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Maximum Power Point Tracking For Three Phase Grid Connected Photovoltaic System Using Fuzzy Logic Control

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Abstract— In this paper, a fuzzy logic control (FLC) is proposed to control the maximum power point tracking (MPPT) for a three phase grid connected photovoltaic (PV) system. The proposed technique uses the fuzzy logic control to specify the size of incremental current in the current command of MPPT. A fuzzy logic controller has been developed for interfacing PV array with utility grid through a three phase line-commutated inverter. The controller tracks and feeds maximum power to the utility grid. The linguistic variables have been selected appropriately to modulate the firing angle of the inverter for tracking the maximum power . A PWM generator has been used for generation of pulses to the thyristors in the inverter with the help of fuzzy logic. And the same simulation set up has been used to be used with P&O technique .Finally the comparison of both the techniques has been carried to to show the superiority of fuzzy logic.

Keywords— photovoltaic system, MPPT, P&O method, Fuzzy Logic Control

I. INTRODUCTION

With the industrial development, the problem of energy shortage is more and more aggravating. The renewable energy as specially photovoltaic (PV) system technologies are rapidly expanding and have increasing roles in electric power technology and regarded as the green energy of the new century [1]. PV system cannot be modeled as a constant DC current source because its output power is varied depending on the load current, temperature and irradiation. Generally, MPPT is adopted to track the maximum power point in the PV system[2]. The efficiency of MPPT depends on both the MPPT control algorithm and the MPPT circuit. The MPPT control algorithm is usually applied in the DC-DC converter, which is normally used as the MPPT circuit[3]. Typical diagram of the connection of MPPT in a PV system is shown in Fig. 1. Various approaches have been reported to implement MPPT. The perturb and observe (P&O) method needs to calculate dP/dV to determine the maximum power point (MPP) [4]. Though it is relatively simple to implement, it cannot track the MPP when the irradiance changes rapidly; and it oscillates around the MPP instead of directly tracking it. The incremental conductance method can track MPP rapidly but increases the complexity of the algorithm, which employs the calculation of dI/dV [5]. The constant voltage method [17], which uses 76% open circuit voltage as the MPP voltage, and the short-circuit current method [18] are simple, but they do not always accurately track MPPs. the fuzzy control algorithm is capable of improving the tracking performance as compared with the conventional methods for both linear and nonlinear loads.

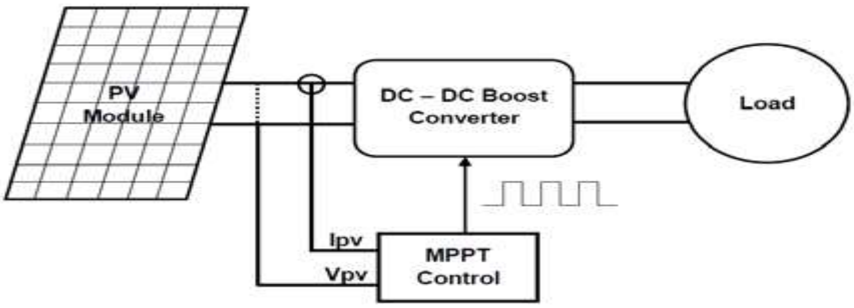

Fig. 1 Typical diagram of MPPT in a PV System

II. GENERALISED PHOTOVOLTAIC CIRCUIT

The model of solar cell can be categorized as p-n semiconductor junction; when exposed to light, the DC current is generated. As known by many researchers, the generated current depends on solar irradiance, temperature, and load current. The typical equivalent circuit of PV cell is shown in Fig. 2.

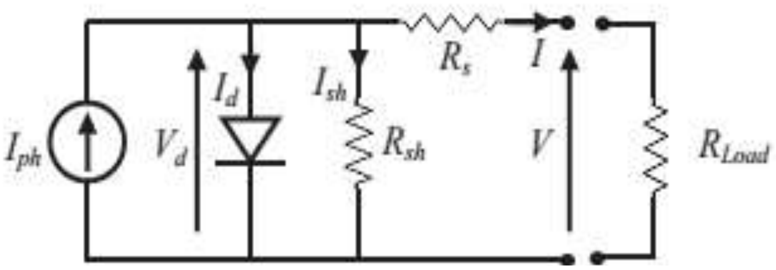

Fig. 2 Typical circuit of PV solar cell

The net output current of PV   I = IphNp – Id– Ish

Where, I = Cell current(A)
NP = Number of solar cell connected in parallel
Iph= Photo current
Id = The diode saturation current
Ish = Shunt Current

III. MAXIMUM POWER POINT TRACKING TECHNIQUES

The efficiency of a solar cell is very low. In order to increase the efficiency, methods are to be undertaken to match the source and load properly. Maximum power point tracking technique is used to improve the efficiency of the solar panel.

