ISSN 2278 - 8875
International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 1, Issue 6, December 2012

Photovoltaic Array Maximum Power Point Tracking Using Fuzzy Control Method

[1]A.Sudhakar, [2]V.G.T. Rakesh,

[1]Associate Professor, Dept. of EEE, SV College of Engineering, Tirupati, Andhra Pradesh, India

[2]Assistant Professor, Dept. of EEE, SV College of Engineering, Tirupati, Andhra Pradesh, India

ABSTRACT: Photovoltaic cells has emerged as a important consideration for meeting the energy demand. The power available at the output of PV cells is not constant because PV cells exhibit a nonlinear V-I characteristics. So, PV cells maximum power point varies with solar isolation and ambient temperature recent developments in the power electronic converters. It is now possible to operate PV cell at its maximum power point. In this paper a simulation based PV cell is designed using MATLAB software. The fuzzy control algorithm shows that efficiency is improved when compared to the conventional method.

I. INTRODUCTION

Solar energy is one of the most important renewable energy sources. Compared to conventional non renewable resources such as gasoline, coal etc. Solar energy is clean in exhaustible and free. Photovoltaic has emerged as a major candidate for meeting the energy demand. It offers an option for clean energy source, with almost no running and maintenance cost. Due to the Convenience and robustness of the solar energy, photovoltaic power system is gaining its importance. Solar power systems have the following advantages overall other alternatives. Robustness, convenience and availability, environmental friendly, renewable. The power output from a photovoltaic array relies on many environmental conditions such as temperature of the cells, intensity of the sunlight as well as cell area. In order to obtain a higher power output we need some sort of regulating system which can ensure the output power is of the maximum possible value, power generated by PV cells depends on the operating voltage of the array. Its V-I curves specify a unique operating point at which maximum possible power is delivered. At the maximum PowerPoint the PV cell operates at its highest efficiency. The MPPT varies with solar insolation and temperature. So, the MPP is difficult to solve analytically, and therefore number of techniques have been proposed to realize MPPT. Those MPPT methods vary in complexity, sensors required, convergence speed, cost, range of effectiveness, implementation hardware and in other respects. Some methods applied in PV system are the constant voltage method, Perturb-and-observe method. the incremental conductance method and so on.

From the power Vs voltage characteristic curve of PV cell, it can be observed that the MPP is in the neighborhood ofa constant Voltage when solar illumination is changing and temperatures change is omitted. So the MPP's voltage Vm can be designed to be constant. This is the Constant Voltage

method (CVT). Although the CVT method is very simple, however, the constant Voltage can't track MPP when temperature changes, so the constant Voltage method is not often used in the true MPPT strategy from the characteristic curves of PV Cell, it can be seen that incrementing (decrementing) the Voltage increases (decreases) the power when operating on the left of the Mpp and decreases (increase) the power when on the right of the MPP. Therefore, if there is an increase in power, the subsequent perturbation should be kept the same to reach the Mpp and if there's a decrease in power, the perturbation should be reversed [5]. Small perturbations are introduced in the system in order to vary the operating point such that the Mpp is achieved. However, this method has several drawbacks such as slow tracking speed and oscillations about Mpp, making it less favorable for rapidly changing environmental conditions and this method can appear fallacious tracking when there is a sudden change in irradiance. The incremental conductance (INC) method is based on the fact that the slope of the PV array power curve is zero at the

MPP, +Ve on the left of the Mpp, negative on the light.
$dp/dv = 0$ at Mpp
$dp/dv > 0$ left of Mpp
$dp/dv < 0$ right of Mpp ……….. (1)

By derivation, it can be gained the relationship between the instantaneous conductance (I/V) and the incremental conductance ($\Delta I/ \Delta V$). The Mpp can be tracked by comparing (I/V) to $\Delta I / \Delta V$. It can be supposed that Vref equals to VMpp at the Mpp. Once the Maximum power point is reached, the operation of the PV array is maintained at this point unless a change in ΔI is noted. The algorithm decrements (or) increments Vref to track the new Mpp when atmospheric condition change. However, from derivation of the INC method, it can be seen that the INC method has no consideration about change of temperature.

In fact, because changes in the environment have uncertainty, changes of load and o/p. Characteristic of PV cell have more nonlinear feature, so above conventional tracking methods have more difficult to track real Mpp. Fuzzy control has adaptive characteristic in nature, and can achieve robust response of a system with uncertainty, parameter variation and load disturbance. It has been broadly used to control ill-defined, non-linear (or) imprecise system.

