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Maximum Power Point Tracking using Incremental Conductance method and Modeling for Photovoltaic Systems

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***Abstract*- In this paper, a fuzzy logic control (FLC) idea is used to control the maximum power point tracking (MPPT) for a photovoltaic system by incremental conductance method. MPPT technology, various diode model, effect of variation of solar irradiance and cell temperature, performances Incremental Conductance method is a cheap and easy algorithm to implement for Maximum Power Point Tracking (MPPT). This method is based on the advantage of an Incremental Conductance of a PV array to determine an optimum operating current for the maximum output power. This work proposes on the Investigation of Incremental Conductance method based Maximum Power Point tracking for photovoltaic system, to have the advantage of low frequency switching and proposes a simple algorithm for Photovoltaic system.**

Index Terms- Photovoltaic system, MPPT, Incremental Conductance Method, Fuzzy Logic Control.

1. INTRODUCTION

This paper presents the Maximum power point tracking by incremental conductance method for photovoltaic systems and fuzzy logic control. The increased in renewable sources of energy is increased to meet the energy demand. To increase the output efficiency of PV arrays we should operate PV energy systems near the maximum power point. Solar energy can be a standalone generating unit or can be a grid connected generating unit depending on the availability of the grid nearby. The development in power electronics has helped to come up with a very small but powerful system to withstand high power demand. The use of newest power control mechanisms known as the Maximum Power Point Tracking (MPPT) algorithm has led to the increase in the efficiency of operation of the solar arrays and thus is upgrading in the field of consumption of renewable sources of energy. Anyway, the mechanisms for enhancing the efficiency of the photovoltaic systems are still under experimenting.

Generally, MPPT is used to track the maximum power point in a photovoltaic cell system. The efficiency of MPPT depends on both MPPT control algorithm and the MPPT circuit (fig.1). As known from the Power – Voltage curve of a solar array, there is an operating point such that the PV delivers the maximum possible power output to the load. The optimum operating point changes with solar irradiance and cell temperature. MPPT algorithm controls the power converters to continuously detect instantaneous maximum power of the PV array.

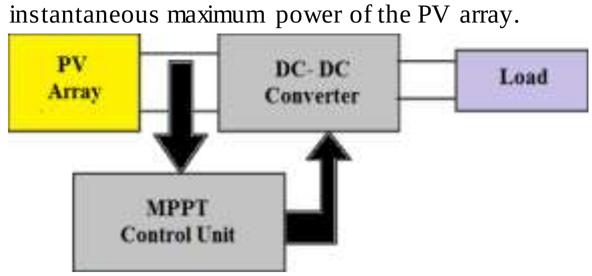

Fig.1. MPPT Block Scheme

2. PHOTOVOLTAIC CELL

Solar cell converts sunlight directly into DC power. Photovoltaic cell generates electricity from the sun. Photoelectric effect principle is used in the working of PV systems. When solar cell exposed to sunlight, it converts solar energy into electrical energy. Usually the PV array is the combination of series and parallel solar cells. This array develops the output power from the solar energy obtained directly and it will be changed depending up on the cell temperature and solar irradiance. So, controlling this to maintain maximum power at output side we are boosting the voltage by controlling the current in the array with the use of PI controller. By depending upon the boost converter output voltage this AC voltage may changes and finally it connect to the utility grid for consumption purposes.

3. MODELLING OF A SOLAR CELL

A solar cell is the single uint of solar panel. For various commercial operations, distinct types of photovoltaic cell technologies have been used. These cell technologies can be classified as multicrystalline, monocrystalline, thin film. Single and double diode PV models have been widely used for modeling the output characteristics of a PV module. Single diode model is the simplest as it has a current source in parallel to diode. This model is expanded by the implementation of one series resistance, Rs. But, thereby exhibiting functional deviations and deficiencies due to the change in temperature.