A. Perturb and Observe method

One of the most simple and popular techniques of MPPT is the P&O technique. The main concept of this method is to push the system to operate at the direction which the output power obtained from the PV system increases. Following equation describes the change of power which defines the strategy of the P&O technique.

$$\Delta P = P_k - P_{k-1}$$

If the change of power defined by is positive, the system will keep the direction of the incremental current (increase or decrease the PV current) as the same direction, and if the change is negative, the system will change the direction of incremental current command to the opposite direction. This method works well in the steady state condition (the radiation and temperature conditions change slowly). However, the P&O method fails to track MPP when the atmospheric condition is rapidly changed.

B. Fuzzy Logic Control

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.3 Fuzzy logic is one of the most powerful control methods. It is known by multi-rules-based resolution and multivariable consideration. Fuzzy MPPT is popular for over last decade. Fuzzy logic controllers (FLC) have the advantages of working with imprecise inputs, no need to have accurate mathematical model, and it can handle the nonlinearity.

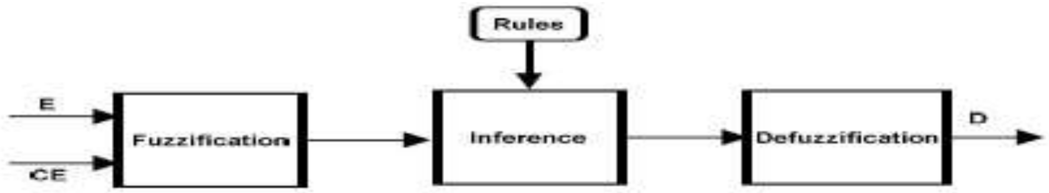

Fig. 3 The Fuzzy Logic Controller

The proposed FLC is shown in Fig. it consists of two inputs and one output. The two FLC input variables are the error (E) and change of error (CE) that expressed by equation

$$E(j) = \frac{P_{pv}(j) - P_{pv}(j-1)}{V_{pv}(j) - V_{pv}(j-1)}$$

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

• Fuzzification

The fuzzification is the process of converting the system actual inputs values E and CE into linguistic fuzzy sets using fuzzy membership function. These variables are expressed in terms of five linguistic variables (such as ZE (zero), PB (positive big), PS (positive small), NB (negative big), NS (negative small)) using basic fuzzy subsets.

• Rule base & inference engine

Fuzzy rule base is a collection of if-then rules that contain all the information for the controlled parameters. It is set according to professional experience and the operation of the system control. The fuzzy rule algorithm includes 25 fuzzy control rules. Fuzzy inference engine is an operating method that formulates a logical decision based on the fuzzy rule setting and transforms the fuzzy rule base into fuzzy linguistic output.

• Defuzzification

Defuzzification of the inference engine, which evaluates the rules based on a set of control actions for a given fuzzy inputs set. This operation converts the inferred fuzzy control action into a numerical value at the output by forming the union of the outputs resulting from each rule. The center of area (COA) algorithm is used for defuzzification of output duty control parameter. i.e If E is NB and CE is ZO then crisp D is PB, it means that if the operating point is far away from the MPP by the right side, and the variation of the slope of the curve is almost Zero; then increase the duty cycle.