Fuzzy logic controllers have the advantages of working with imprecise inputs, not needing on accurate mathematical model, and handling nonlinearly. Fuzzy control has been successfully applied in many fields. Fuzzy control does not require accurate models of control object to overcome the limitation of the above conventional tracking methods, fuzzy control is applied to deal with MPPT of PV generation system in this paper, with this technique, not only can the real Mpp be readily tracked but also fast dynamic responses can be achieved.

Photovoltaic system

A photovoltaic system is a system which one or more solar panels to convert solar energy into electricity. It consists of multiple components, including the photovoltaic modules, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output. PV cells are made of semi conductor materials, such as silicon for solar cells, a thin semiconductor water is specially treated to form on electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current that
is electricity.

Photons of light with energy higher than the band gap energy of PV material can make electrons in the material break free from atoms that hold then and create hole-electron pairs.

Phase electrons, however, will soon fall back into holes causing change carriers to disappear. If a nearby electric field is provided, those are the conduction band can be continuously swept away from holes toward a metallic contact where they will emerge as an electric current.

Photovoltaic module

Due to the low voltage generated in a PV cell, several PV cells are connected in series (for high voltage) and in parallel (for high current) to form a PV module for desired output. Separate diodes may be needed to avoid reverse currents, in case of partial or total shading, and at night. The pn junction of monocry stalline silicon cells may have adequate reverse current characteristics and these are not necessary.

Reverse currents waste power and can also lead to overheating of shaded cells. Solar cells become less efficient at higher temperatures and installers try to provide good ventilation behind solar panels.

Photovoltaic array

The power that one module can produce is not sufficient to meet the requirements of home or business. Most PV arrays use an inverter to convert the DC power in to alternating current that can power the motors, loads, lights etc. The modules in a PV array are usually first connected in series
to obtain the desired voltages; the individual modules are then connected in parallel to allow the systems to produce more current.

II. CHARACTERISTICS OF PHOTOVOLTAIC CELL

Photo voltaic cell consists of a silicon P-N junction that when exposed to light releases electrons around a closed electrical client from this premise the circuit equivalent of a pv cell. It Can be modeled through the circuit shown in Fig.1 electronics from the cell are excited to higher energy levels when a collision with a photon occur. These electrons are free to move across the junction and create a current. This is modeled by the light generated current source (Iph). The intense P-N junction characteristic is introduced a diode in the circuit equivalents.

The photo current Iph generated in the PV cell is proportional to level of solar illumination. I is the O/P current of photovoltaic cell. The current (Id) through the bypass diode varies with the junction voltage vj and the cell reverse saturation current ± IO. 'V' is the output of the photovoltaic cell. Rsh and Rs are the parallel and series resistances, respectively. Parallel resistance when the number of cell in series is ns, and the number of cell in parallel is np. There are relevant mathematical equations expressing as following:

ISSN 2278 - 8875
International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 1, Issue 6, December 2012

$$I = n_p Ish - n_p Io\left[e^{q}\frac{(v/n_s + IRs)}{nkP}\right] - \frac{V/ns + IRs}{Rsh} \quad \ldots (2)$$

$$Iph = IscC\left(\frac{s}{1000}\right) + CT(T - T_{ref}) \quad \ldots (3)$$

$$\text{Where } I_0 = Ido\left(\frac{T}{T_{ref}}\right)^3 e^{\left[\frac{qeq}{nK}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right]},\ q = 1.6022\times10^{-19}C$$

is the electronic charge, n is the emission coefficient of diodes, 23 K 1.3807 10− = × JK-1 is Boltzman's constant, T is ambient temperature in Kelvin, and Tref is reference absolute temperature. Isc is the short current, S is the level of solar illumination, Eg. Is the energy of the band gap for silicon which is (1 = 3)er, CT is the short circuit – current temperature coefficient (= 0.0016A/K), Ido is the reverse current ± of diode.

And from equations (2) and (3), it is known that the characteristics of pv will be changed when S and T change. Change in these variables s and T cause the current voltage (I-V) curves of photovoltaic array to change as well. As s variation from 250w/m2 to 1000w/m2 is reported and temperature t is constant at 40^0C.

