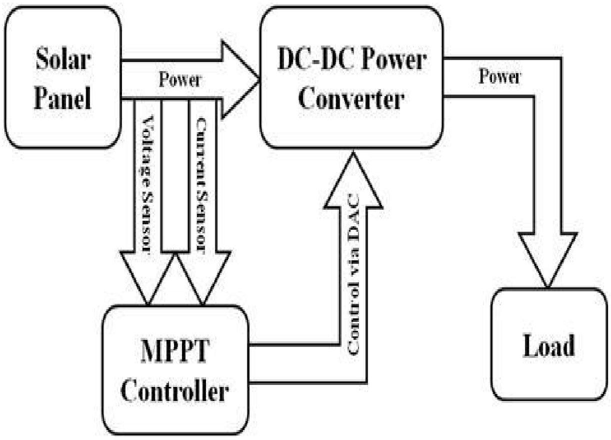

Fig.5 Block diagram of typical MPPT system

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.

III. MPPT TECHNIQUES

There are many MPPT Techniques are available which are as follows.

- Perturb and observe
- Incremental conductance
- Fuzzy Logic Control
- Current Sweep Method
- Fractional Open-Circuit Voltage

- Fractional Short-Circuit Current
- Neural Network

A. Perturb and observe

In this method a slight perturbation is introduce system [7]. This perturbation causes the power of the solar module changes. If the power increases due to the perturbation then the perturbation is continued in that direction [15]. After the peak power is reached the power at the next instant decreases and hence after that the perturbation reverses. When the steady state is reached the method oscillates around the peak point. In order to keep the power variation small the perturbation size is kept very small. The method is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module [7]. A PI controller then acts moving the operating point of the module to that particular voltage level. It is observed that there some power loss due to this perturbation also the fails to track the power under fast varying atmospheric conditions. But still this method is very popular and simple[7].

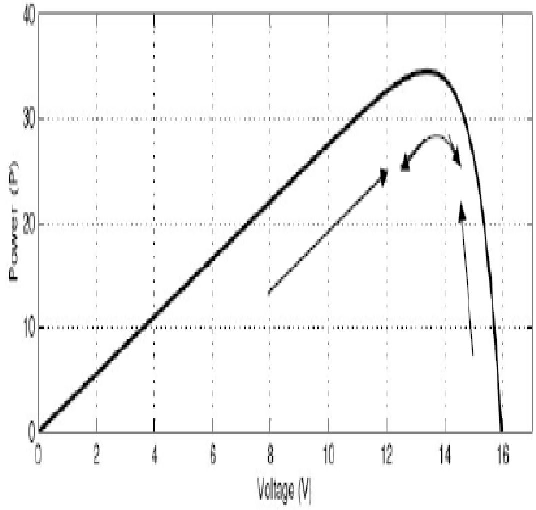

Fig.6 P-V characteristics for Perturb and Observe Algorithm

The maximum power point tracking is successfully carried out by this research using perturb and observe method. The PV module working on photovoltaic effect actually improves the system efficiency. Compared to other methods of maximum power point tracking, the perturb and observe method seems to be easy for the optimization of the photovoltaic system using buck boost converter. By varying the duty cycle of the buck boost converter, the source impedance can be matched to adjust the load impedance which improves the efficiency of the system. The performance has been studied by the MATLAB/ Simulink. In future, the maximum power point tracking could be carried out without the use of controllers in order to reduce the cost and complications of hardware can be removed.

B.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.

