Fuzzy Logic based Maximum Power Point Tracker in Photovoltaic Cell

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Abstract: ***This paper presents the analysis, modeling and control of a grid connected photovoltaic generation system. The model contains a detailed representation of the solar array, grid side multilevel neutral point clamped voltage source inverter. Fuzzy logic controller for the maximum power point tracking of a photovoltaic system under variable temperature and insulation conditions is discussed. The PQ control approach has been presented for the multilevel inverter. One of the most common control strategies structures applied to decentralized power generator is based on power direct control employing a controller for the dc link voltage and a controller to regulate the injected current to the utility network. The proposed models were implemented in Matlab/Simulink.***

Keywords: Power, Fuzzy Logic, Inverter, MPPT

1. Introduction

In recent years, the efforts to spread the use of renewable energy resources instead of pollutant fossil fuels and other forms have increased. Photovoltaic systems offer the possibility of converting sunlight into electricity. The transformation of electricity through photovoltaic provides case of installation, maintenance and become more affordable. One of the most common control strategies structures applied to decentralized power generator is based on power direct control employing a controller for the dc link voltage and a controller to regulate the injected current to the utility network. The system components and power control scheme are modeled in terms of dynamic behaviors.

An improved MPPT converter with current compensation method for small-scaled PV-applications is presented in [1]. He proposed method implements maximum power point tracking (MPPT) by variable reference current which is continuously changed during one sampling period. Lot of research has been done on maximum power point tracking of Photovoltaic cell. He introduced a new maximum power point tracking algorithm for photovoltaic arrays is proposed in [2]. The algorithm detects the maximum power point of the PV. The computed maximum power is used as a reference value of the control system. The proposed MPPT has several advantages: simplicity, high convergence speed, and independent on PV array characteristics. The many different techniques for maximum power point tracking of photovoltaic (PV) arrays are discussed in [3]. Paper should serve as a convenient reference for future work in PV power generation in [4].

An improved perturbation and observation maximum power point tracking algorithm for PV arrays. Improved perturbation and observation method of Maximum Power Point Tracking control for photovoltaic power systems in [5]. He explained about the perturbation observation method. Maximum photovoltaic power tracking an algorithm for rapidly changing atmospheric conditions explained in [6]. Evaluation of maximum power point tracking methods for grid connected photovoltaic systems discussed in [7]. In the maximum power point tracking method so many methods are available but he used the suitable tracker. The fuzzy inference is carried out by using Sugeno's method in [8]**.** So this is Sugeno, or Takagi-Sugeno-Kang, method of fuzzy inference. Introduced in 1985[9], it is similar to the Mamdani method in many respects. Hardware Implementation of Fuzzy Logic based Maximum Power Point Tracking Controller for PV System explained in [9]. The electric power supplied by a photovoltaic power generation systems depends on the solar irradiation and temperature. A Rule-Based Fuzzy Logic Controller for a PWM Inverter in Photo-voltaic Energy Conversion Scheme discussed in [10]. The modeling and simulation of the electric part of a grid connected photovoltaic generation system explained in [11]. This work proposed a fuzzy logic based controller to track MPPT in photovoltaic cell. A diode clamped multilevel inverter is used to reduce the harmonics.

2. Constructional Features

The photovoltaic with multilevel inverter is connected to load. Figure 1 shows the block diagram of photovoltaic with multilevel inverter.

