Maximum Power Point Tracking for Photovoltaic System Using Fuzzy Logic Controller

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ABSTRACT - The photovoltaic generators have a nonlinear V-I characteristics and maximum power points which vary with the illumination levels and temperatures. Using maximum power point tracker with the intermediate converter can increase the system efficiency by matching the PV systems to the load. A novel MPPT control for photovoltaic system is proposed. The system input parameters are (dP, dI, and last incremental of duty ratio LδD)and the output is the new incremental value (new δD) according to the maximum power point under various illumination levels. Using fuzzy logic controller allows extracting the maximum power rapidly and without significant oscillations. Also FLC provides excellent features such as fast response, good performance and the ability to change the fuzzy parameters to improve control system.

Keywords: photovoltaic array, maximum power point tracking, fuzzy logic control.

1. Introduction

The photovoltaic solar panels are semiconductor devices that convert the solar illumination power directly to electricity. Their operational characteristics depend on the incidents sun light level and surface temperature that developed on the cell surface as the illumination, ambient temperature and current flow varies [1]. The photovoltaic arrays exhibit an extremely non-linear voltage-ampere characteristic, which varies with array temperature and illumination all times. It makes the locating of maximum power point complex, so it is necessary to draw the maximum power of the solar array. Therefore, in order to draw the maximum utilization efficiency, the technique, called maximum power point tracking (MPPT) control to extract the maximum power from the PV array, is essential in the system powered by PV array [2].

Generally, there are several methods which are commonly used to determine the maximum power point like P&O method and Incremental Conductance method. On the other hand, fuzzy logic theory has received attention of a number of researchers in the area of the power electronics. The FLC is somehow easy to implement because it doesn't need the mathematical model of a system. Since it gives robust performance, the interest in practical application of fuzzy logic is growing rapidly. [3]

In this paper, a new, simple and high efficient method using FLC is applied to step-up maximum power point tracker PV array. Practically, input variables of fuzzy controller are dp/dI(where p is the PV array output power and I is the PV array output current) and the last increment in the converter duty ratio, and the output variable is the new increment in the duty ratio.

The proposed MPPT system is studied by simulation using Matlab/Simulink and compared by conductance method. The comparison indicates that the proposed

method have a quicker tracking performance during condition change and smaller output power oscillations.

2. PV array characteristics

The building block of PV arrays is a solar cell, which is basically a p-n semiconductor junction, shown in Fig. 1. The VI characteristics of a solar array are given by eq. (1)[1]:

$$I= I_{SC} - I_o \{\exp[q(VR_S + I)/KT_k]-1\} - (V+R_S)/R_{Sh} \quad (1)$$

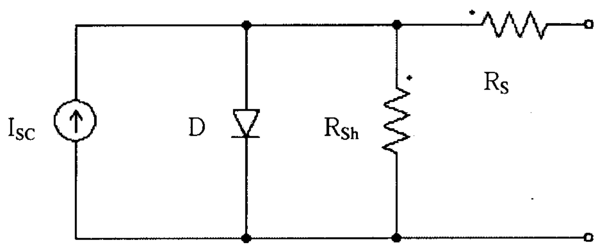

Fig. 1. Equivalent circuit of PV array.

Where V and I represent the output voltage and current of the PV, respectively; Rs and R_{Sh} are the series and shunt resistance of the cell; q is the charge of an-electron I_{SC} is the light-generated current; I_o is the reverse saturation current; K is the Boltzman constant, and T_K is the temperature in K.

Equation (1) is used in computer simulation to obtain the output characteristics of the PV array which are non-linear and influenced crucially by solar radiation and temperature (Fig. 2 and 3). Each curve has MPP, at which the solar array operates most efficiently.

3. Maximum power point tracking

To determine the operating point corresponding to maximum power for different illumination levels, eq.(1) is commonly used to compute the partial derivative of power with respect to the cell current. Instead of finding the maximum via derivative, we use the FLC.

The FLC block or MPP tracker is shown in Fig. 4, inputs are dP/dI and last variation of the duty ratio (LδD), and output is the new variation in the duty ratio δD.