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

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

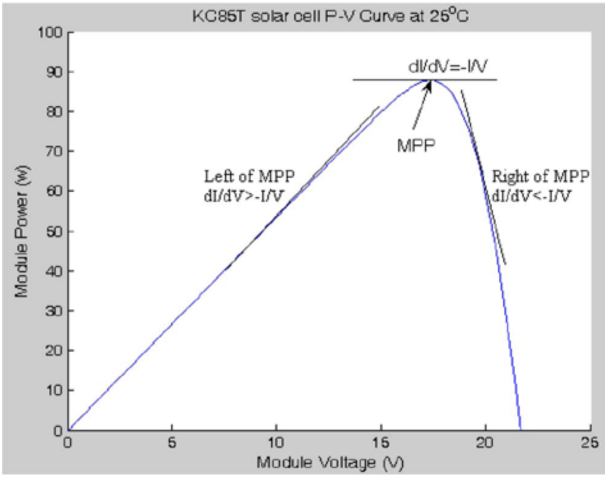

Fig.7 P-V characteristics for Incremental Conductance Algorithm

C. Fuzzy Logic Control

Microcontrollers have made using fuzzy logic control [18- 28] popular for MPPT over last decade. As mentioned in [27], fuzzy logic controllers have the advantages of working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity. Fuzzy logic control generally consists of three stages: fuzzification, rule base table lookup, and defuzzification. During fuzzification, numerical input variables are converted into linguistic variables based on a membership function similar to Fig. 8. In this case, five fuzzy levels are used: NB (Negative Big), NS (Negative Small), ZE (Zero), PS (Positive Small), and PB (Positive Big). References [24] and [25] use seven fuzzy levels, probably for more accuracy. In Fig. 8 are based on the range of values of the numerical variable. The membership function is sometimes made less symmetric to give more importance to specific fuzzy levels.

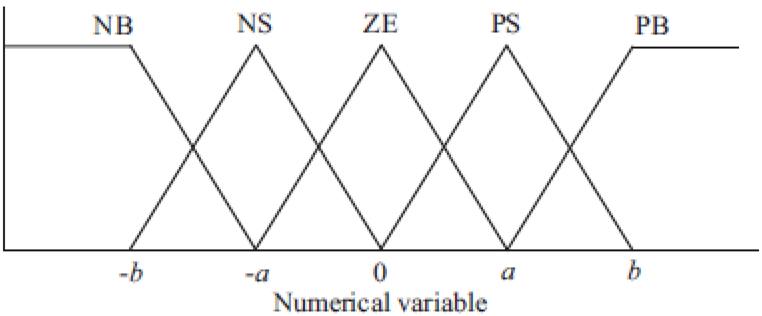

Fig. 8 Membership function for inputs and output of fuzzy logic controller

In the defuzzification stage, the fuzzy logic controller output is converted from a linguistic variable to a numerical variable still using a membership function as in Fig. 8. This provides an analog signal that will control the power converter to the MPP. MPPT fuzzy logic controllers have been shown to perform well under varying atmospheric conditions. However, their effectiveness depends a lot on the knowledge of the user or control engineer in choosing the right error computation and coming up with the rule base table. Reference [25] proposes an adaptive fuzzy logic control that constantly tunes the membership functions and the rule base table so that optimum performance is achieved. Experimental results from [21] show fast convergence to the MPP and minimal fluctuation about it. Reference [27] empirically uses two different membership functions to show that the tracking performance depends on the type membership functions considered.

D. Neural Network

Along with fuzzy logic controllers came another technique of implementing MPPT – neural networks [59-63], which are also well adapted for microcontrollers. Neural networks commonly have three layers: input, hidden, and output layers as shown in Fig. 6. The number nodes in each layer vary and are user-dependent. The input variables can be PV array parameters like *VOC* and *ISC*, atmospheric data like irradiance and temperature, or any combination of these. The output is usually one or several reference signal(s) like a duty cycle signal used to drive the power converter to operate at or close to the MPP. How close the operating point gets to the MPP depends on the algorithms used by the hidden layer and how well the neural network has been trained.