IV. PROPOSED MODEL SCHEME

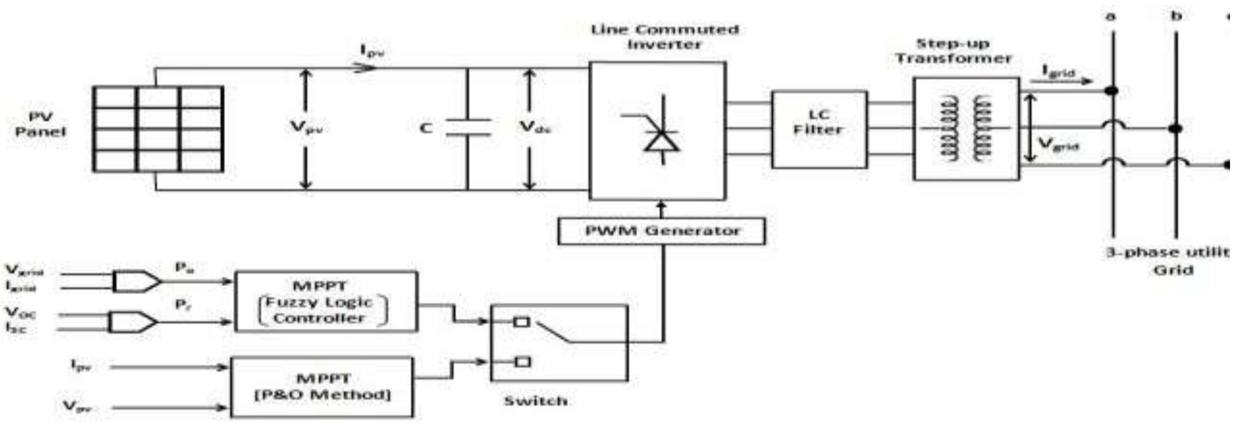

Fig. 4 Basic PV system integrated with 3-Phase Utility grid

In the above circuit we have connected the designed PV panel with 600/40MVA grid. The designed transmission line consists of 2 transformers one at DG side and another at grid side. For tracking maximum power and at the same time to match the generated voltage with grid we have used fuzzy logic. The same circuit has been tested when connected to grid with P&O MPPT technique. This scheme of power generation consists of PV array, a line commutated SCR inverter, a step-up transformer and the MPPT . The PV array converts the solar radiation into electrical power. This is fed to the six-pulse thyristor bridge, which acts as line commutated inverter through dc link capacitance. This dc link capacitance is used to obtained a steady direct current from the PV panel . The line commutated inverter converts the dc to ac and transfers the power from the PV panels to the utility grid via the step-up transformer. The PWM generator is used to give firing angle delay to the inverter. The pulse are generated by comparing a triangular carrier waveform to a reference modulating signal.