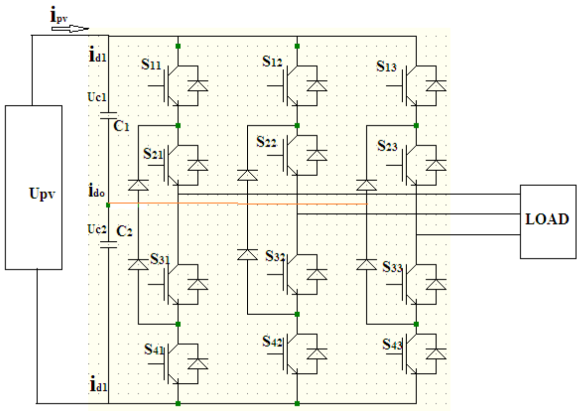

Figure 1: Block diagram of photovoltaic with multilevel Inverter

2.1 Multilevel Inverter

The multilevel inverters have drawn tremendous interest in the power industry they present a new set of features that are well suited for use in reactive power compensation it is easier to produce a high power, high voltage inverter with the multilevel structure. As the number of voltage level increases the harmonics content of the output voltage waveform decreases significantly. The three-level neutral point-clamped voltage source inverter is shown in figure 1. It contains 12 unidirectional active switches and 6 neutral point clamping diodes. The middle point of the two capacitors "*n*" can be defined as the neutral point. The major benefit of this configuration is each switch must block only one-half of the dc link voltage ($V_{dc}/2$). In order to produce three levels, only two of the four switches in each phase leg should be turned on at any time. The dc-bus voltage is split into three levels by two series-connected bulk capacitors, C_a and C_b, they are same in rating. The diodes are all same type to provide equal voltage sharing and to clamp the same voltage level across the switch, when the switch is in off condition. Hence this structure provides less voltage stress across the switch.

2.2 Photovoltaic Cell

Photovoltaic cells are only one way of generating electricity from solar energy. PV cells are made of silicon, similar to that used in computer "chips". A number of photovoltaic cells will be connected together in a "Module", and usually encapsulated in glass held a frame which can then be mounted as required. In most cases, a number of panels (modules) will be connected together to form an "Array". Panels of a similar type may be connected in series to give a higher voltage. Usually a number of panels will be connected in parallel to give an increased current.

3. Fuzzy Based MPPT

Model-based approaches use the model of the solar cell from to accurately calculate and set the maximum power point. A model-based approach is presented in [4] which use manufacturer-supplied data in addition to measurements of the solar irradiation and cell temperature.

Several different types of optimization of the algorithm such as varying the perturbation size [5] or varying the perturbation and sampling speed [3] are trivial to implement as they only require software changes in the control system. Many researchers have been focused on various MPP control algorithm to lead the operating point of the PV panel to optimum point [3]. The two FLC input variables are the error e (k) and change of error e (k-1) at sampled times k defined by:

$$e(k) = \frac{Pph(k) - Pph(k-1)}{Vph(k) - Vph(k-1)}$$

$$\Delta e(k) = e(k) - e(k-1) \quad \ldots\ldots(21)$$

Where Pph (k) is the instantaneous power of the photovoltaic generator and Vph (k) is the voltage of the PV. The input e (k) shows if the load operation point at the instant k is located on the left or on the right of the maximum power point on the PV characteristic, while the input e (k-1) expresses the moving direction of this point. The fuzzy inference is carried out by using Sugeno's method**.** So this is Sugeno, or Takagi-Sugeno-Kang, method of fuzzy inference. Introduced in 1985[9]. The main difference between Mamdani and Sugeno is that the Sugeno output membership functions are either linear or constant. Figure 2 shows general block diagram of a fuzzy controller. Basically FLC has three parts namely Fuzzification, Inference Engine and Defuzzification.

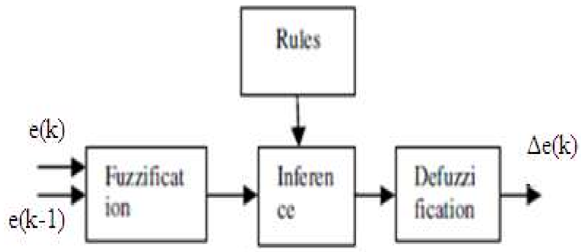

Figure 2: General diagram of a fuzzy controller

a) Fuzzification

The fuzzification is the process of converting the crisp set into linguistic fuzzy sets using fuzzy membership function. The membership function is a curvature that describes each point of membership value in the input space [12]. Variables are assigned as int1mf1, int1mf2, int1mf3, int1mf4, int1mf5, int1mf6, int1mf7. The inputs of fuzzification are the error and change in error. The value of input error e(k) and change in error e(k-1) are normalized by an input scaling factor. The input scaling factor has been designed such that input values are between -0.5 and 18. Membership function has many structures; among those bell shape memberships function is used because for any particular input there is only one dominant fuzzy subset. Fuzzy rule base is the basic function of fuzzification.

b) Inference Engine

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 [10]. Fuzzy linguistic descriptions are formal representations of systems made through fuzzy IF-THEN rules. They encode knowledge about a system in statements of the form: IF (a set of conditions) are satisfied THEN (a set of consequents) can be inferred.

c) Defuzzification

The last step in the FLC process is the defuzzification. These will have a number of rules that transform a number of variables into a fuzzy result, that is, the result is described in terms of membership in fuzzy sets. The Centre of Gravity defuzzification method is used [11].