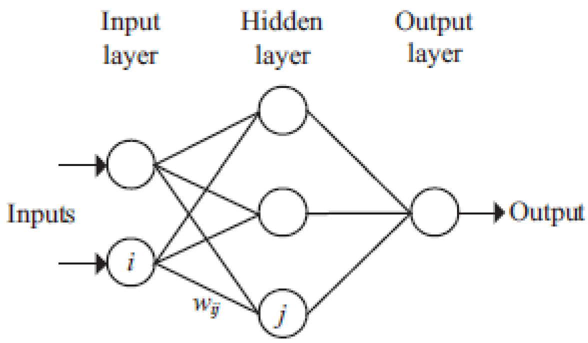

Fig. 9 Neural Network

The links between the nodes are all weighted. The link between nodes *i* and *j* is labeled as having a weight of *wij* in Fig. 9. To accurately identify the MPP, the *wij*'s have to be carefully determined through a training process, whereby the PV array is tested over months or years and the patterns between the input(s) and output(s) of the neural network are recorded. Since most PV arrays have different characteristics, a neural network has to be specifically trained for the PV array with which it will be used. The characteristics of a PV array also change with time, implying that the neural network has to be periodically trained to guarantee accurate MPPT.

IV. COMPARISON BASED ON DIFFERENT MPPT TECHNIQUE

Reference	Method in detail	Advantage	Disadvantage
1	a. Includes elimination of the proportional integral control loop and investigation of the effect of simplifying the control circuit. b. Fixed-step-size IncCond MPPT with direct control method was used	a. Good tracking efficiency, High response. b. Well control for the extracted power. c. Capable of tracking MPPs accurately and rapidly without steady-state oscillation.	a. Realization is very complex. b. Costly.
2	a. The controller adjusts the voltage by a small amount from the array and measures power, if the power increases. b. By varying the duty cycle of the buck boost converter, the source impedance can be matched to adjust the load impedance to improve the efficiency of the system.	a. Seems to be easy for the optimization of the photovoltaic system using buck boost converter.	a. Hardware complexity. b. Some power loss due to this perturbation also the fails to track the power under fast varying atmospheric conditions. c. Oscillates around the MPP.
3	a. No proportional or integral control loop exists and an adaptive FL controller generates the control signals. b. The control signal for the buck boost converter was built by using TMS320F2812 DSP.	a. Control system works without steady-state error and has the ability of tracking MPPs rapid and accurate which is useful for the sudden changes in the atmospheric condition. b. Capable and satisfactory in terms of fastness and dynamic performance.	a. Its effectiveness is highly dependent on the technical knowledge of the engineer in computing the error and coming up with the rule-based table

V. SELECTION OF CONVERTER

It Operate as the main part of the MPPT. 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, When proposing an MPP tracker, the major job is to choose and design a highly efficient converter, which is supposed to operate as the main part of the MPPT. [13]The efficiency of switch-mode dc–dc converters is widely discussed in [1]. Most switching-mode power supplies are well designed to function with high efficiency. Among all the topologies available, both Cuk and buck–boost converters provide the opportunity to have either higher or lower output voltage compared with the input voltage. Although the buck–boost configuration is cheaper than the Cuk one, some disadvantages, such as discontinuous input current, high peak currents in power components, and poor transient response, make it less efficient.[12]

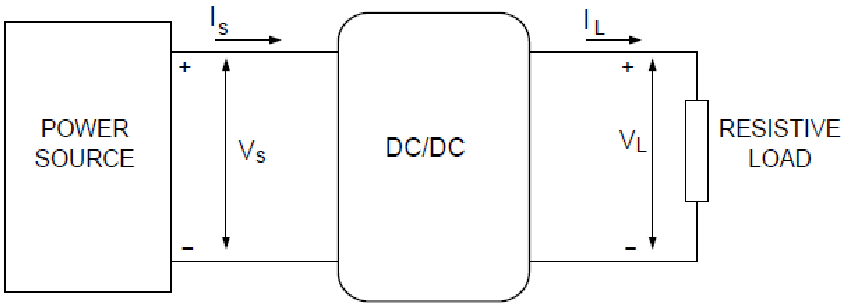

Fig.10 DC-DC Converter

The Cuk converter has low switching losses and the highest efficiency among nonisolated dc–dc converters. It can also provide a better output-current characteristic due to the inductor on the output stage. Thus, the Cuk configuration is a proper converter to be employed in designing the MPPT. Figs. 5 and 6 show a Cuk converter and its operating modes, which is used as the power stage interface between the PV module and the load. The Cuk converter has two modes of operation. The first mode of operation is when the switch is closed (ON), and it is conducting as a short circuit. In this mode, the capacitor releases energy to the output.