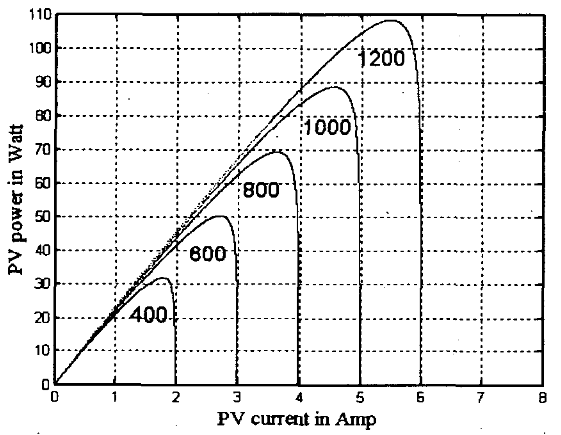

Fig. 2. P-I Characteristics of PV array.

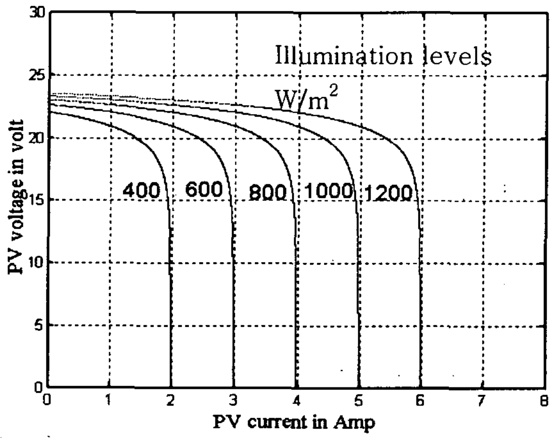

Fig. 3. V-I Characteristics of PV array.

The FLC consists of three functional blocks which are fuzzification, fuzzy rules, and defuzzification [5].

Fuzzification: Inputs can be measured or computed from panel current and voltage. Figure 5 shows the membership functions of the input variables: n(negative), nb(negative big), nm(negative medium), ns (negative small), z(zero), p(positive), ps(positive small), pm(positive medium, and pb(positive big).

Fuzzy rule algorithm: The fuzzy rules include nineteen rules. These rules are used for control of the boost converter tracker such that maximum power is achieves at the output of the solar panel. A fuzzy inference method, Mamdani's method, is used with Max-min operation combination [6]. The linguistic description is expressed in terms of " If.....Then".

Defuzzification: The output of fuzzy is a fuzzy subset. As the actual system requires a non-fuzzy value of control, defuzzification is required. The center of area algorithm is used for defuzzification of output control parameters[7].

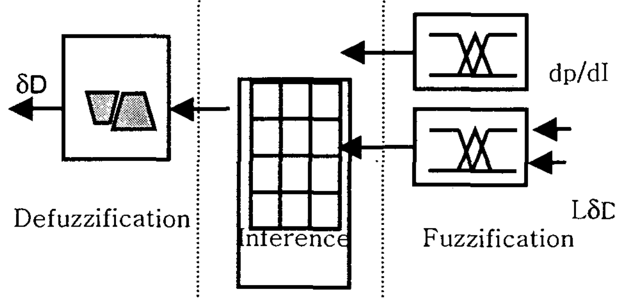

Fig. 4. Fuzzy logic controller.

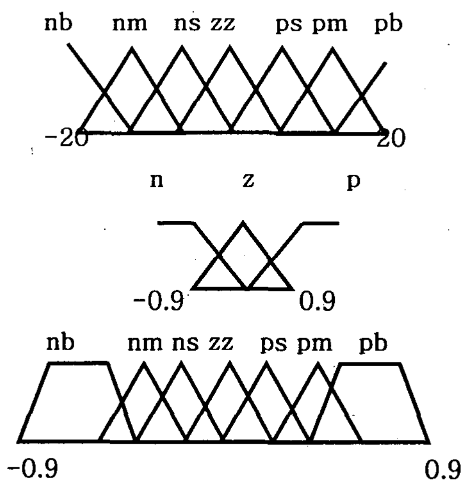

Fig. 5. Membership functions for inputs and outputs

4. System description

In order to show the feasibility of maximum power point tracking using fuzzy control, the photovoltaic power system with a step-up converter is constructed. The circuit configuration of the system is shown in Fig. 6.