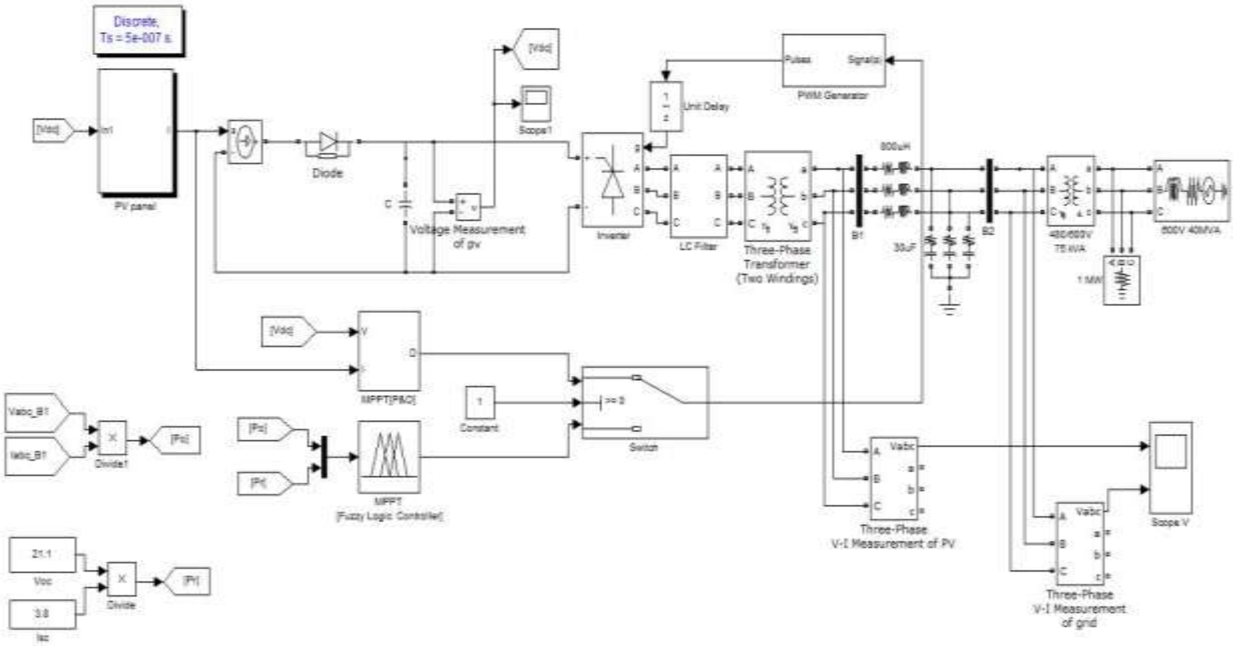

Fig. 5 Proposed grid connected Simulink model

When the circuit has been tested when connected to grid with P&O MPPT technique. Here the input voltage and current is used to calculate power and compared with its previous values by accessing previous values of voltage and current from memory block. Depending on difference in power the predefined delta value is assigned that to be multiplied with D delta. Again that delta value is compared with previous one which will produce a pulse when combined with reference repeating signal. which is then fed to inverter which converts generated dc voltage to ac.

When the circuit has been tested when connected to grid with Fuzzy logic MPPT technique. The FLC takes two inputs, namely the actual power output at the output of the transformer and the maximum reference power which is calculated based on open circuit voltage Voc and short circuit current Isc of the PV array . It is to be noted that the Voc of the array will vary with temperature and Isc will vary with irradiation. The error between the actual power and the reference power is used for modulating the firing angle delay for the line-commutated inverter, which converts generated dc voltage to ac.

To reduce the current harmonics introduced by the line-commutated inverter on the grid side, a LC filter is connected after inverter. A two winding transformer next to LC filter steps up the PV 3 phased voltage to approximate grid level and supplied to transmission line through bus B1. A RLC load is connected to give physical realization to the transmission line.

V. RESULT

Figs.6 show the results of the I-V and P-V characteristic curves of the PV module