There are 3 types of converter which are as follow.

A. Buck Converter

The buck converter can be found in the literature as the step down converter [9]. This gives a hint of its typical application of converting its input voltage into a lower output voltage, where the conversion ratio M = Vo/Vi varies with the duty ratio D of the switch [9, 10].

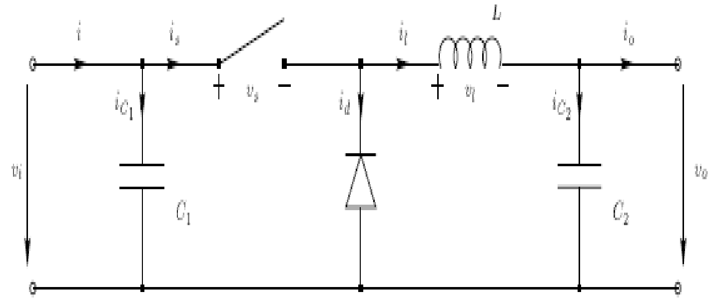

Fig.11 Buck Converter Circuit

B.Boost Converter

The boost converter is also known as the step-up converter. The name implies its typically application of converting a low input-voltage to a high out-put voltage, essentially functioning like a reversed buck converter [15, 16].

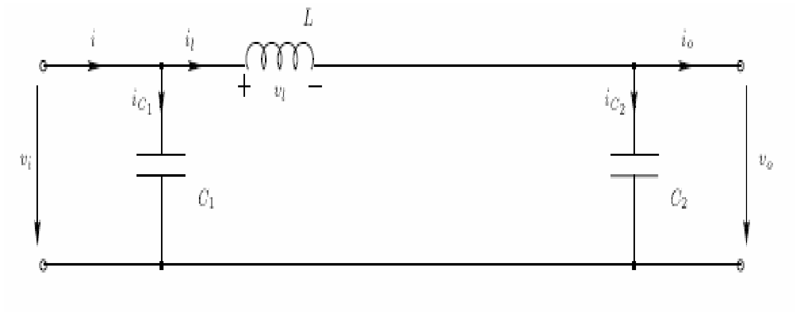

Fig. 12 Boost converter circuit

C.Cuk Converter

The cuk converter is used as Step up or step down. Two modes of operation– Closed(ON) & Open (OFF).

The average values of the periodic inductor voltage and capacitor current waveforms are zero when the converter operates in steady state. It can also provide a better output-current characteristic due to the inductor on the output stage. Thus, the Cuk configuration is a proper converter to be employed in designing the MPPT.

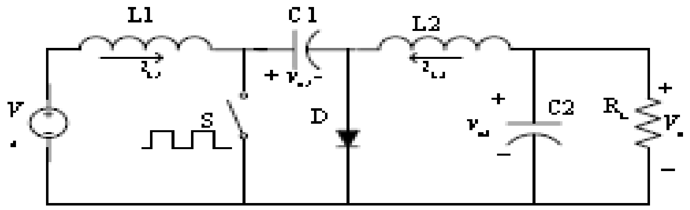

Fig.13 Cuk Converter Circuit

VI. CONCLUSION

In this paper various MPPT techniques are discussed. These methods mainly include Incremental Conductance , Perturb and Observe and Fuzzy Logic .Here we also mention advantages and disadvantages of different method. 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. This paper focus on comparison of three different converter which will connected with the controller. This controller gives a better output value for buck, boost and cuk converter.

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