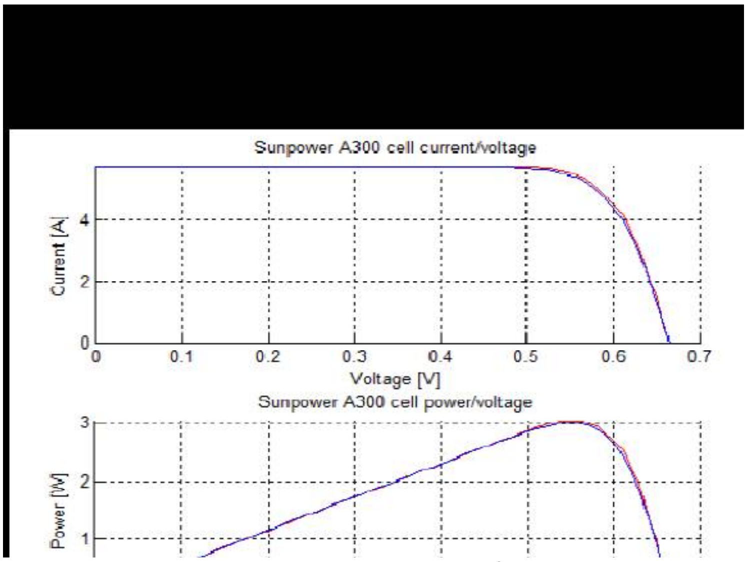

Fig.1:V-I curve and P-V curve of pv array

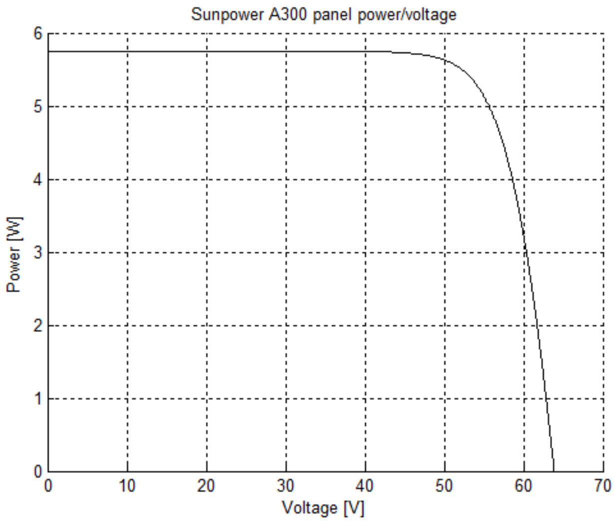

Fig:2:P-V curve for PV cell

The solar illumination another important factor influencing the characteristics of a photovoltaic module is ambient temperature in fig (2), when solar illumination is constant 1000w/m2 and temperature changes from 20^0C to 100^0C.

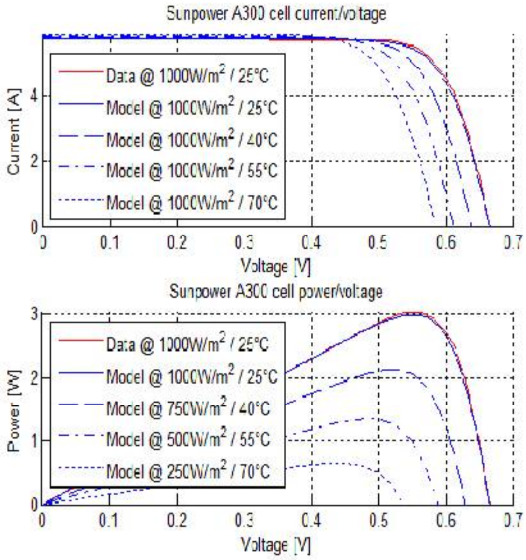

Fig:3:V-I and P-V curve of PV cell influenced by solar illumination

The output power of a pv array is the product of current I and terminal voltage v, thus

$$p = n_p V I_{ph} - n_p V I_o \left[e^{\frac{q(V/n_s + IR_s)}{nkT}} - 1 \right] - \frac{V^2/n_s + VIR_s}{R_{sh}} \quad \ldots\ldots (4)$$

From above equation, it can be known that the solar illumination and ambient temperature will influence the output power of a pv module, the output power of a PV changes with the solar illuminations variation when temperature constant 400C shown in fig (3) and the characteristic of output power changes with the ambient temperature is variation when the solar illumination is
constant 1000w/m^2