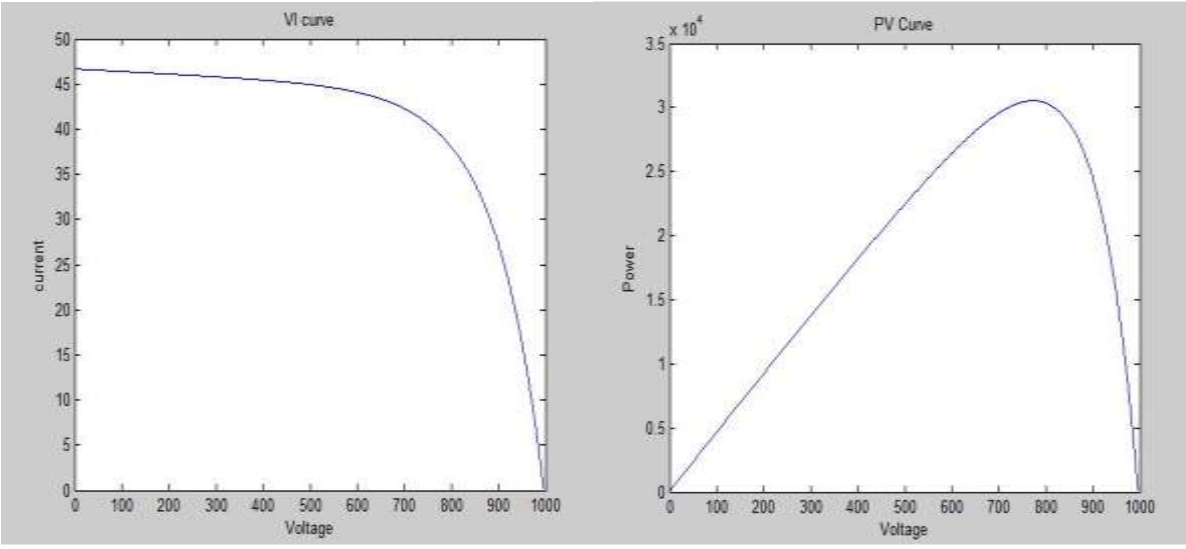

Fig .6 IV & PV curve of Photovoltaic cell

COMPARISION BETWEEN GRID VOLTAGE & PV VOLTAGE

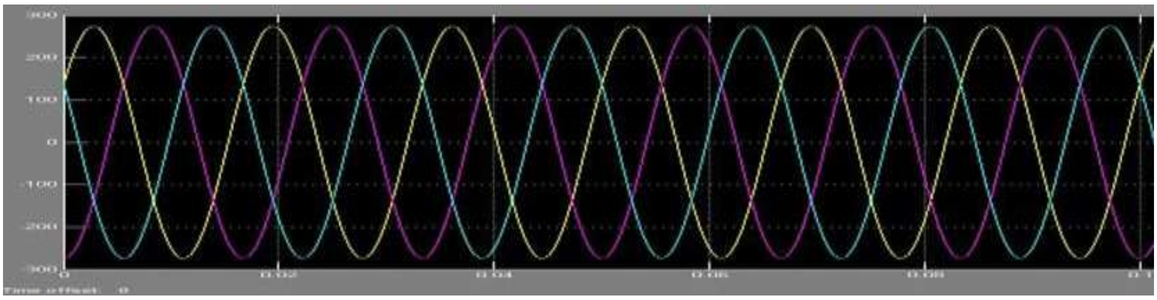

Fig. 7 3 Phase grid voltage

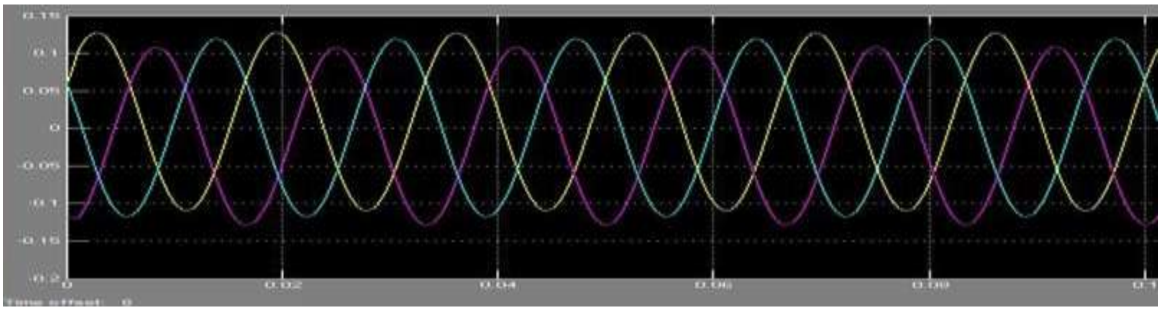

Fig .8 3 Phase PV Voltage with MPPT using P&O method

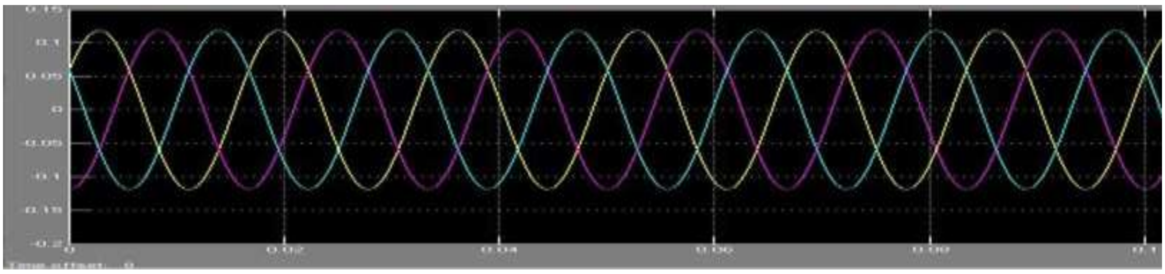

Fig .9 3 Phase PV Voltage with MPPT using FUZZY LOGIC CONTROL Method

In our proposed technique of fuzzy logic based MPPT we have compared the power of grid side with maximum possible power of PV panel to generate pulse which is then fed to inverter which converts generated dc voltage to ac. And as it is compared with the voltage levels of grid side and hence produces a 3-phase signal with same frequency as of grid side and with no amplitude fluctuation. But when the same circuit has been tested when connected to grid with P&O MPPT technique & when compared with voltage levels of grid side with the PV 3 phase voltage having same frequency as of grid side but there is some amplitude fluctuation.

VI. CONCLUSION

The designed PV panel has been simulated individually which provides good PV response. It is then used with the grid with the generated 3 phase voltage. At the time of P&O technique it has been seen that it is able to track maximum power point but with a little fluctuation in amplitude level but with the use of fuzzy logic it is possible to track maximum power point with a steady output.So our aim of synchronizing PV voltage with grid has been achieved without any flicker in the output.

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