4. Results and Discussion

4.1 Simulation Model and Results

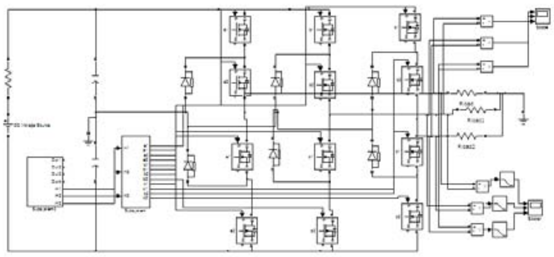

Figure 3: Simulink model of multilevel inverter with load

4.2 Simulation Results

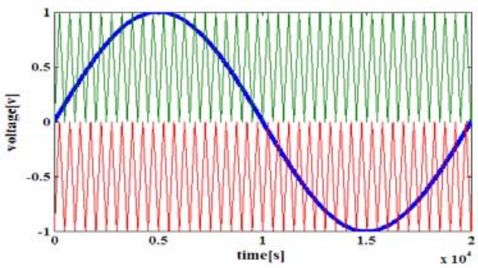

Figure 4: Career signal together with modulation Signal

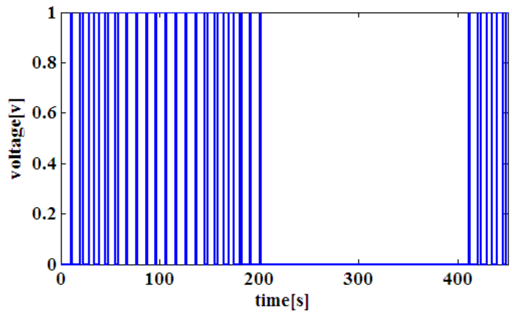

Figure 5: Gate pulse for A1 Switch

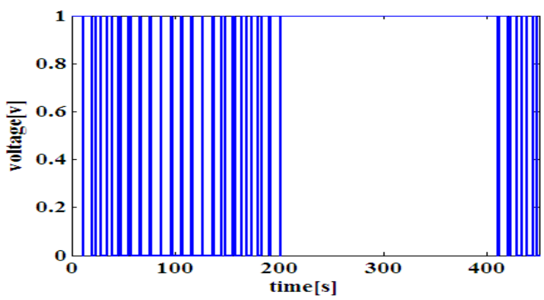

Figure 6: Gate pulse for A1' Switch

Figure 4 shows the waveform of sine-triangle intersection. And two carriers together with modulation signal have been used to obtain SPWM control. Figure 5, 6 shows the gate pulses for A1, A1' Switches.