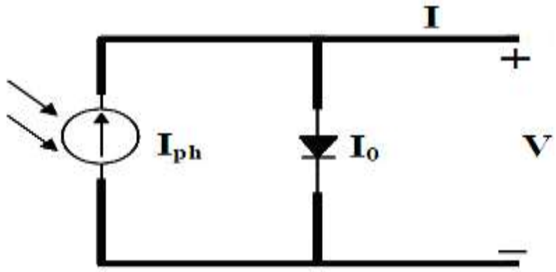

Fig.2: Ideal Solar PV equivalent Circuit

The ideal condition is referred by considering the series resistance of the cell as zero and the shunt resistance as infinity, resulting in no further voltage drop before the load. But in actual practice the shunt and series resistance has finite values which will alter the characteristics. So the practical model is implemented.

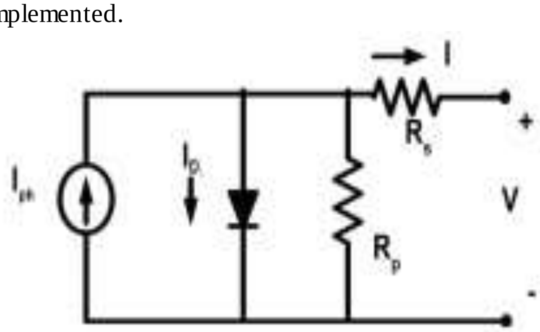

Fig.3: Electrical model of one diode PV cell

The various parameters are:

I_{PV} is the cell current (A).
I_{SC} is the light generated current (A).
I_D is the diode saturation current (A).
R_s is the cell series resistance (ohms).
R_P is the cell shunt resistance (ohms).
V_D is the diode voltage (V).
V_T is the temperature voltage (V).
V_{PV} is the cell voltage (V).

The output current equation using the above model is given as:

$$I = I_{ph} - I_o\left[\exp\left(\frac{V + IR_s}{aV_T}\right) - 1\right] - \frac{V + IR_s}{R_p}$$

This model gives more accurate result than the Rs model,[1] but at the expense of more computational time. Recombination losses in the depletion region are ommitted through single diode model. But a real solar cell has a recombination represented as a substantial loss, which cannot be modeled using a one diode equivalent circuit. Taking account of these losses targets to a more precise model known as the double diode model[2].

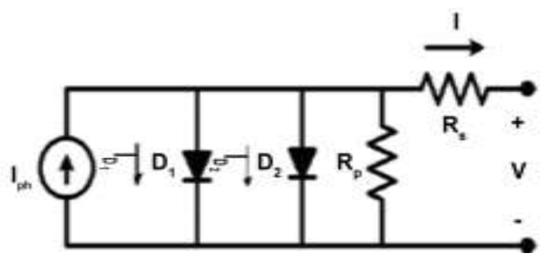

Fig.4: Electrical model of double diode PV cell

$$I = I_{ph} - I_{D1} - I_{D2}$$

$$I_{D1} = I_{o1}\left[\exp\left(\frac{V + IR_s}{a_1 * V_T}\right) - 1\right]$$

$$I_{D2} = I_{o2}\left[\exp\left(\frac{V + IR_s}{a_2 * V_T}\right) - 1\right]$$

The output current I can be determined by combining the above equations in I.

It take into account different properties of solar cell as:

The power dissipation across internal resistances affects efficiency as well as maximum output power of solar cells. The maximum power as well as the cell efficiency reduced with increasing value of series resistance for both models. Rs is introduced as to consider the voltage drop across and internal losses due to the current flow, Rp is taken into account of the leakage current to the ground when diode is reverse biased. The characteritics equation of the solar module depends on the number of cells arranged in parallel and in series. It is observed that the variation of current is less dependent on the shunt resistance and more dependent on the series resistance.

4. EFFECT OF VARIATION OF SOLAR IRRADIANCE AND CELL TEMPERATURE

The power-voltage curve and current-voltage curves of a solar cell mainly depends on the solar irradiation value and a negative impact on the power generation capability is observed when temperature around the solar cell increases. The solar irradiation as a result of environmental conditions keeps on varying, but various control mechanisms are available that can track this change and can alter the further processing of the solar cell to meet the required demand of loads.

