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Fuzzy Logic Based MPPT Algorithm for Solar PV systems

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Abstract:
The studies on photovoltaic systems are extensively increasing now days. The various techniques and algorithms are proposed to increase the efficiency of solar systems. In this paper, a maximum power point tracking algorithm based on fuzzy logic is presented. The designing of whole system is done in MATLAB/Simulink environment. The fuzzy logic controller is designed to give a good response to the variations in solar radiation and cell's temperature. The controller is used to change the duty cycle of DC-DC converter which is the control parameter. The simulation results show that the proposed system effectively increase the efficiency of the system.

Key words: *Fuzzy Logic Controller, MPPT, MATLAB/Simulink, DC-DC converter*

1. Introduction

A great attention has been achieved by the Solar Photovoltaic Systems in research field due to energy crisis and increasing pollution. The main challenge is to increase the efficiency of the solar photovoltaic systems. The other drawback of Solar PV systems is the variation in output voltage with variations in solar radiation and temperature. Several techniques and algorithms have been proposed in this area to overcome the drawbacks of the Solar PV system. PV modules have unique power vs voltage (P-V) characteristics. From the P-V characteristics, PV systems must be operated at a maximum power point (MPP) of specific current and voltage values so as to increase the PV efficiency. For any PV system, the output power can be increased by tracking the MPP of the PV module by using a controller connected to a buck-boost converter. One of such techniques is the use of Fuzzy Logic controllers in Maximum Power Point Tracking of the Solar PV systems. The Maximum power point changes with the variation in the solar radiation and temperature, so FLC is used to force the PV system to operate at the maximum power point.
In this paper, a highly robust Fuzzy Logic based controller is designed in MATLAB/Simulink environment. The FLC is used in Solar PV system along with a DC-DC buck boost converter to increase the efficiency of the Solar PV system. In the Fuzzy Logic Controller the modifications are done in Rule base and membership functions according to the variations in solar radiation and temperature. The output of the FLC is the change in the duty cycle of the DC-DC buck boost converter.

2. Modeling of PV System

The MATLAB/Simulink model of a Solar PV cell is designed by using basic equations. A typical equivalent circuit of solar cell is shown in figure 1.

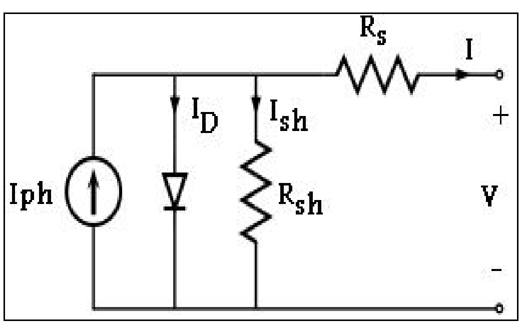


Figure 1: Equivalent circuit of solar cell

It consists of basically a current source, doide, series resistance and shunt resistance. The Solar Module and Arrays are designed by connecting multiple solar cells(36 or 72) in series and several modules in parallel respectively. The solar PV cell developed in MATLAB/Simulink environment is shown in figure 2.

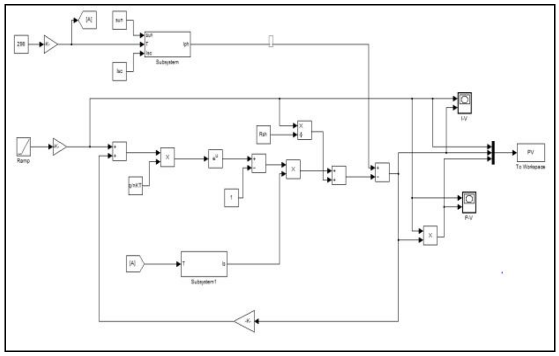
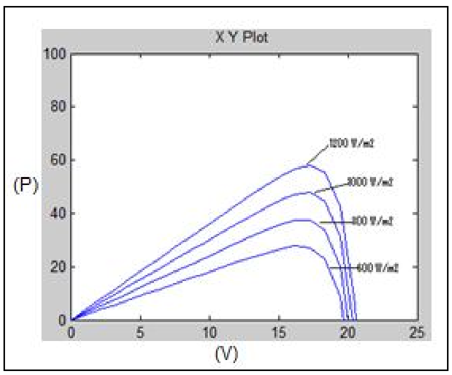


Figure 2: Solar cell model

The PV curves of solar module obtained by varying solar radiation and temperature are shown in figure 3 and 4 respectively.



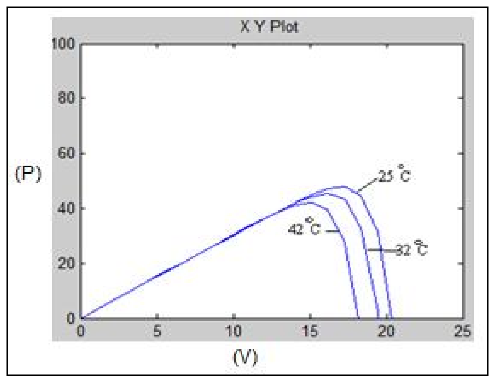


Figure 3: PV curves with Soalr radiation variation
Figure 4: PV curves with temperature variation

3. Fuzzy logic controller

The Fuzzy logic controller uses the fuzzy logics to make the decisions and to control the output of the controller. The main components in fuzzy logic based MPPT controller are fuzzification, rule-base, inference and defuzzification as shown in figure 5.

