Fuzzy Logic Based MPPT Controller for Photovoltaic System

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Abstract: *Due to variation of temperature and solar intensity, the power output from photovoltaic panel will not be steady. The method of locating a point on IV and PV characteristics of PV panel, at which the output power of PV panel is maximum is known as maximum power point tracking [MPPT]. By the use of MPPT technique, maximum power can be extracted from the PV panel. There are many MPPT techniques such as Perturb & Observe method, Incremental Conductance method, fractional open circuit method and others. In this paper Perturb and Observe method and fuzzy logic controller [FLC] for maximum power point tracking are discussed. The MPP is tracked for varying and constant solar irradiance. The design and performance of P&O method and FLC are analyzed in this paper. From simulation results it is clear that FLC MPPT method is advanced technique which provides better performance when compared with P&O and other MPPT techniques.*

Keywords: Photovoltaics, Maximum Power Point Tracking (MPPT), Perturb & Observe Method, Fuzzy Logic Controller (FLC).

1. Introduction

The growth of population has considerably increased the demand for electrical energy production. To satisfy this demand, there is utter need of utilization of non renewable and renewable energy source reserves for the purpose of electricity generation. In order to reduce the consequences of non-renewable energy power plants, it is necessary to commission renewable energy power plants. In this context, PV generation plays a major key role. Renewable energy sources plays major role during generation of electricity. The daily energy requirements can be met by using renewable energy sources such as wind, hydro, PV etc for electricity generation [1].

PV arrays are installed in the areas which are of no use and where the solar energy is abundantly available for example roof tops, deserts, remote areas etc. The sun light is a clean and green energy. Sun light gets transformed into electricity by the use of solar cells. The PV cell shows non linear characteristics. From fig1 it is observed that there exists a unique location point, where the solar cell produces maximum power, at stated temperature and illumination. This unique location point is called maximum power point [MPP]. At this point the change of power rate with respect to voltage will be zero [2].

The PV panel power output depends on temperature as well as irradiation. Therefore the MPP changes with the variation in weather conditions. In PV generation the higher efficiency is achieved by properly matching the PV source impedance with the load impedance, under changing weather conditions. The technique of forcing the PV array to extract the maximum PV system power output is known as maximum power point tracking [2, 3].
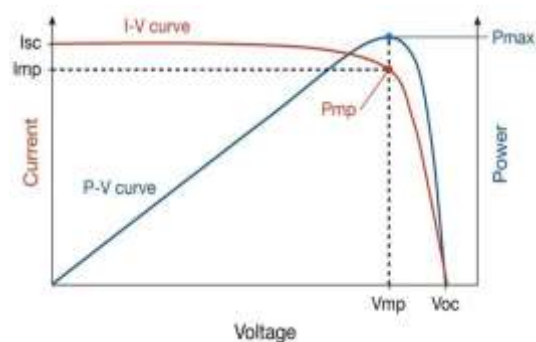

Figure 1: PV Array I-V and P-V Non Linear Characteristics Curves

The non linear current voltage characteristics have resulted in difficulty to track MPP under changing temperature and irradiance conditions. When PV panel is operated at MPP, efficiency and output power produced will be maximum. The control MPPT of solar array is an essential aspect to be considered. Numerous methods are proposed to implement MPPT. These techniques differ in cost, complexity, range of effectiveness, popularity and hardware implementation. These methods include constant voltage technique, Perturb and Observe method, fractional voltage method, Incremental Conductance technique and others [3].

This paper discusses the application of fuzzy logic controller for MPPT control. In this project both the methods are designed in detail using MATLAB/Simulink library. The design consists of array of PV panels, DC-DC Boost Converter, MPPT controller. P&O method and FLC method together with PV generation without the use of MPPT controllers are discussed in this project. Finally the comparison between the outputs of FLC and conventional P&O method is observed.
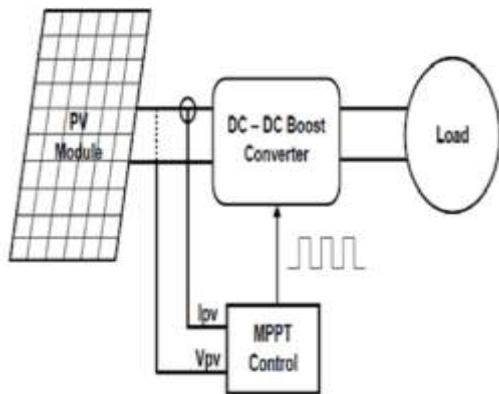
2. Proposed Work

