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Comparison Between MPPT P&O and MPPT Fuzzy Controllers for Photovoltaic Maximum Power Point Tracking

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Abstract
The main advantage of using fuzzy controller for instance solar is the reduction of effect of uncertainty in system control. This paper presents a comparative study between two controller's methods for Maximum Power Point Tracking (MPPT) for photovoltaic (PV) systems which maximizes the power that can be transferred from the PV system to an electrical system. I design and simulate a MPPT controller using FLC in MATLAB/FUZZY TOOL BOX/SIMULINK. The results validate that MPPT can significantly increase the efficiency of energy production from PV.

Keywords: Photovoltaic array, Maximum power point tracking (MPPT), Fuzzy controller, Perturb & Observe

Introduction

There are many innovative methods and all of them use this fact that the power voltage curve slope has a value of zero in the maximum point. In a generalized classification, this method can be divided into for mains categories: Control Algorithm, Control variable, Math-based methods, and intelligent control. If light intensity and temperature don't change, the MPP will occur in a constant voltage. With modifying level of voltage to this constant voltage will be tracked MPP. But if environmental conditions change with time, voltage in MPP will change too. In this case for a better performance, a more complicated controller is required which its parameters with changing atmospheric conditions. Serial or parallel cells generate photovoltaic array in order to receive more power. Fuzzy method is much sought after due to its suitable answer towards uncertainty present in the system and it's desirable speed and precision, A control scheme is presented which allows better control of the converter current reference using voltage and current from the PV system as inputs. The performance of the proposed FLC is tested by simulation and the results show that the FLC is faster in finding the maximum power point than the conventional perturbation and observation method.

Maximum Power Point Tracking

For any PV system, the output power can be increased by tracing the maximum power point (MPP) of the system. To achieve this, a maximum power point tracking (MPPT) controller is required to track the optimum power of the PV system. An MPPT controller is usually connected to a boost converter between a PV panel and load as shown in Fig. 1.

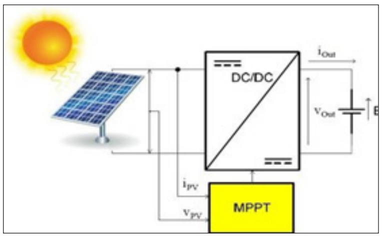

Figure 1: A MPPT controller in a PV system

Many researches has been developed concerning the different algorithms for the maximum power point tracking (MPPT) considering the variations of the system parameters and/or weather changes (Liu et al., 2004; Elgendy et al., 2012), such as perturb and observe method, open and short circuit method, incremental conductance algorithm, fuzzy logic and artificial neural network. The block diagram in Fig.1 presents a PV generator with MPPT (Ameur, 2009; Bernardo, et al., 2009). The load or the battery can be charged from a PV panel using a MPPT circuit with a specific controller to track the peak power generated by the PV panel.

A. P&O Algorithm

P&O method involves a perturbation in the operating voltage of the PV array, while hill climbing strategy introduces a perturbation in the duty ratio of the power converter. A main problem in their methods are oscillation at around of the MPP. The oscillation can be minimized by reducing the perturbation step size. But, a smaller perturbation size slows down the MPPT. Another problem is MPPT failure under rapidly changing atmospheric conditions. Flow chart of P&O method is described in fig.2.

Figure 3: Flow Chart of P & O Method.

Mppt Using Fuzzy Logic Controller

MPPT using Fuzzy Logic Control gains several advantages of better performance, robust and simple design. In addition, this technique does not require the knowledge of the exact model of system. The main parts of FLC, fuzzification, rule-base, inference and defuzzification, are shown in Fig. 4. In the proposed system, the input variables of the FLC are the change in PV array power (ΔP_{pv}) and the change in PV current (ΔI_{pv}), whereas the output of FLC is the magnitude of the change of boost converter current reference (ΔIref). The current reference is the command for controlling the current drawn from the PV. Flow chart of the proposed FLC is shown in Fig. 4. The equations for ΔPpv and ΔIpv are given as follows:

$$P_{pv}^{k} = V_{pv}^{k} \cdot I_{pv}^{k} \quad (1)$$
$$\Delta P_{pv}^{k} = P_{pv}^{k} - P_{pv}^{k-1} \quad (2)$$
$$\Delta I_{pv}^{k} = I_{pv}^{k} - I_{pv}^{k-1} \quad (3)$$