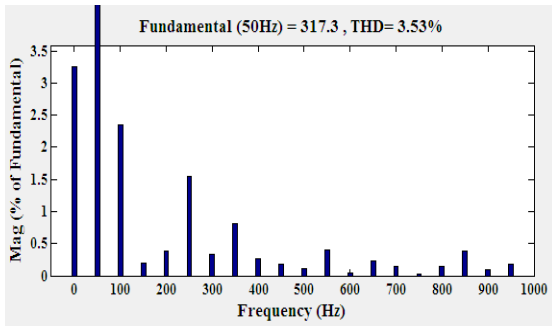

Figure 7: Harmonics of MLI with PQ control

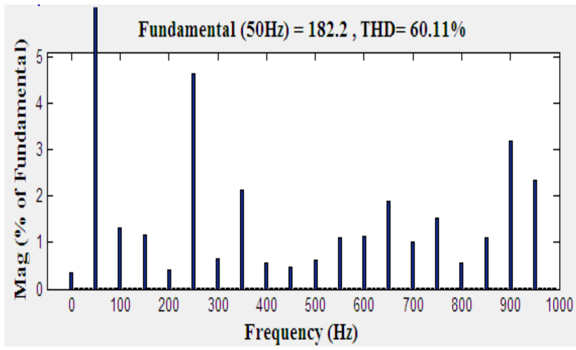

Figure 8: Harmonics of MLI without control

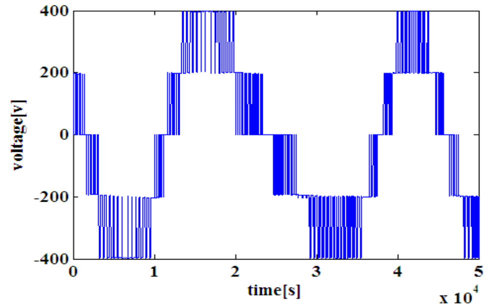

Figure 9: MLI output line to line voltage V_{ab} waveform of without filter

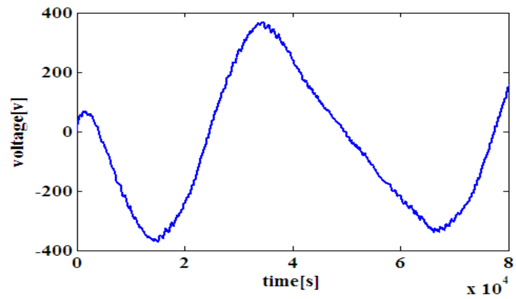

Figure 10: MLI output line to line voltage V_{ab} waveform of filter

4.3 Hardware Circuit

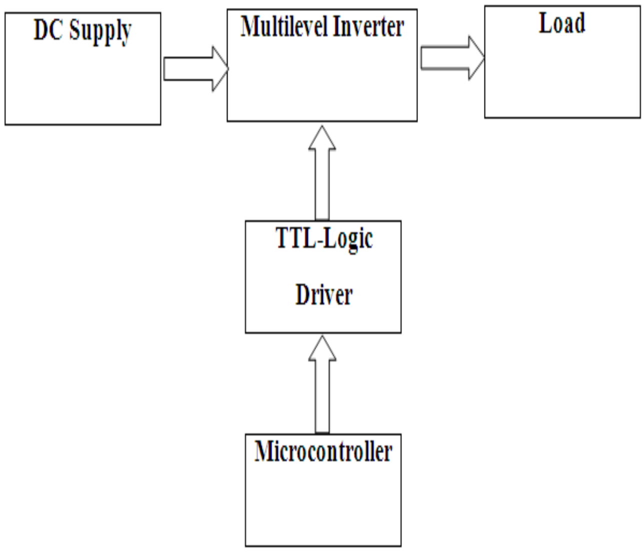

Figure 11: Block diagram of hardware circuit

Single phase AC supply is given to bridge rectifier. It converts AC into DC. The transformer can raise or lower the voltage in the circuit, but with a corresponding decrease or increase in current. The function of driver circuit is to amplify the voltage generated in the microcontroller. The microcontroller generates 2v to 5v. This voltage is not sufficient for driving the MOSFET. Therefore this voltage is amplified and using in the driver circuit. The external code memory and data memory connected to the 8051 chip. Variants of the chip will allow a lot more memory devices and I/O devices to be accommodate within the chip but such enhanced features will not be considered right now.

4.4 Hardware Results

Experimental results and Observations

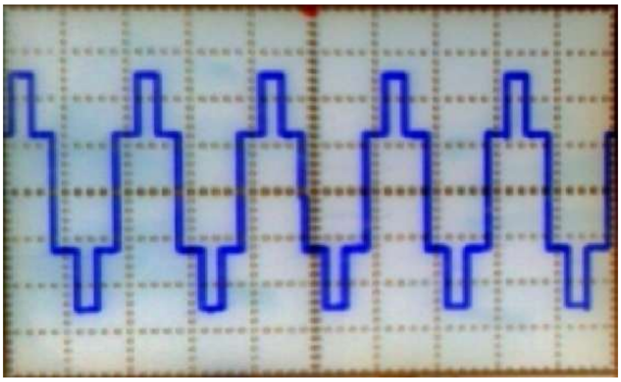

Figure 12: Output voltage with R Load

Figure 12 shows the output voltage with R Load. The output voltage is 12.5V and the peak to peak value is 25V.And it have the duty ratio 0.5 at 50Hz, V=5V.