Figure 2: Block diagram of proposed work

The figure 2 represents the block diagram of PV system with MPPT controller. It includes PV panel, DC-DC boost converter, MPPT controller and load. This method mainly works on the principle that by forcing the PV system to operate in such a direction so that the output power obtained by photovoltaic system increases. Based on load current, temperature and irradiation the output power is varied. Hence PV model cannot be designed as constant DC current source. The photovoltaic system adopts MPPT for obtaining MPP. The MPPT algorithm and the MPPT circuit govern the efficiency of MPPT. The MPPT circuit consisting of MPPT and MPPT algorithm will governs DC-DC converter. In this paper we discuss two controllers they are P&O method and FLC [4].

In this project we have used PV array which is directly available in MATLAB/SIMULINK library. Solar panel with rating 600W is used for the design. The module type is Kyocera KD205GX-LP. In this PV module one module consists of 54 cells. Number of series connected modules per string is three and the number of parallel strings is one. This PV array is connected to the boost converter. In the middle of photovoltaic array and converter the MPPT block is present. Two MPPT controllers are used they are FLC and P&O methods.

3. Perturb & Observe Method

Among many MPPT techniques Perturb & Observe method is the simplest method. Fig 3 shows the flowchart of P&O algorithm. The algorithm is initialized and measures the voltage and currents at instants k, k-1. The power is calculated at both instants k, k-1. Depending on the power and voltage variation the duty cycle is produced. If the power at instant k is more than the power at instant k-1, then the array voltage must be increased by increasing the duty cycle. The tracker will be perturbed in the same direction until MPP is reached. Similarly if the power at instant k is less than the power at instant k-1, then the array voltage must be decreased by decreasing the duty cycle. The tracker will be perturbed in reverse direction until MPP is reached [5].
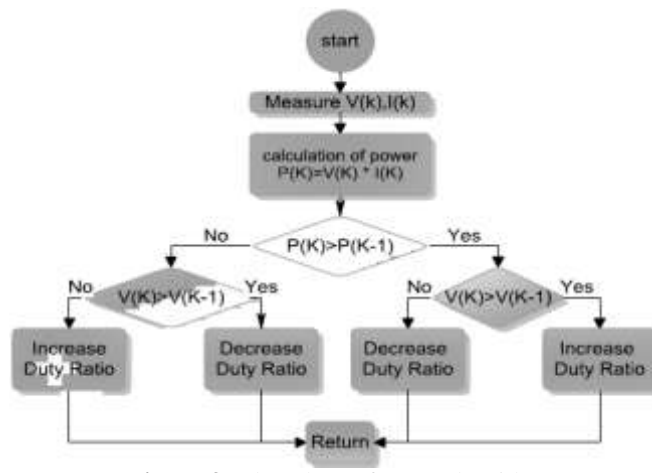

Figure 3: Flowchart of P&O algorithm

4. Design of Fuzzy Logic Controller

Whenever the input data are imprecise and mathematical modeling is infeasible in such cases FLC becomes a powerful reasoning tool. In order to design FLC specific components are required. The structure of FLC is shown in fig 4.

Preprocessing: By using some measuring instruments the inputs to FLC are obtained. These input values are hard or crisp values. Therefore it is needed to condition these input measurements, before they enter the controller. This can be achieved by the use of pre-processing block [6].
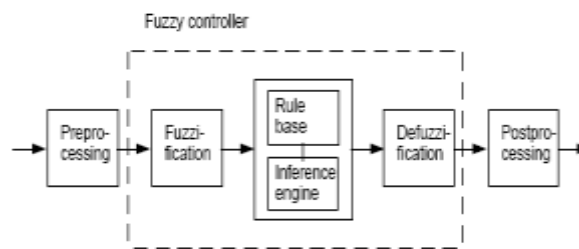

Figure 4: Fuzzy Logic Controller

Fuzzification: The actual values or crisp values i.e. dP and dV are converted into fuzzy variables. The values of power and voltage at instants K and K-1 are measured. The dP and dV values are obtained by differentiating the obtained values at K and K-1 instants. The input variables are plotted on the membership function plots with their degree of membership. These input variables are expressed in terms of fuzzy variables. The input variables dP and dV consists of 5 fuzzy sets. They are positive big [PB], positive small [PS], zero [ZE], negative small [NS], negative big [NB]. Here the actual inputs dV and dP gets converted into fuzzy sets by the use of MF's. The input variables are plotted on these fuzzy MF's with their DOM, thereby the input variables gets converted into fuzzy variables [7].