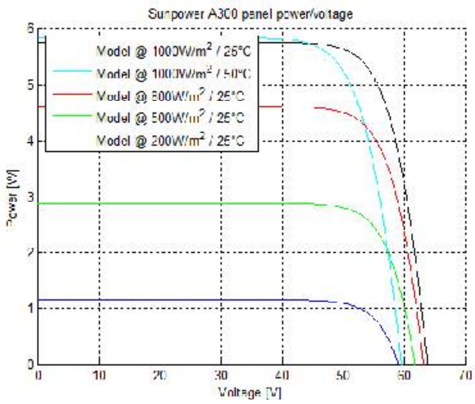

Fig:4:P-V curve of PV array

From fig 3 and fig 4 it can be seen that the output power of a pv module is influenced by the solar
illumination and ambient temperature. So, the MPP will be change when peripheral condition is changed, especially, the solar illumination and temperature changes at the same time.

III. A NEW MPPT METHOD WITH FUZZY CONTROL

In recent years, fuzzy logic controllers have been widely used for industrial processes owing to their heuristic nature associated with simplicity and effectiveness for both linear and nonlinear systems [8]. A MPP search based on fuzzy heuristic rules, which does not need any parameter
information, consists of a stepwise adaptive search, leads to fast convergence and is sensor less with respect to sunlight and temperature measurements [9]. The control objective is to track and extract maximum power from the PV arrays for a given solar insolation level. The maximum power
corresponding to the optimum operating point is determined for a different solar insolation level and temperature. The fuzzy controller consists of three functional blocks: *A)* Fuzzification,

B) Fuzzy rule algorithm and *C)* Defuzzification. These functions are described as follows:

A. Fuzzification

The fuzzy control requires that variable used in describing the control rules has to be expressed in terms of fuzzy set notations with linguistic labels. In this paper, the fuzzy control MPPT method has three input variables, namely voltage .current and temperatureand one output variable power