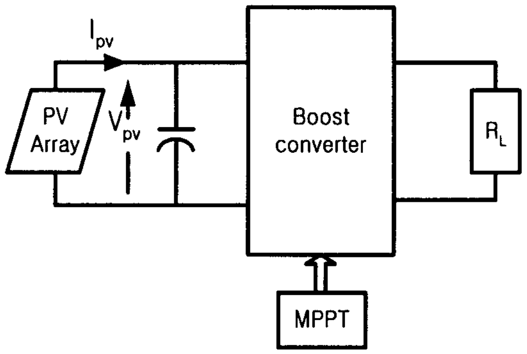

Fig. 6. System configuration.

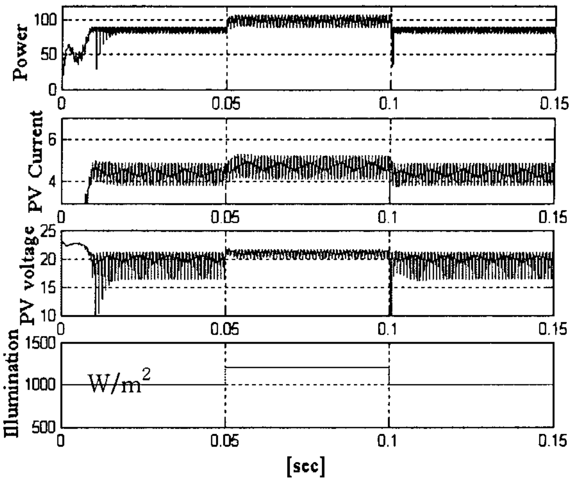

Fig. 7. Power, current and voltage at different illumination level controlled by conductance method.

5. Simulation results

As mentioned before, the solar illumination varies quickly with time, it means that the maximum power point moves to another curve quickly.

Such a case requires a maximum power point tracking controller able to extract the maximum power point as quick as possible to reduce the output power oscillations and the system power loss. As shown in Fig. 7, the PV characteristics in case of using the conductance method, the maximum power point extracting depend on the fixed incremental step of the duty ratio. The output power oscillations in case of changing conditions are noticeable and these oscillations are considered a source of power loss especially if the illumination level and temperature is varying frequently or rapidly. Fig. 8 shows the FLC tracking the maximum power point from the starting point and also during the illumination variation conditions, the new incremental duty ratio varies according to the change in power derivative and the last increment or decrement in the duty ratio, these relations between the inputs and output are determined and written in the base-rule form.

6. Conclusions

Two powerful and practical methods for maximum power point tracking of PV systems are investigated and compared, the FLC method and conductance method. For theoretical analysis, Matlab/Simulink software was employed.

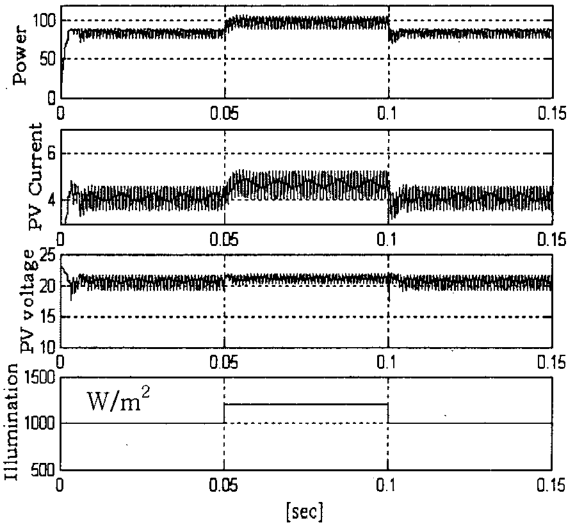

Fig. 8. Power, current and voltage at different illumination level controlled by FLC.

As a result of using FLC method, the dynamic performance of the controlled PV array is improved compared with the case of using the conductance method. This improvement includes reduction in the power oscillations and fast response compared with the output conductance method.

Finally, the simulation and comparison between the proposed control method and conductance method supports the validity of the proposed maximum power point tracking control and proves that the FLC gives an adaptive nature for the system performance.

The overall results indicate that the system is operated with FLC better than the conductance method.

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