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A Fuzzy Logic Control Method for MPPT to Improve Solar System Efficiency

Mr. A.A. Sutar[1], Mr. M.C. Butale[2]

[1]Lecturer, Dept. of Electrical Engineering, SBGI College, Miraj, Maharashtra, India
[2]Assistance Professor, Dept. of Electrical Engineering, PVPIT College, Maharashtra, India.

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Abstract - *Maximum power point trackers are so important in photovoltaic systems to increase their efficiency. Many methods have been proposed to achieve the maximum power that the PV modules are capable of producing under different weather conditions. This paper proposed an intelligent method for maximum power point tracking based on fuzzy logic controller. The system consists of a photovoltaic solar module connected to a DC-DC Buck-boost converter. The system has been experienced under disturbance in the photovoltaic temperature and irradiation level. The simulation results show that the proposed maximum power tracker could track the maximum power accurately and successfully in all condition tested. Comparison of different performance parameters such as: tracking efficiency and response time of the system shows that the proposed method gives higher efficiency and better performance than the conventional perturbation and observation method*

1. INTRODUCTION

Energy has the great importance for our life and economy. The energy demand has greatly increased due to the industrial revolution. Fossil fuels have been started to be gradually depleted. The sustainability of our civilization is seriously threatened. On the other hand the greenhouse gas emissions are still increasing due to the conventional generation of energy. It is a really global challenge to reduce carbon dioxide emissions and ensuring secure, clean and affordable energy, and to achieve more sustainable energy systems. Renewable energy sources are considered as a perfect option for generating clean and sustainable energy.

The growth of the world's population involves increased needs of sustainable energy resources. The energy consumption, always increasing, reduces the fossil fuel reserves (oil, coal…) approaching their exhaustion limit. The consequences of the massive exploitation of these natural reserves could be severe: the global industry will suffer from the shortage of fossil fuels and their burning will generate air pollution and global warming gases. The use of renewable energy sources is a solution that could reduce these problems, mainly thanks to their insignificant environmental impact and to the fact that these energies are abundant and available.

The photovoltaic renewable energy generation is attracting a growing amount of political and commercial interest. The growth of photovoltaic (PV) systems has exceeded the most optimistic estimations because of the many merits they have such as providing a green renewable power by exploiting solar energy, autonomous operation without any noise generation. In addition their easy use make them suitable to both home energy applications and small-scale power generation applications.

However, the PV systems are subject to power fluctuations caused by atmospheric conditions. It therefore becomes important to operate PV energy conversion systems around the maximum power point (MPP) in order to improve the generated power for a given set of atmospheric conditions.

1.1 Different MPPT control Methods

1. Fractional I_{sc}
2. Fractional V_{oc}
3. Incremental Conduction
4. Perturb and Observe
5. Fuzzy Logic
6. Neural Network

1.2 Literature review

Renewable energy from solar photovoltaic (PV) is the most ecological type of energy to use. It is based on a clean and efficient modern technology, which offers a glimmer of hope for a future based on sustainable and pollution-free technology. The importance of using renewable energy system, including solar photovoltaic (PV) has been attracted much these days, because the electricity demand is growing rapidly all over the world. The solar energy is directly converted into electrical energy by solar PV module. Each type of PV module has its own specific characteristic corresponding to the surrounding condition such as irradiation, and temperature and this makes the tracking of maximum power point (MPP) a complicated problem. To overcome this problem, many maximum power point tracking (MPPT) control algorithms have been presented. Fuzzy Logic (FL) has been used for tracking the MPP of PV modules because it has the advantages of being robust, relatively simple to design and does not require the knowledge of an exact model. In this paper, mathematical models of the PV module, DC-DC converter, are used in the study of FL based MPPT algorithm

This paper proposes Maximum Power Point Tracking (MPPT) of a photovoltaic system under variable temperature and solar radiation conditions using Fuzzy Logic Algorithm. The cost of electricity from the PV array is more expensive than the electricity from the other non- renewable sources. So, it is necessary to operate the PV system at maximum efficiency by tracking its maximum power point at any weather conditions. Boost converter increases output voltage of the solar panel and converter output voltage depends upon the duty cycle of the MOSFET present in the boost converter. The change in the duty cycle is done by Fuzzy logic controller by sensing the power output of the solar panel. The proposed controller is aimed at adjusting the duty cycle of the DC-DC converter switch to track the maximum power of a solar cell array. MATLABI Simulink is used to develop and design the PV array system equipped with the proposed MPPT controller using fuzzy logic

2. Problem Statement

Performance Improvement of Solar System by MPPT Tracking algorithm using Fuzzy Logic Control Technique.

3. Objectives

The main objective is to increase the efficiency of the solar panel by using MPPT tracking system

4. Methodology

Regardless of the ultimate destination of the solar power, though, the central problem addressed by MPPT is that the efficiency of power transfer from the solar cell depends on both the amount of sunlight falling on the solar panels and the electrical characteristics of the load. As the amount of sunlight varies, the load characteristic that gives the highest power transfer efficiency changes, so that the efficiency of the system is optimized when the load characteristic changes to keep the power transfer at highest efficiency. This load characteristic is called the maximum power point (MPP) and MPPT is the process of finding this point and keeping the load characteristic there. Electrical circuits can be designed to present arbitrary loads to the photovoltaic cells and then convert the voltage, current, or frequency to suit other devices or systems, and MPPT solves the problem of choosing the best load to be presented to the cells in order to get the most usable power out.