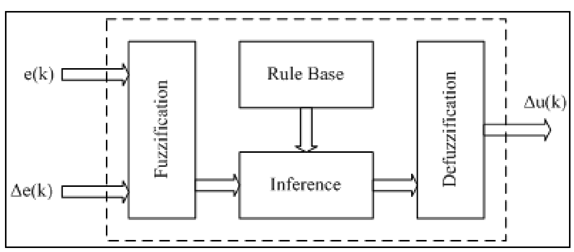


Figure 5: Fuzzy Logic basic block diagram

There are two inputs to the controller – error e(k) and change in error Δe(k). The Fuzzification block converts the crisp inputs to fuzzy inputs. The rules are formed in rule base and are applied in inference block. The defuzzification converts the fuzzy output to the crisp output. The fuzzy inference is carried out by using Mamdani's method, and the defuzzification uses the centre of gravity to compute the output of this FLC which is the change in duty cycle.

4. Methodology

The fuzzy logic controller used in the system has two inputs. The error is the change in the power with respect to the change in the voltage. The equations for error and change in error is given by

$$E(k) = \frac{P_{ph}(k) - P_{ph}(k-1)}{V_{ph}(k) - V_{ph}(k-1)} \quad (1)$$

$$CE(k) = E(k) - E(k-1) \quad (2)$$

The output of the controller is ΔD, change in the duty cycle of the DC-DC buck boost converter.
In the rule base, there are 5 membership functions of error and change in error each, whereas, the output i.e. change in duty cycle also has 5 membership functions. There are 17 rules in the rule base. The rules are formed as shown in table 1.

CE / E	NB	NM	ZE	PM	PB
NB	-	-	NB	NB	NB
NM	-	-	NM	NM	NM
ZE	NM	ZE	ZE	ZE	PM
PM	PM	PM	PM	-	-
PB	PB	PB	PB	-	-

Table 1: Rule Base

The Input Output membership functions are shown in figures 6, 7 and 8 respectively.

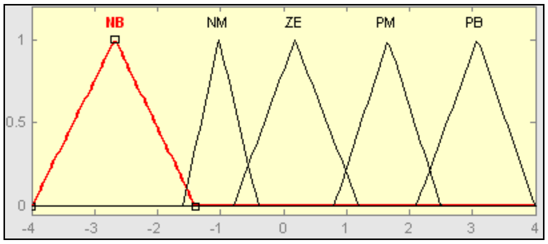


Figure 6: Membership functions of E(k)

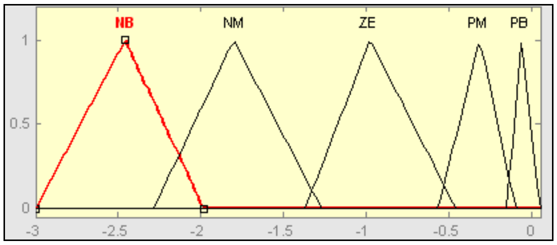


Figure 7: Membership functions of ΔE(k)

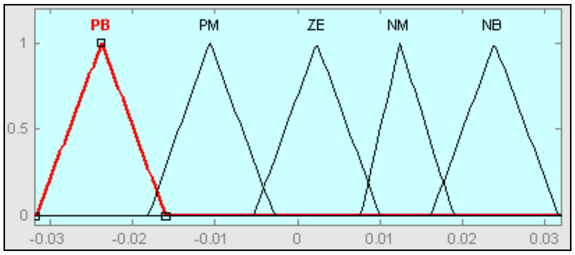


Figure 8: Membership functions of ΔD

The developed MATLAB/Simulink model is shown in figure 9.

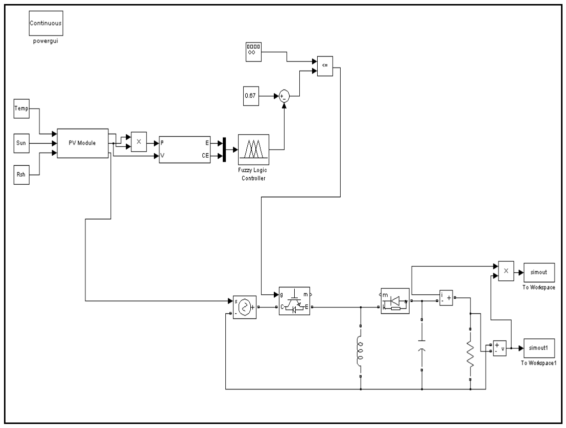


Figure 9: Simulink Model FLC based PV system

5. Results and Conclusion

The proposed model was simulated in MATLAB/Simulink environment. The system was first simulated by varying solar radiation and then by varying temperature. The results show that the output power and voltage obtained from Fuzzy logic based MPPT system is more than that of conventional solar module. Also, rapid change in solar radiation and temperature does not affect the performance of the system. Hence, the overall system efficiency has been increased.

The results conclude that by using Fuzzy logic controller in solar PV systems, the efficiency of the system can be increased. The designing of controller is also simple than other conventional MPPT techniques.

FUTURE SCOPE

The designed model can be implemented on hardware using PIC microcontrollers. The Fuzzy logic controller can be used in conjunction with neural network techniques for further increase in system performance and efficiency.

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