Fuzzy rule base and Inference system: By the use of fuzzy logic, the inputs are mapped and then formulated. This process is known as inference system. This process consists of MF's, logical operators and IF-THEN rules. The type of inference method used will be Mamdani system [8]. This is the method in which output MF's values will be fuzzy sets

after aggregation process. The rules are defined and stored for the fuzzy inputs, based on the requirements for our applications. In this project there are 25 sets of rules are defined by using IF-THEN rule. Table 1 gives the rule base [9]. The outputs are mapped by using IF-THEN rules for each active rule. These outputs are fuzzy values. These outputs are fuzzy sets [10].

Deffuzification: The most common 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 [2].

Table 1: Proposed Fuzzy Rule

ΔV_{pv}*[o/p]		ΔV_{pv}[i/p]				
		NB	NS	ZE	PS	PB
ΔP_{pv}[i/p]	NB	PS	PB	NB	NB	NS
	NS	PS	PS	NS	NS	NS
	ZE	ZE	ZE	ZE	ZE	ZE
	PS	NS	NS	PS	PS	PS
	PB	NS	NB	PB	PB	PS

5. Simulation Model

The implementation of MPPT using P&O and FLC in PV system is carried out by using MATLAB R2014a. The MPPT controller is placed between the output of PV panel and boost converter. Fig 5 represents the simulation model of PV generation employing P&O MPPT method. In the above figure P&O MPPT method is applied to PV system. Between PV panel and boost converter the MPPT controller with P&O technique is implemented.
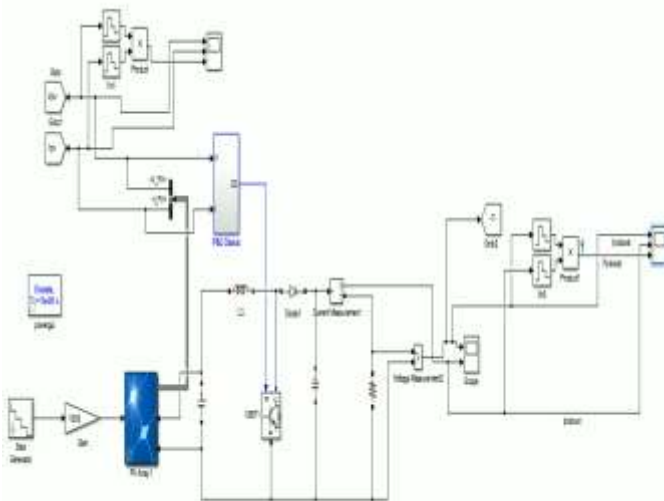

Figure 5: Matlab Simulink Model of Perturb and Observe based MPPT Technique for PV system
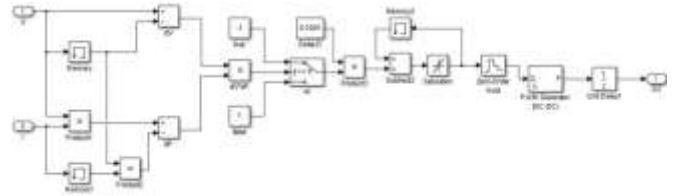

Figure 6: Matlab Simulink subsystem of P&O Method

In fig 5 the Perturb and Observe MPPT control strategy is applied to PV generation system. Fig 6 shows the P&O control structure. If the differential voltage [dV_{pv}] is positive value and the differential power [dP_{pv}] is positive value, then the array voltage should be increased. This can be achieved by providing small increment to the step size of the duty cycle. Similar situation takes place if both dV_{pv} and dP_{pv} are of negative value. Thus until MPP is reached, the operating point is moved in the same forward direction.