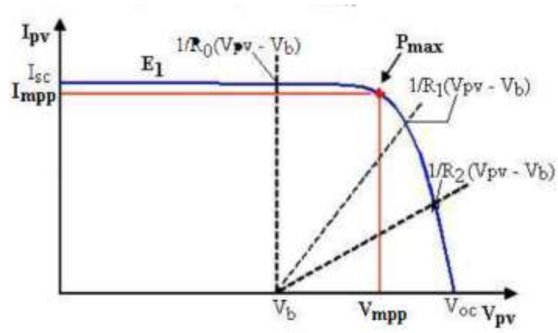

Fig.1 V-I Characteristics of Solar Panel

When a load is directly connected to the solar panel, the operating point of the panel will rarely be at peak power. The impedance seen by the panel derives the operating point of the solar panel. Thus by varying the impedance seen by the panel, the operating point can be moved towards peak power point. Since panels are DC devices, DC-DC converters must be utilized to transform the impedance of one circuit (source) to the other circuit (load). Changing the duty ratio of the DC-DC converter results in an impedance change as seen by the panel. At a particular impedance (or duty ratio) the operating point will be at the peak power transfer point. The I-V curve of the panel can vary considerably with variation in atmospheric conditions such as radiance and temperature. Therefore, it is not feasible to fix the duty ratio with such dynamically changing operating conditions.

MPPT implementations utilize algorithms that frequently sample panel voltages and currents, then adjust the duty ratio as needed. Microcontrollers are employed to implement the algorithms. Modern implementations often utilize larger computers for analytics and load forecasting.

Solar energy is viewed as clean and renewable source of energy for the future. So the use of Photovoltaic systems has Increased in many applications. Wide spread usage has led to reduced costs in the manufacturing of solar panels. But one of the most important issues remains the low efficiency of a solar panel due to factors like solar isolation, clouds and shading effect. During cloudy weather due to varying isolation levels the output of the panel keeps varying. A maximum power point tracking algorithm is required to increase the efficiency of the solar panel as it has been found that only 30-40% of energy incident is converted into electrical energy. The design of DC-DC converter (Boost converter) helps in increasing the output of the panel thus increasing the efficiency and the output voltage using proper control technique. This paper deals with the development of a fuzzy logic control for MPPT to track the maximum power point and also compensate for fluctuating.

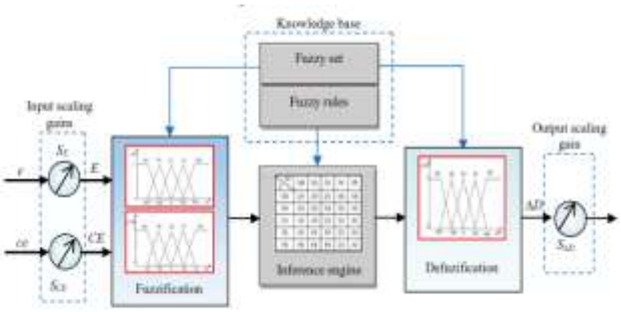

Fig.2 Structure of Fuzzy logic Controller

4.1 Fuzzification

The fuzzification makes it possible to pass from the real variables to fuzzy variables. The actual voltage (V) and current (I) of PV generator can be measured continuously and the power can be calculated (P = V×I). The control is determined on the basis of satisfaction of two criteria relating to two input variables of proposed controller, namely error E (which represents the slope of P-I characteristic) and change of this error (CE), at a sampling instant k .

The variable E and CE are expressed as follows,

$$E(k) = \frac{P(k) - P(k-1)}{I(k) - I(k-1)}$$

$$CE(k) = E(k) - E(k-1)$$

Where P(k) and I(k) are the power and current of the PV generator, respectively. Therefore, the input E(k) shows if the operating point at the instant k is located on the left or on the right of the MPP on the P-I characteristic, while the input CE(k) expresses the displacement direction of this point . The change in duty ratio of the DC-DC converter is used as the output of proposed controller. Therefore, the control is done by changing this duty ratio according to the slope E(k) in order to bring back the operation point on the optimal point where the slope is zero. the input variables of the fuzzy controller (E, CE) are derived from the actual signals (e, ce)by multiplying with the corresponding scale gains (SE, SCE), and then converted to the linguistic variables such as PB (positive big), PS (positive small), Z0 (zero), NS (negative small), NB (negative big) using basic fuzzy subset. the membership grades of five basic fuzzy subsets for input and output variables. The interference engine apply the rules to fuzzy logy input to determine the fuzzy outputs. Therefore , before the rules can be evaluated the crisp input values must be fuzzified to obtain the corresponding linguistic values and the degree to which each part of the antecedent has been satisfied for each rule [16]. Table.2 shows the rule table of fuzzy controller, where all the entries of the matrix are fuzzy sets of error (E), change of error (CE) and change of duty ratio (ΔD) to the converter.