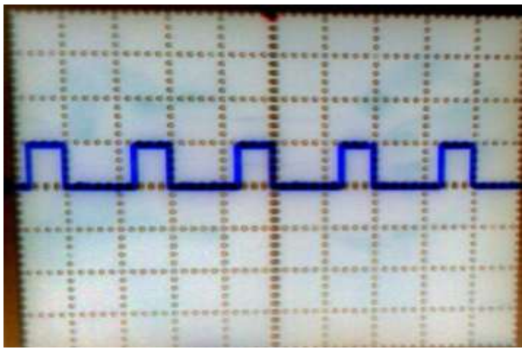

Figure 13: Pulse Generated by the Microcontroller
Figure 13 shows pulse generated by the microcontroller and it have the duty ratio 0.34 at 50Hz, V=5V

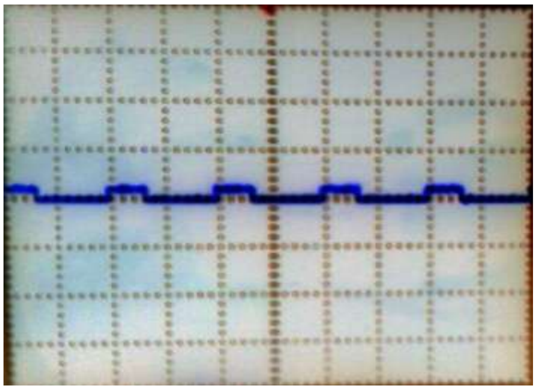

Figure 14: Optocoupler Input

Figure 14 shows the optocoupler input at V= 5V.

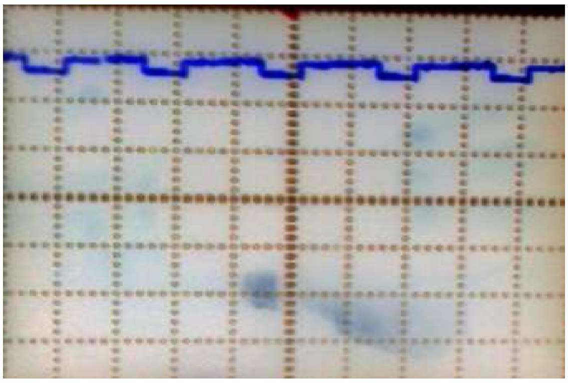

Figure 15: Optocoupler Output

Figure 15 shows the opto coupler output at V=5V.

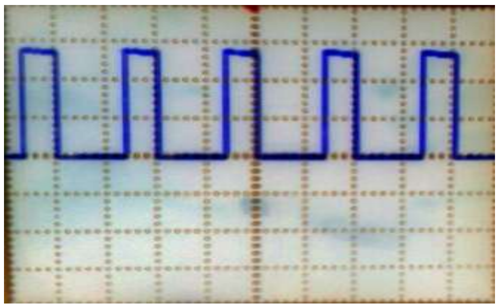

Figure 16: Driver Output

Figure 16 shows the driver circuit output. And the duty ratio 0.33 at 50Hz, V=5V.

5. Conclusion

This paper we have studied an approach of modeling and control of photovoltaic system. In this work, the aim was to control the voltage of the solar panel in order to obtain the maximum power possible from a PV generator, whatever the solar insulation and temperature conditions. The results obtained with this solution confirm the good performances of the proposed solution. The results obtained are full of promises to use the inverter in high voltage and great power applications as electrical power applied to decentralized power generator is based on Power direct control. In PV system the maximum power point tracked by fuzzy logic method. It is more efficient method and no mathematical equations are there. The topology is simulated using MATLAB and analyzed. The harmonics was reduced in the output waveform of the diode clamped multilevel inverter. The hardware circuit is built and the experiments are carried out to test the performance of the circuit.

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