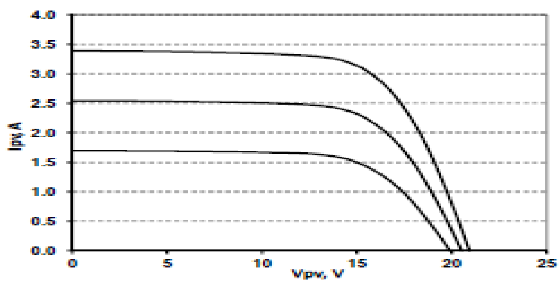

Fig.5: Variation of I-V curve with solar irradiation

Higher is the solar irradiation higher is the solar input and hence power magnitude would increase for the same voltage value. On the other side the bandgap of the material is more when the temperature is increased and a decrease in open circuit voltage value is observed. As bandgap increases more energy is required to cross the barrier and hence the efficiency of the solar cell is decreased.

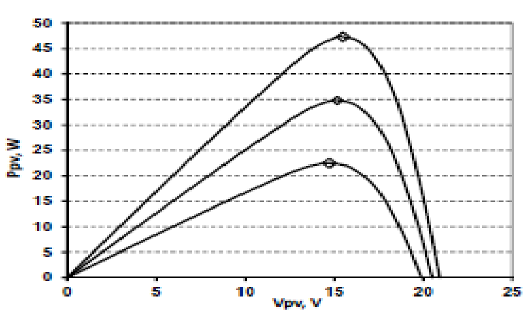

Fig.6: Variation of P-V curve with solar irradiation

The I-V characteristic of a PV array under constant irradiance has a unique point, called maximum power point (MPP) at which the array reaches the maximum power for given conditions. The quality of the cell is indicated by the term fill factor (FF), which is the ratio of maximum power that the solar cell can provide under normal operating conditions to the product of the open circuit voltage and short circuit current. An ideal solar cell will have a fill factor of unity, i.e. give maximum power. The normal percent efficiency is determined by taking the ratio of maximum power the solar cell can produce to the amount of solar irradiance hits in the solar cell. The cell conversion efficiency is determined by taking the ratio of electrical power output to incident solar power.

Various loss mechanisms limit the conversion efficiency of the solar cell and the major cause of the losses are due to:

1. Inherent nature
2. Energy distribution of incident photons

5. MAXIMUM POWER POINT TRACKING AND VARIOUS METHODS

An electronic system that operates the PV modules in a manner to extract the maximum power from the system. For to increase the efficiency of the PV systems various control methods are to be taken to match the source and load. It is a technique used to obtain maximum possible power from a varying source. There are number of studies on the implementation of a fuzzy logic controller to track the MPP of photovoltaic arrays. Matching of source impedance with that of the load impedance should be properly checked. So the impedance matching should be clearly done to get the maximum power point. The introduction of a DC-DC converter between the PV array and the inverter (or the load), so to increase the output voltage which has to given to the load and the PV array operating voltage and current are independent from the load and are can be maintained at the MPP by an appropriate control algorithm. The location of the MPP is not known a priori, due to the fact that this point moves in function of the solar irradiance and cell temperature. There are many methods used for MPPT, they are: Perturb and Observe method, Incremental Conductance method, Parasitic Capacitance method, Constant current method and Constant voltage method. However, studies proved that results obtained from the IC method to that of the P&O method have proper similarity which makes them difficult to say which method is best in functioning.

When using P&O method, the current (or voltage) from the photovoltaic array is perturbed by a small change of increment (ΔI or ΔV) and the resulting small change in power (ΔP) is measured respectively. If ΔP *is* positive, the next perturbation is in this same direction itself (with same algebraic sign). If ΔP is negative, the system's operating point has moved away from the MPP, thus the perturbation sign will be changed by backward movement, towards to reach the MPP.

The P&O algorithm couldn't able to locate the MPP point exactly as it is oscillates around by changing the sign of the perturbation after each measurement.

The various MPPT methods are:

Open circuit voltage, which uses the ratio of the array's MPP voltage to its open-circuit voltage.

Short-circuit current method. Uses short-circuit current instead of open-circuit voltage.

Pilot cell method. Here any one of the above two methods are used, but permits on a single PV cell rather than on the whole array.

Incremental conductance method is based on the fact, that the derivative of the power, as a function of the voltage is zero at the point of MPPT.