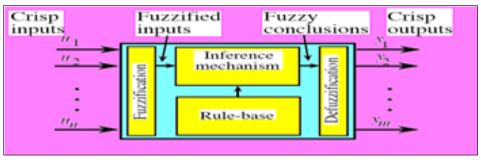

Figure 4: Structure of Fuzzy logic controller

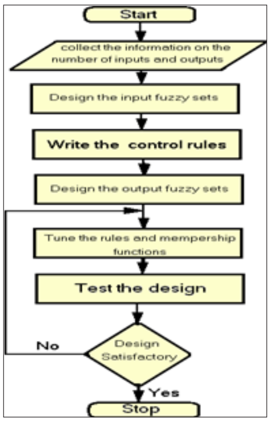

Figure 5: Flow Chart of Fuzzy Logic method

The universe of discourse for the first input variable (ΔP_{pv}) is assigned in terms of its linguistic variable by using seven fuzzy subsets which are denoted by NB (negative big), NM (negative medium), NS (negative small), Z (zero), PS (positive small), PM (positive medium), and PB (positive big). The membership functions for the variable are shown in Figure 6(a). Figure 6(b) shows the universe of discourse for the second input variable (ΔIpv) which is classified into 3 fuzzy sets, namely, Negative (N), Zero (Z) and Positive (P). Figure 7 depicts the universe of discourse for the output variable, ΔI_{ref}.

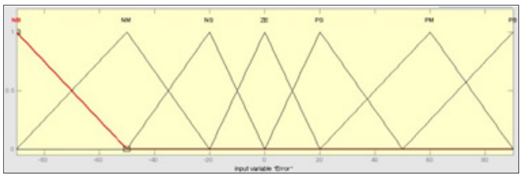

Figure 6: (a) Membership Functions of the 1st Input Variable 1st (ΔP_{pv})

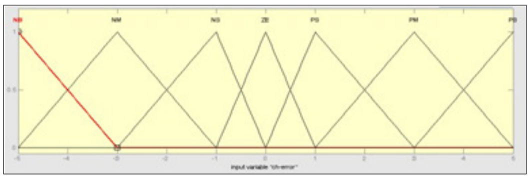

Figure 6: (b) Membership Functions of the 2nd Input Variable 2nd (ΔI_{pv})

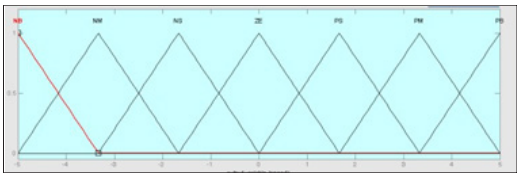

Figure 7: Membership Functions of the Output Variable (ΔI_{ref})

The fuzzy system rule base is created as shown in Table. 1 with (ΔP_{pv}) and (ΔI_{pv}) as inputs while ΔIref is the output. The fuzzy inference of the FLC is based on the Mamdani's method which is associated with the max-min composition. The defuzzification technique is based on the centroid method which is used to compute the crisp output, ΔI_{ref}.

Er \ CE	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Table 1: Rule Base for The Proposed FLC

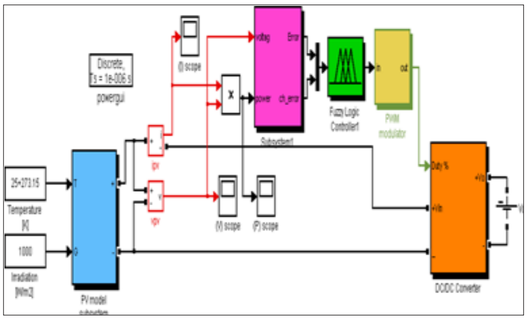

Figure 8: PV system controlled by Fuzzy MPPT

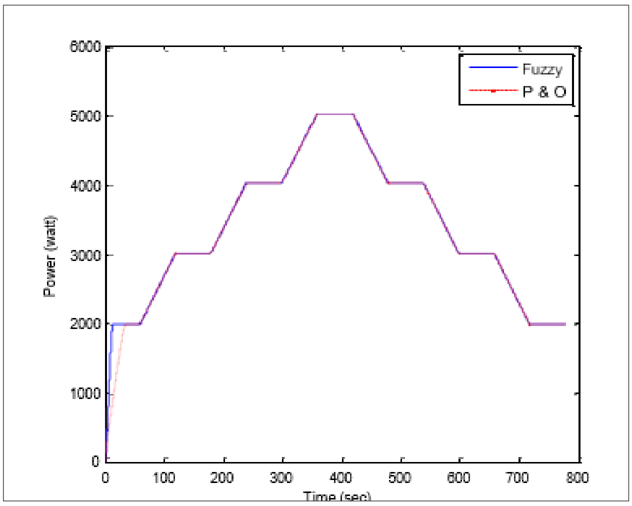

Figure 1.a PV System Response a) Constant Temperature with Variation in The Irradiation

