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Implementation of Fuzzy Logics to design MPPT controller for Photovoltaic systems

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Abstract: The cell has optimum operating point to be able to get maximum power. To obtain Maximum Power from photovoltaic array, photovoltaic power system usually requires Maximum Power Point Tracking (MPPT) controller. This thesis research work will provides a small power photovoltaic control system based on fuzzy control with FPGA technology design and implementation for MPPT. The proposed maximum power point tracking controller for photovoltaic system is tested using model designed by Matlab/Simulink program with graphical user interface (GUI) for entering the parameters of any array model using information from its datasheet. Simulation and experimental results show that performance of the fuzzy controller with FPGA in a maximum power tracking of a photovoltaic array can be made use of in several photovoltaic products and obtain satisfied result. The resultant system is capable and satisfactory in terms of fastness and dynamic performance. The results also indicate that the control system works without steady-state error and has the ability of tracking MPPs rapid and accurate which is useful for the sudden changes in the atmospheric condition.

Keywords: Fuzzy Logic, MPPT, FPGA, GUI, Matlab/Simulink.

I. INTRODUCTION

In recent times, due to its development and cost decline, PV system becomes a resourceful solution to the environmental problem. On the other hand, the development for improving the efficiency of the PV system is still a demanding field of research. PV system cannot be modeled as an invariable DC current source since its output power is assorted depending on the temperature, load current, and irradiation. In general, MPPT is adopted to track the maximum power point in the PV system. The effectiveness of MPPT depends on both the MPPT control algorithm and the MPPT circuit [1]. The MPPT control algorithm is generally functional in the DC-DC converter, which is usually used as the MPPT circuit.

The most accepted approach of implementing fuzzy controller is by means of a general-purpose microprocessor or microcontroller. Microprocessor based controllers are more economical, but often face difficulties in dealing with control systems that need high dispensation and input/output managing speeds [2]. Rapid advances in digital technologies have given designers the choice of implementing a controller on a range of Field Programmable Gate Array (FPGA), Programmable Logic Device (PLD), etc.

II. PHOTOVOLTAIC CELL

Numerous requisitions identified with situating frameworks are, no doubt actualized with stepper engines. One of the principle preferences of stepper engines is the solid connection between electrical beats and revolution discrete edge steps [3]

As known by numerous scientists, the created current relies on upon sunlight based irradiance, temperature, and load current. The typical equivalent circuit of PV cell is shown in Fig. 1.

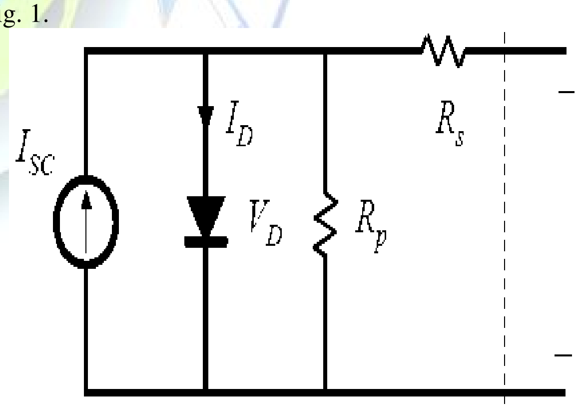

Fig. 1: Typical circuit of PV solar cell

The basic equations describing the I-V characteristic of the PV model are given in the following equations:

$$0= I_{SC}-I_D- V_D/Rp-I_{PV} \qquad (1)$$

$ID=I_o(e^{V_D/V_T}-1)$ (2)

$V_{PV}=V_D-R_S*I_{PV}$ (3)

Where:

I_{PV} is the cell current (A).
I_{SC} is the light generated current (A).
I_D is the diode saturation current (A).
R_s is the cell series resistance (ohms).
R_P is the cell shunt resistance (ohms).
V_D is the diode voltage (V).
V_T is the temperature voltage (V).
V_{PV} is the cell voltage (V).

III. Fuzzy Logic

The fuzzy theory based on fuzzy sets and fuzzy algorithms offers a universal method of expressing linguistic rules so that they may be processed swiftly. The advantage of the fuzzy logic control is that it does not severely need any arithmetical model of the plant. It is based on plant operator knowledge, and it is very simple to be relevant. For this reason, many composite systems can be controlled without perceptive the exact mathematical model of the plant [4]. In accumulation, fuzzy logic simplifies dealing with nonlinearities in systems [5]. The excellent of using fuzzy logic control is that the linguistic system description becomes the direct algorithm.

An essential provision may portray subranges of a nonstop variable. For example, temperature estimation for non-freezing stopping devices may have a few separate participation capacities characterizing specific temperature extents required to control the brakes legitimately.

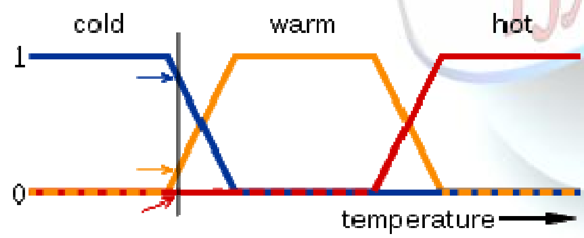

Fig. 2: Fuzzy logic temperature

In this image, the meanings of the expressions *cold*, *warm*, and *hot* are represented by functions mapping a temperature scale. A point on that scale has three "truth values"—one for each of the three functions. The vertical line in the image represents a particular temperature that the three arrows (truth values) gauge. Since the red arrow points to zero, this temperature may be interpreted as "not hot". The orange arrow (pointing at 0.2) may describe it as "slightly warm" and the blue arrow (pointing at 0.8) "fairly cold".