The membership functions and their values are shown in Figures

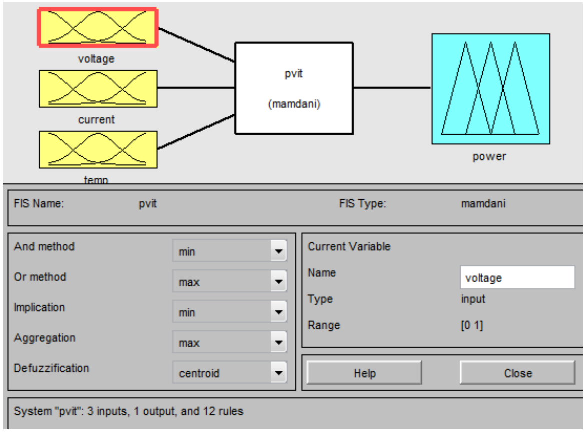

Fig. 5:Membership function of input voltage

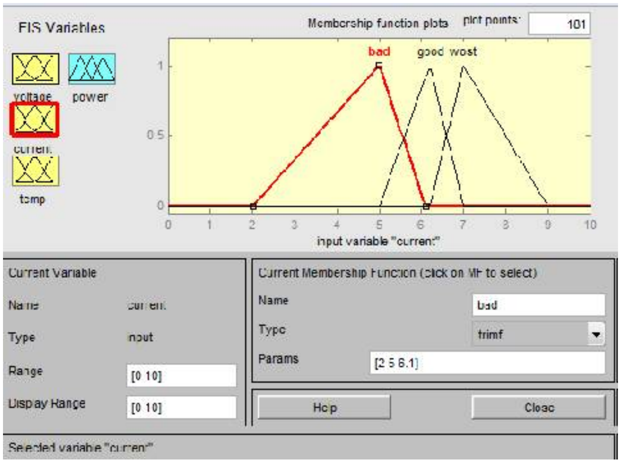

Fig. 6:Membership functions of the input variable Current

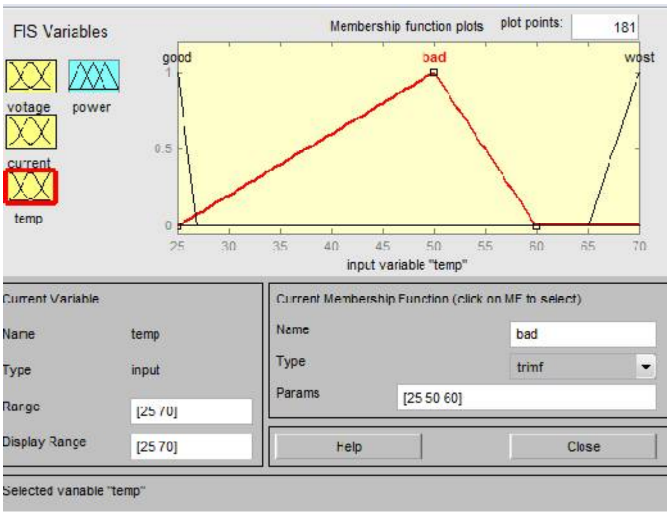

Fig.7:Membership function of input variable Temperature

ISSN 2278 - 8875
International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 1, Issue 6, December 2012

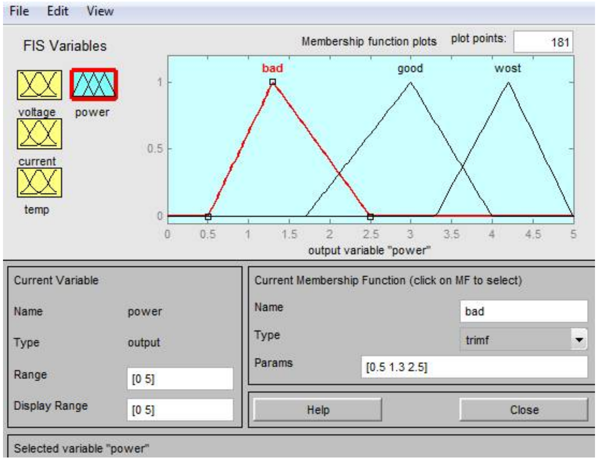

Fig:8: Membership function of output variable power

The rules are framed as shown below

1. if voltage is bad, current is bad ,temperature bad then, output power is bad
2. if voltage is good ,current is bad, temperature is bad then output power is bad

The rules are framed to track the maximum power point in fuzzy control method

RULE BASE TABLE FOR THE FUZZY LOGIC CONTROLLER

As a fuzzy inference method, Mamdani's method is used with max--min operation fuzzy combination law in this paper. To satisfy different conditions and gain better tracking performance, several possible combinations of the degree of supports are with varying strengths to the corresponding rules.

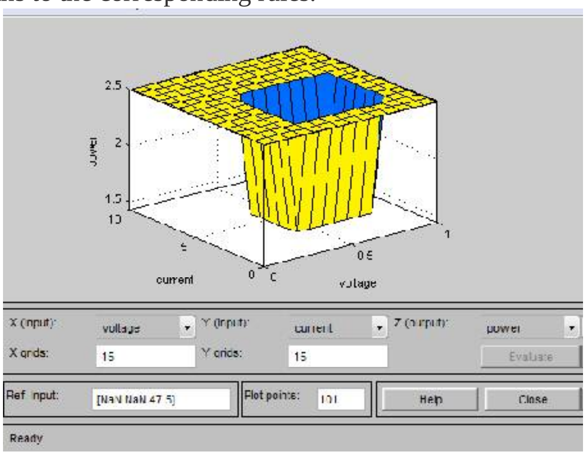

Fig. 9. A three-dimensional view of the fuzzy surface for MPPT

C. Defuzzification

After the rules have been evaluated, the last step to complete the fuzzy control algorithm is to calculate the crisp output of the fuzzy control with the process of defuzzification. The well-known center of gravity method for defuzzification is used in this paper. It computes the center of gravity from the final fuzzy space, and yields a result which is highly related to all of the elements in the

same fuzzy set [10]. The crisp value of control output ΔU(k+1) is computed by the following equation:

$$\Delta U = \frac{\sum_{i=1}^{n} W_i \Delta U_i}{\sum_{i=1}^{n} W_i} \qquad (7)$$

Where n is the maximum number of effective rules, wi is the weighting factor, and άUi is the value corresponding to the membership function of άU. Then, the final control voltage is obtained by adding this change to the previous value of the control voltage:

TABLE I
THE TRACKING PERFORMANCE COMPARISON BETWEEN VARIABLE STEP SIZE INC AND FUZZY CONTROL MPPT METHODS

MPPT METHOD	200 TO 1000W/m2 at 0.03s	250c to 750c at 0.06s	1000 to 2000w/m2
VARIABLE INC METHOD	0.34s	0.003s	0.0024s
FUZZY CONTROL METHOD	0.32s	0.0005s	0.0004s

Table I, compare to variable step size INC MPPT method, it can be known that fuzzy control MPPT algorithm can fast track MPP in voltage, current, and power sides. So the fuzzy control MPPT method is able to improve the dynamic and steady state performance of the PV system simultaneously. MPPT fuzzy logic controllers have been shown to perform well under varying atmospheric conditions both solar illumination and temperature.

IV. CONCLUSION

A complete fuzzy logic solar array maximum power tracking controller has been designed and simulated in the software in this paper. Simulation results show fast convergence to the MPP and minimal fluctuation about it. Fuzzy controlled the maximum power point of a PV module at given atmospheric conditions very fast and efficiently. The sudden change in atmospheric conditions shifts the maximum power point abruptly which is tracked accurately by this controller. If practically implemented, this method can increase the efficiency of the PV system by quite a large scale. Since the proposed approach requires only the measurement of PV array output current and voltage, not the measurement of solar irradiation level and temperature, it decreases the number and
cost of equipment as well as the design complexity. So the proposed algorithm is simple and can be easily implemented on any fast controller such as the digital signal processor. The advantages of the fuzzy controller are that the control algorithm gives fast convergence and robust performance
against parameter variation, and can accept noisy and inaccurate signals. The system was found to reliably stabilize the maximum power transfer in all operating conditions, and it is ready to be fitted in a larger installation.

REFERENCES

[1] Vineeta Agarwal, and Alck Vishwakarma, "A Comparative Study of PWM Schemes for Grid Connected PV Cell," in *Proc. 2007 IEEE The 7th International Conference on Power Electronics and Drive Systems*, pp. 1769-1775.
[2] Cuauhtemoc Rodriguez, and Gehan A. J Amaratunga, "Analytic Solution to the Photovoltaic Maximum Power Point Problem," *IEEE Transactions on Circuit and Systems*, Vol. 54, No. 9, pp. 2054–2060, September 2007.
[3] J. Nelson, *The Physics of Solar Cells*. London, U.K.: Imperial College Press, 2003.
[4] Z. M. Salameh, D, Fouad, and A. William, "Stepdown maximum power point tracker for photovoltaic systems," *Solar Energy*, Vol. 46, No. 5, pp. 279-282, 1991.
[5] Trishan Esram, and Patrick L. Chapman, "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques," *IEEE Transactions on Energy Conversion*, vol. 22, No. 2, pp. 439-449, June. 2007.
[6] Tsai-Fu Wu, Chien-Hsuan Chang, and Yu-Kai Chen, "A Fuzzy-Logic- Controlled Single-Stage Converter for PV-Powered Lighting System Application," *IEEE Transactions on Industrial Electronics*, Vol. 47, No. 2, pp.287-296, April 2000.
[7] Nicola Femia, Giovanni Petrone, Giovanni Spagnuolo, and Massimo Vitelli, " Optimization of Perturb and Observe Maximum Power Point Tracking Method," *IEEE Trans. on Power Electronic*, Vol. 20, No. 4, pp.963- 972, July 2005.
[8] Mummadi Veerachary, Tomonobu Senjyu, and Katsumi Uezato, "Feedforward Maximum Power Point Tracking of PV Systems Using Fuzzy Controller," *IEEE Transactions on Aerospace and Electronic System*, Vol. 38, No. 3, pp. 969-981, July 2002.[
[9] M.Godoy Simoes, and N.N.Franceschetti, "Fuzzy optimisation based control of a solar array system," *IEEE Proc.-Electr. Power Appl.*, Vol. 146, No. 5, pp.552-558, Sepetember 1999.
[10] Mummadi Veerachary, Tomonobu Senjyu, and Katsumi Uezato, "Neural-Network-Based Maximum- Power-Point Tracking of Coupled-Inductor Interleaved-Boost-Converter-Supplied PV System Using Fuzzy Controller," *IEEE Transactions on Induetrial Electronics*, Vol. 50, No. 4, pp.749-758, August 2003.