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Application of Fuzzy Based MPPT Algorithm to Grid Connected PV System

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Abstract

This paper presents an efficient fuzzy logic based maximum power point tracking (MPPT) for a grid connected PV system. A DC-DC boost converter topology is used for the implementation of the proposed MPPT. The PV array, boost converter, voltage source converter (VSC) and fuzzy logic (FL) MPPT are modeled using Matlab/Simulink software. The proposed FL based MPPT continuously controls the duty cycle of the boost converter to maintain the constant DC voltage. A detailed simulation study was carried out and their results are presented. Thesimulation results revealed that the maximum power could be extracted from the PV array by this MPPT with minimum loss and oscillations at MPP under different irradiance and temperature levels.

Keywords:***Fuzzy logic (FL), Maximum power point tracking (MPPT), photovoltaic (PV), Grid connected.***

I. INTRODUCTION

Because of the pollution and environmental impacts caused by fossil fuels, renewable energy sources replace fossil fuels. Due to the decrease in PV module cost, fast development in the technology, solar PV system is frequently used in power generation. However, the conversion efficiency of the PV panel is low. The output power of PV is affected by solar irradiance level and temperature. The increase in solar radiation increases the current and the output power. The increase in temperature decreases the output power. Due to this nonlinearity, a MPPT controller is required between the PV panel and load to operate the PV system at MPP [1-3].In literature, many MPPT algorithms are proposed like perturb and observe (P&O), adaptive neuro fuzzy inference system (ANFIS) incremental conductance (INC), fuzzy logic based (FL) and artificial neural network (ANN) [3-8].ANN and fuzzy logic are the most common intelligent controllers used for many applications like optimization problems,sensorless drive control [9] and tuning of controllers. Due to the simplicity and memory requirement, P&O and INC are commonly used [9-10]. However, the P&O algorithm perturbs around the MPP and its accuracy is less. The conventional INC algorithm is slow and accuracy is medium. No mathematical modeling is required for the ANN and ANFIS networks but a separate huge data set is required for training and testing of the networks.

In this paper, fuzzy logic is used for the development of the MPPT algorithm that is best suited for dynamic climatic conditions. However, the selection of membership function greatly affects the system performance. This paper presents the design and implementation of fuzzy logic based MPPT for a boost converter to produce constant DC voltage under any dynamic condition.
The duty cycle of the boost converter is controlled to give better performance to the system.

II.PROPOSED METHOD - FUZZY LOGIC BASED MPPT

Figure 1 shows the basic block diagram of the fuzzy inference system.The rule base contains fuzzy IF-THEN rules and the membership functions are defined by the database. Based on these rules,the required operation is performed by the decision-making unit. The crisp quantities are converted into fuzzy quantities by the fuzzification interface unit. The defuzzification interface unit converts the fuzzy quantities into crisp quantities. The linguistic variables used are defined as NB- Negative Big, NS-Negative Small, ZE-Zero, PS-Positive Small and PB-Positive Big.

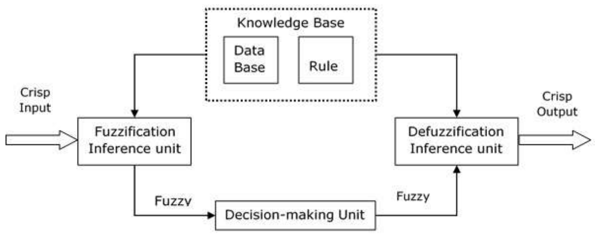

Fig.1Block diagram of fuzzy interference system

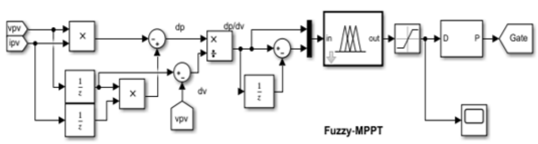

Fig.2 Fuzzy logic based MPPT algorithmThe fuzzy logic based MPPT is developed in the Simulink model as shown in Figure2 and the Fuzzy toolbox is used for implementation. Error E (K) and change in error CE (K) as written in equations (1) and (2)are the two inputs and the duty cycle is the output of the FLC. The duty cycle D is given toDC-DC PWM generator block to generate PWM pulses to the boost converter as shown in Figure 2.