The main advantage of this method against the P&O method is that the location of MPP is exactly seen as it can able to decide in which direction to perturb, instead of oscillating around it.

The parasitic capacitance method is similar to the incremental conductance but the effect of the cell's parasitic junction capacitance is taken into account.

6. INCREMENTAL CONDUCTANCE MPPT

The disadvantage of the P&O method to track the maximum power under fast varying atmospheric condition is overcome by incremental conductance method. The IC can be determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not reached, the direction of perturbation of the MPPT operating point can be calculated using the relationship between dI/dV and –I/V. This relationship is shown as that when the MPPT is to the right of the MPP the dP/dV is a negative value and when MPPT is to the left of the MPP the dP/dV is a positive value. The algorithm has the advantage over P&O in that it can determine when the MPPT has reached the peak power, where as P & O oscillates around the MPP. Also, the incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than P & O. Many sensors are needed to operate in this method which makes it as a complex and hence is economically less effective. Here the array terminal voltage is always varied according to the MPP voltage and it is based on the incremental and instantaneous conductance of the PV module.

Fig.7 shows that the slope of the PV array power curve reaches zero at the MPP, increasing on the left of the MPP and decreasing on the right of the MPP. The basic equations are as follows:

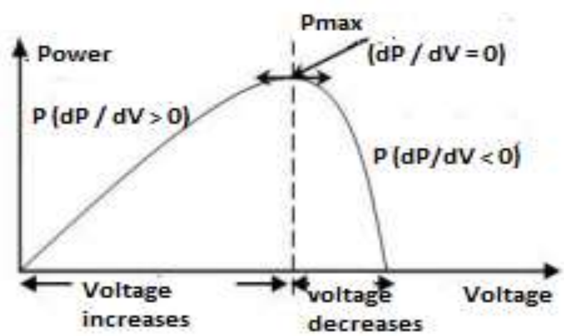

Fig.7: Graph Power versus Voltage for IC algorithm

$$\frac{dI}{dV} = -\frac{I}{V} \ at\ MPP \quad (1)$$

$$\frac{dI}{dV} > -\frac{I}{V} \ left\ of\ MPP \quad (2)$$

$$\frac{dI}{dV} < -\frac{I}{V} \ right\ of\ MPP \quad (3)$$

where I and V are P-V output current and voltage respectively. Incremental conductance of P-V module is represented by LHS of the equation and that of instantaneous conductance represented by RHS of the equations. Whenever the ratio of change in output conductance is same as that of negative output conductance, the solar array will operate at the maximum power point.

7.1INCREMENTAL CONDUCTANCE MPPT ALGORITHM

This method makes use of the assumption that the ratio of change in conductance output is equal to the negative output conductance instantaneous conductance. We have,

P = VI

Applying the chain rule,

$(\partial P/\partial V) = [\partial(VI)]/\ \partial V$

At MPP, as

$\partial P/\partial V=0$

The former equation could be transferred in terms of voltage V and current I of array as,

$(\partial I/\partial V) = (- I/V)$

The PWM control signal of the DC-DC boost converter is regulated by MPPT until the following condition is satisfied

$[(\partial I/\partial V) + (I/V)] = 0$.

The flow chart of the IC MPPT is shown below:

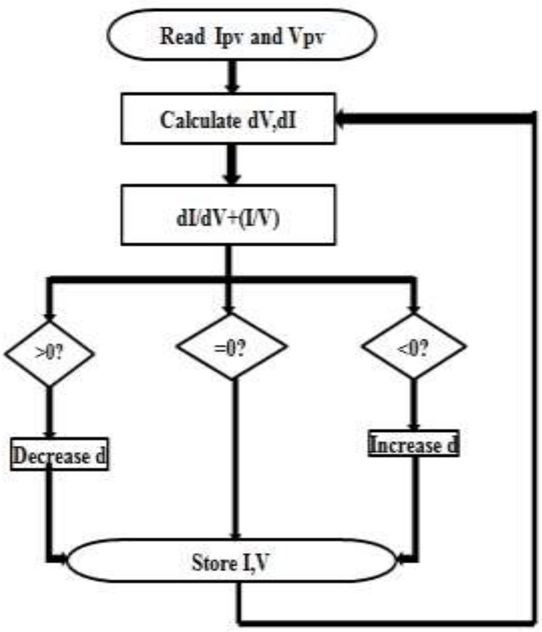

Fig.8: Incremental Conductance MPPT Flowchart

7.2DESIGN FUZZY – INCREMENTAL CONDUCTANCE

Recently FLC have been introduced in the tracking of the MPP in PV systems. They are efficient and relatively easier to design as they do not require the knowledge of the exact model which makes them more relevant.