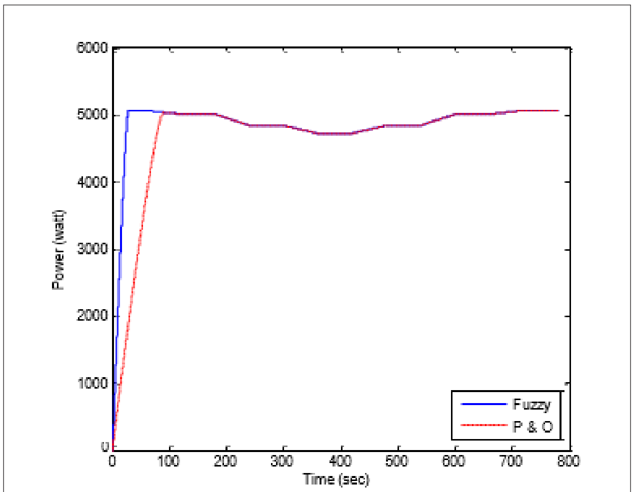

Figure 1.b Constant Irradiance with Variation in Temperature

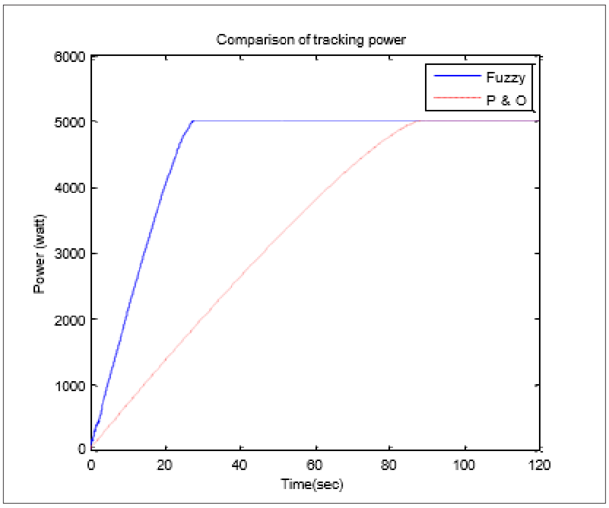

Figure 2.a Tracking Power by FLC and P&O Methods

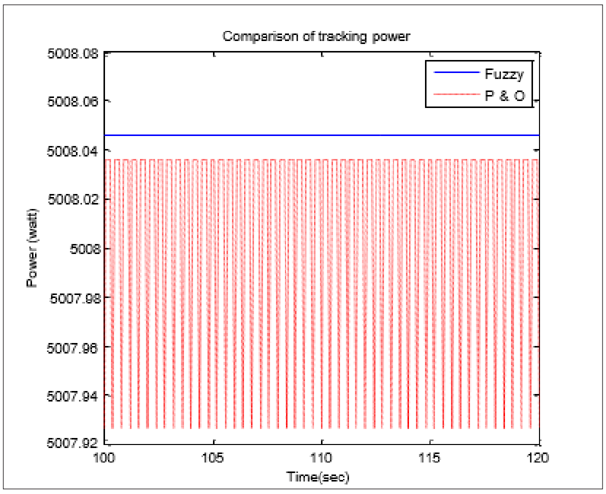

Figure 2.b Tracking Power by FLC and P&O Methods steady state behaviour

The proposed MPPT using FLC is compared with the MPPT controller using P&O algorithm in terms of its tracking capability at a standard condition with irradiation 1000 W/m^2 and ambient temperature ambient of 25^{0}C. Figure 2 (a) shows the transient responses of the tracked powers obtained from both controllers. It can be observed that the rise time of tracked power by P&O method is approximately 0.14s while the rise time achieved by the FLC is only about 0.035s. Hence, the tracking speed response is significantly improved by four times by using FLC. The steady-state behaviour of the PV system using FLC is characterized by a stable and small oscillation around the maximum power point while the MPPT using P&O is having larger steady state oscillations as illustrated in Figure 2 (b). Therefore, the results show good performance of the proposed MPPT using FLC in both transient and steady-state operations.

Figure 1(a) and (b) show the performance of the PV system using FLC and P&O algorithms under constant temperature of 25°C and fast changing irradiance ([400, 400, 600, 600, 800, 800, 1000, 1000, 800, 800, 600, 600, 400, 400]W/m2) at times ([0 1*60 2*60 3*60 4*60 5*60 6*60 7*60 8*60 9*60 10*60

11*60 12*60 13*60]second) and under constant irradiance of 1000W/m2 and changing temperature ([20, 20, 25, 25, 40, 40, 50, 50, 40, 40, 25, 25, 20, 20]°C). The simulation results show that the performance of the P&O and the proposed FLC method are quite similar under these two conditions.

Conclusions

This paper presented an intelligent MPPT control strategy for the PV system using fuzzy logic. Simulation results have shown that the proposed MPPT using fuzzy logic provides faster tracking of maximum power as compared to the MPPT using the P&O method. The results have also demonstrated that the MPPT using fuzzy logic gives stable and small oscillation around the maximum power point. In conclusion, the proposed MPPT using fuzzy logic gives better performance than the MPPT using the P&O method.

These used controllers results can be compared to other methods of control as using neural networks in optimizing the photovoltaic generator power, the idea of our future work as extension of our research to improve more the PV systems yield.

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