$$E\ (K) = \Delta I/\ \Delta V + I\ /V = \Delta P\ /\Delta V = \Delta P/\ \Delta I \qquad (1)$$

$$\text{CE}\ (K) = E\ (K) - E\ (K-1) \qquad (2)$$

$$\Delta I = I\ (K) - I\ (K-1) \qquad (3)$$

$$\Delta V = V\ (K) - V\ (K-1) \qquad (4)$$

$$\Delta P = P\ (K) - P\ (K-1) \qquad (5)$$

Table1. Fuzzy rules

ΔP / ΔV	NB	NS	ZE	PS	PB
NB	PB	PS	NB	NS	NS
NS	PS	PS	NB	NS	NS
ZE	NS	NS	NS	PB	PB
PS	NS	PB	PS	NB	PB
PB	NB	NB	PB	PS	PB

III. RESULTS AND DISCUSSION

A detailed simulation work is carried out using Matlab/Simulink software to prove the superiority of the proposed MPPT. A 100kW grid connected PV system is designed (Fig 3) using the simulation parameters shown in Table2.The output voltage of the boost converter is maintained at 500 V DC throughout the simulation period with the use of this proposed MPPT algorithm. The DC voltage is given as input to the three level VSC to generate stepped output voltage as shown in the simulation results (Figures 4 and 5). The developed fuzzy linguistic rules are shown in Table1. There are 5 membership functions and 25 rules generated by this FLC. Triangular membership functions are used in this work with the universe of disclosure lying between -2 and +2.

LC filters are used to reduce the ripples and the pure AC voltage is supplied to the 100kW grid. Initially, the irradiance level is at 1000W/m^2 at 25^{0}C the grid power is almost equal to 100kW and the duty cycle of the boost converter is 0.5. At t=1 s, it is decreased to 200 W/m^2 power is correspondingly decreased to 20kW and the duty cycle is controlled at 0.468. The simulation results show the better tracking capability of the system and minimum power loss and oscillations at MPP.Figure 5 shows that a constant 500 V DC is maintained at the output of the boost converter under varying climatic conditions.

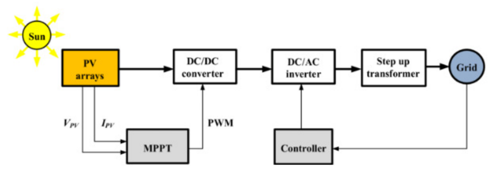

Fig3. Grid connected PV system

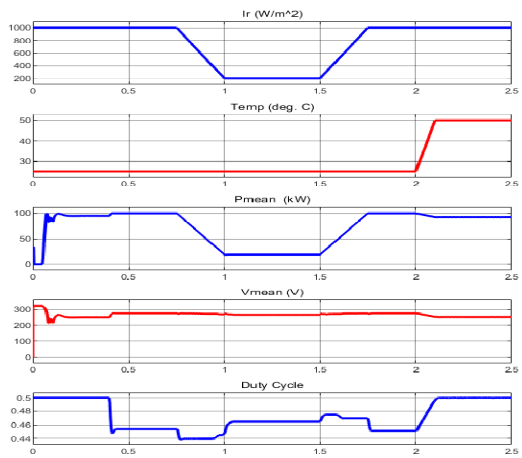

Fig.4 Simulation results of FL based MPPT

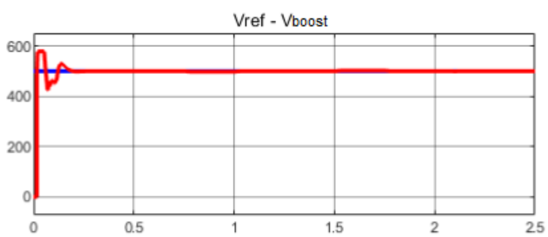

Fig. 5 Boost converter output voltage

Table 1. Simulation Parameters

Parameter	Value
PV array-100kW Open circuit voltage (Voc)	64.2 V
Maximum voltage (Vm)	54.7 V
Short circuit current (Isc)	5.96 A
Maximum power (Pm)	305.2 W
Diode saturation current (Is)	1.1753e−08
Shunt Resistance (Rsh)	993.51 Ω
Maximum Power Current (Im)	5.58 A
Series Resistance (Rs)	0.0379 Ω
Boost Converter Inductance	5.5 mH
Input Capacitance	110 µF
Output Capacitance	15 mF
Switching frequency	5kHz

IV. CONCLUSION

The design and implementation of a fuzzy logic based MPPT algorithm under dynamic climatic conditions are presented in this paper. The FL based MPPT algorithm is used to control the duty cycle of the boost converter continuously to get the constant DC voltage without ripples. The results of the simulation study show better tracking efficiency and minimum oscillations at MPP under varying irradiance and temperature levels.

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