Fuzzy IC is a fuzzy logic controller for MPPT which is based on the incremental conductance method. The block diagram of a PV system with fuzzy IC controller is in fig.9. It consists of PV panels, PV power calculation, Incremental Conductance fuzzy controller, buck-boost converter and the load.

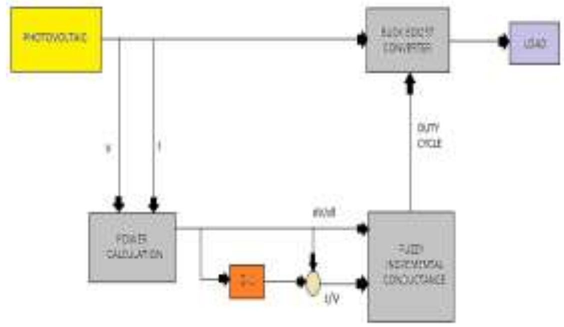

Fig.9: Block diagram of Fuzzy IC based MPPT

Using IC method, the MPP can be determined based on the rate of change / slope of dP/dV on the PV curve. At dP/dV = 0 at maximum power point, larger than zero (increasing slope) to left of the maximum point, and less than zero (decreasing slope) to the right of the maximum point. Based on these observations, the algorithm for Mppt IC takes the following form:

$$\frac{dP}{dV} = \frac{d(V.I)}{dV} = I\frac{dV}{dV} + V\frac{dI}{dV} = I + V\frac{dI}{dV}$$

When it reaches MPP, dP/dV = 0, then

$$\frac{dI}{dV} = -\frac{I}{V}$$

To determine the output power of the PV, it is necessary to perform calculation based on the output and current of PV before it is further processed in the FLC. The IC FLC has dV/dI and I/V as the two inputs and duty cycle as the output for controlling the converter. Input dV/dI is the ratio of the output voltage change and output current change of PV while input I/V is the ratio between the current and the output voltage that can be expressed by,

$$\frac{dI}{dV} = \frac{I(n)-I(n-1)}{V(n)-V(n-1)}$$

8. CONCLUSION

Incremental Conductance algorithm which holds good performance than any other methods under normal and varying atmospheric conditions. Power output obtained from IC method is high as compared to other methods under varying atmospheric conditions. MPPT algorithm which plays a major role for a grid connected Photovoltaic system. The use of fuzzy logic controller can provide an order more effective than the traditional controllers for the nonlinear systems, because there is more flexibility. The fuzzy logic MPPT controller that obtained was fast and steady in nature.. MPPT with the fuzzy incremental conductance method is studied. Fuzzy incremental conductance method is an extension of the incremental conductance method to improve PV output power.

REFERENCES

[1] Pongsakor Takun, Somyot Kaitwanidvilai and Chaiyan Jettanasen,"Maximum Power Point Tracking using Fuzzy Logic for Photovoltaic Systems"

[2] Takun P., S. Kaitwanidvilai and C. Jettanasen, "Maximum power point tracking using fuzzy logic control for photovoltaic systems"

[3] Vladimir Dimitrov Lazarov, Ludmil Stoyanov, Zahari Zarkov, Hristiyan Kanchev,"Grid – Connected PV System with MPPT Control"

[4] Farhat M. and L. Sbita, "Advanced fuzzy MPPT control algorithm for photovoltaic systems",

[5] Hristiyan Kanchev1), Nikolay Hinov, Dimitar Arnaudov and Rad Stanev," Modelling and Control of a Grid Connected PV System with Smart Grid Integration"