4.2 Defuzzification

It was seen that the inference methods provide a function for the resulting membership variable; it thus acts of fuzzy information. Being given that converter DC-DC requires a precise control signal D at its entry it is necessary to envisage a transformation of this fuzzy information into deterministic information, this transformation is called defuzzification. Defuzzification can be performed normally by two algorithms: Center of Area (COA) and the Max Criterion Method (MCM). The most used defuzzification method is that of the determination of the centre of gravity (COA) of final combined fuzzy set. The final combined fuzzy set is defined by the union of all rule output fuzzy set

4.3 Inference engine

The interference ingine apply the rules t the fuzzy inputs (that where generated from the fuzzification process) to determine the fuzzy outputs. Therefore , before the rules can be evaluated , the crisp input values must be fuzzified to obtain the corresponding linguistic values (that are necessary to determine the active or fired rule) and the degree to which each part of the antecedent has been satisfied for each rule. Following table shows fuzzy controller , where all the entries of the matrix are fuzzy set of error (E) change of error(CE) change of duty ratio (ΔD)to the convertor.

Fuzzy rules

E	*CE*				
	NB	NS	ZO	PS	PB
NB	ZO	ZO	NB	NB	NB
NS	ZO	ZO	NS	NS	NS
ZO	NS	ZO	ZO	ZO	PS
PS	PS	PS	PS	ZO	ZO
PB	PB	PB	PB	ZO	ZO

IF *E* is PB AND *CE* is NB THEN Δ*D* is PB

The 25 control fuzzy rules included in Table.2 can be presented in 3-dimensions (3-D) graph as shown in figure. These rules are employed for the controlling of the DC-DC buck converter such as the MPP of the PV generator is reached. As shown in the Table 2, the main idea of the rules is to bring operating point to the MPP by increase or decreasing the duty ratio depending on the position of the operating point from the MPP. If the operating point is distant from MPP, the duty ratio will be increased or decreased is largely. Fig.7(b) demonstrates an example of control rule: IF E is PB AND CE is NB Then ΔD is PB. This implies that if operating point is distant from MPP towards left hand side and the change of slope in P- I characteristic is big in the opposite direction, then the duty ratio is largely increased.

In general the fuzzy control uses one of the following methods: Max-Min, Max-Prod, Somme-Prod inference technique. In our case we used the inference method of Mamdani, which is the Max-Min fuzzy combination.

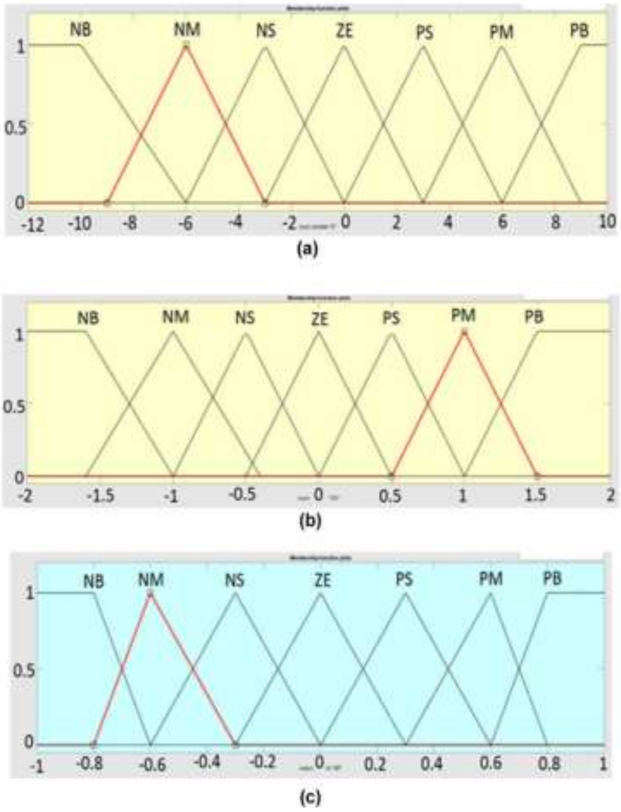

Fig.3 (a) The input of FLC (Error, E), (b) The input of FLC (Change of error, CE) (c)The output of FLC (Duty, D).

5. CONCLUSION

In this work, an adaptive fuzzy controller is used to track the maximum power point in photovoltaic systems. The gain of the controller is adjusted by fuzzy rules defined on error and change of error. Simulation results show that the proposed controller can track the maximum power point with better performances when compared to its conventional counterpart. Thus the introducing of an adaptive gain in the structure of conventional fuzzy controllers is well justified.

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BIOGRAPHIES

Lecturer,
Department of Electrical Engineering,
Sanjay Bhokare Group of Institute
Miraj, Sangli

Assistance Professor,
Department of Electrical Engineering,
Padmabhushan Vasantraodada Patil Institute of Technology,
Budhgaon, Sangli.