If the differential voltage [dV_{pv}] is positive value and the differential power [dP_{pv}] is negative value or vice versa, then the array voltage should be decreased. This can be achieved by providing small decrement to the step size of the duty cycle. Thus the operating point is moved in reverse direction until MPP is reached.
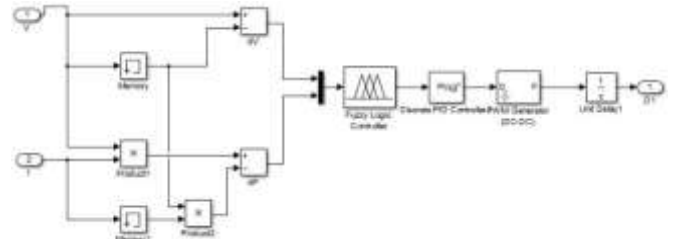

Figure 7: Matlab Simulink Subsystem of Fuzzy Logic Method

Fig 7 shows FLC control strategy and placed the P&O controller in fig 6 is replaced by fuzzy logic controller MPPT, implemented in PV generation. Here the inputs for FLC are change in change in PV voltage dV_{pv} and PV array power dP_{pv}. The value of change in input is the difference between the value of input in the present instant 'K' and the previous instant 'K-1'. The rules are defined by FLC as given in Table 1. As per the rules the duty cycle is adjusted such that the array voltage is increased or decreased so that MPP is reached.

6. Results & Discussions

The models discussed in the present paper have been modeled using MATLAB R2014a and simulated using simulink environment. The simulated results shown in fig 8, 9 and 10 represents the output voltage, output current and power output of boost converter for the photovoltaic generation which doesnot contain MPPT controller, P&O controller and FLC controllers respectively. Here the irradiance is varied as 1000W/m^2, 800W/m^2, 600W/m^2, 400W/m^2, 200W/m^2, again 1000W/m^2 at constant temperature of 25°C. It is observed that the initial oscillations are more.
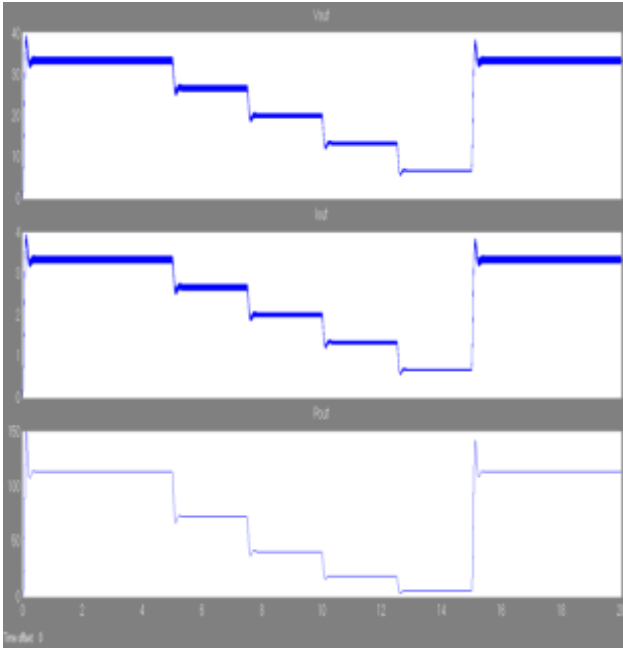
Figure 8: Voltage, Current and Power Outputs of boost converter without using MPPT techniques for PV system for fixed temperature and varying irradiance