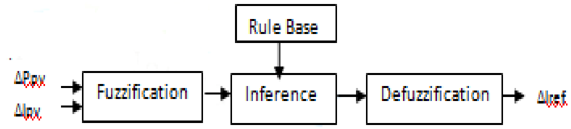

Fig. 3: Fuzzy logic Controller

IV. MPPT Controller Design

In beam of the photovoltaic cell, energy can exchange the strength of sunlight photons to the electrical energy. Since the measure of transformed energy produced by a sun powered cell is little, just about 45 milliwatts, they must be sorted out and introduced in arrangement or parallel to prepare a helpful extent of electrical energy whether for industry or domestic use [6]. The nonlinear and exponential connection between current and voltage of a PV module is depicted by below equations. The generated current by a solar cell is obtained based on the equation in below Equation 1 and 2:

$$I_{ph} = (I_{ph,n} + k_i \Delta T)\, G/G_n \quad (1)$$

where, I_{ph} is called photocurrent generated by the influence of solar irradiation and cell's temperature. ΔT is the difference of temperature from the reference STC (T_0 = 25°C). G is the insulation and G_n is its normal rated value which is equal to 100 mW m^{-2}. While k_i is the temperature coefficient of short circuit current. The main equation of a PV cell is as follow:

$$I_c = I_{ph} - I_v\,[\exp((Vc + RsIc) / m.Vt) - 1] \quad (2)$$

where, Ic and Vc are the output current and voltage of the cell respectively. I0 is the diode reverse saturation current and Rs is the series resistor modeled for the cell.

Vt is called temperature voltage and it is applied 25mV and m is the diode factor which is equal to 1.5 in practice.

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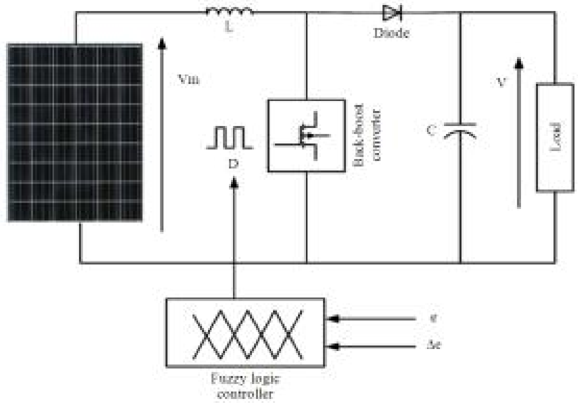

Fig. 4: The block diagram of the designed and implemented MPPT system

The voltage and current of the PV panel are measured instantly and connected to the MATLAB software by a DAQ card. Then, the power is calculated and saved in a vector [7]. The input variables of the Fuzzy logic controller are created based on the Equations (1) and (2). The power functions is generated as follows

$e(t) = \Delta P(t)/ \Delta V(t) = (P(t)- P(t-1)) / (V(t)- V(t-1))$ (4)

V. RESULTS AND DISCUSSION

Coordinating FPGA in a MPPT control framework gives various favorable circumstances. To meet execution prerequisites, FPGAs are alluring since their execution can without much of a stretch surpass the execution of microcontrollers and DSPs. On account of their high logic limit, FPGAs could be adjusted to control MPPT for multi-divert frameworks in parallel without forcing complex correspondence between the distinctive controls of each one channel [8].

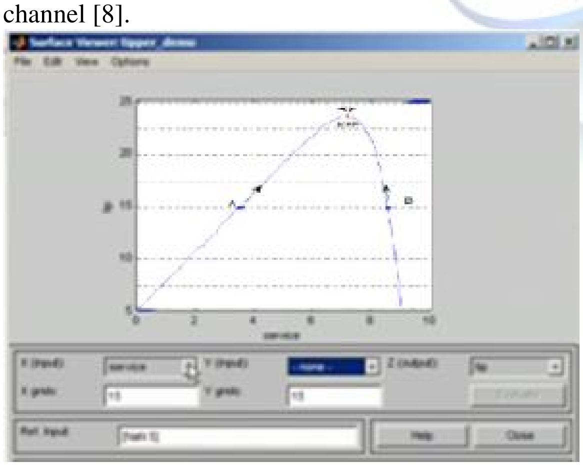

Fig. 5: MPPT value according to energy function

Fig. 6 shows the performance of the PV system using FLC and other existing (P&O) algorithms under fast changing of irradiance. The MPPT using FLC gives the results better than the P&O in several areas of the tracking curve.

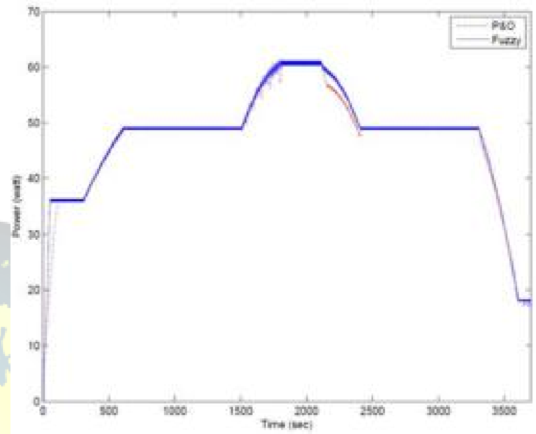

Fig. 6: Comparison tracking curves by FLC and P&O methods

VI. CONCLUSION

This paper presents an intellectual control strategy of MPPT for the PV system using the FLC. Simulation results illustrate that the proposed MPPT can track the MPP faster when compared to the conservative P&O method. In conclusion, the projected MPPT using fuzzy logic can advance the performance of the system. For the future work, we propose to implement the planned technique in the real PV system.

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Biography

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