Figure 9: Voltage, Current and Power Outputs of boost converter with P&O based MPPT Technique for PV system for fixed temperature and varying irradiance
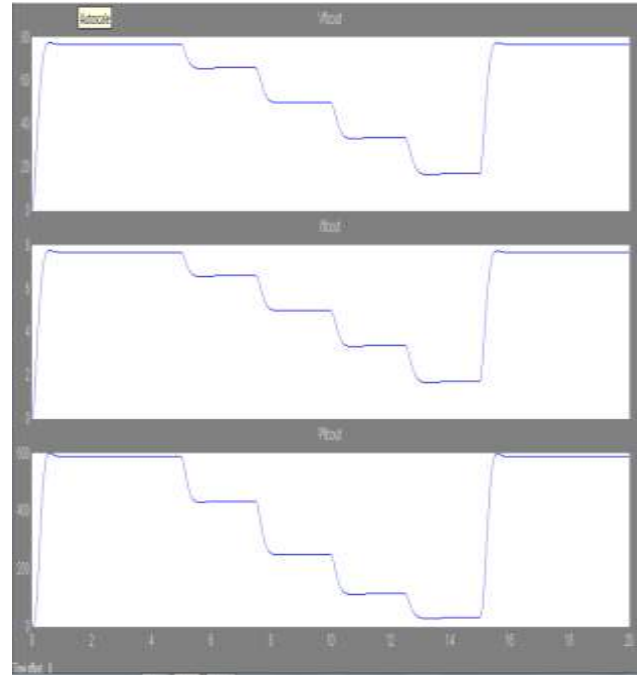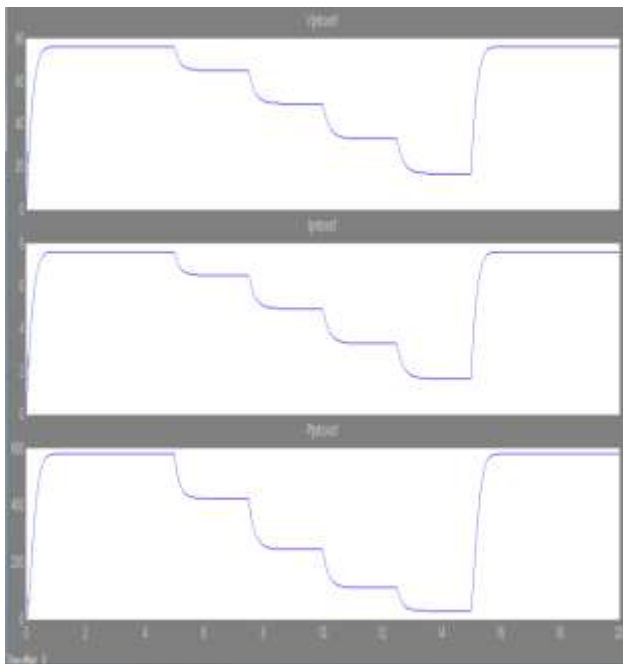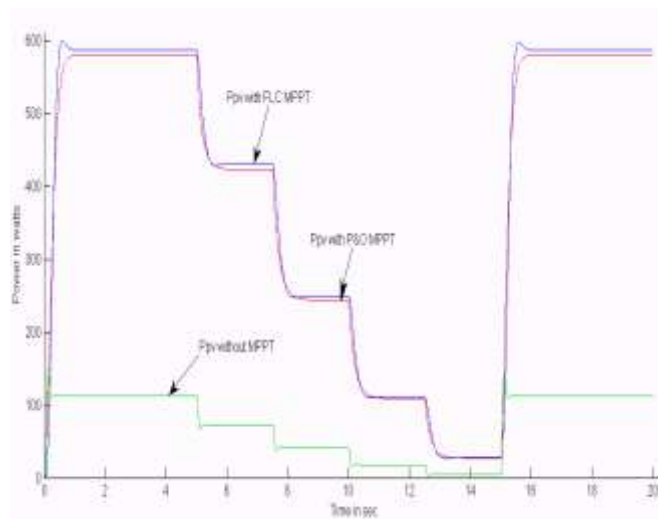

Figure 10: Voltage, Current and Power Outputs of boost converter using FLC based MPPT Technique for PV system for fixed temperature and varying irradiance

Figure 11: Comparative Analysis of Different MPPT Methods

Table 2: Comparision of P&O and FLC

Methods	Without MPPT	P&O MPPT	FLC MPPT
Time [s]	3	3	3
Vpv [V]	33.14	76.175	76.59
Ipv [A]	3.4	7.6176	7.66
Power [W]	113.8	580.27	586.654

7. Conclusion

PV system without having MPPT controller is also implemented. Simulation is carried for constant and varying irradiance keeping temperature constant. After simulation it is observed from the results given in table2, that at instant 3sec with irradiance of 1000W/m2, the power output from

boost converter of PV system without using MPPT will be equal to 113.8W, by using P&O based MPPT will be equal to 580.27W and by using FLC based MPPT will be equal to 586.65W. From fig11 it is noticed that the power output obtained by employing FLC based MPPT will be maximum. The output of PV system consisting FLC MPPT will have lesser oscillations. For different weather conditions, FLC tracking mechanism tracks MPP more accurately. Therefore it is concluded that FLC MPPT has higher performance when compared to P&O method.

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