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# Photovoltaic System Based Cascaded H-bridge Eleven Level Inverter With Fuzzy Based Algorithm

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**ABSTRACT**

The photovoltaic (PV) systems exhibit nonlinear I-V characteristics, and maximum power point varies with solar radiation or insolation and temperature. Multi-level inverter may be a promising inverter topology for prime voltage and high power applications. This inverter synthesizes many different levels of DC voltages to provide a stepped AC output that approaches the pure sine waveform. This analysis particularly concentrates on photovoltaic power supply as input to the system and shows the potential of one section cascaded H-bridge eleven level inverter ruled by the fuzzy based algorithm using sinusoidal pulse width modulation technique to enhance the quality by reducing the overall harmonic content at the output voltage. Thus the potency of the system is improved.

***Keywords:*** Multilevel inverter, Cascaded H-Bridge multilevel inverter, Total Harmonic Distortion, Photovoltaic cell, Sinusoidal Pulse width modulation, Fuzzy logic algorithm

## 1. INTRODUCTION

The inverter is an electrical device which converts direct current (DC) to alternate current (AC).The AC power is used mainly for electrical devices like lights, radar, radio, motor and other devices. A multilevel inverter is a power electronic device which is capable of providing desired alternating voltage level at the output using multiple lower level DC voltages as an input. The need of multilevel inverters are medium voltage sources.

Solar panels are medium voltage sources. Nowadays many industrial applications have begun to require high power. Some appliances in the industries however require medium or low power for their operation. Some medium voltage motor drives and utility applications require medium voltage. The multi-level inverter has been introduced as alternative in high power and medium voltage situations [1].

Initially, multilevel term was coined by Nabae Et Al with the use of three level inverters. A multilevel converter has several advantages over a conventional two-level converter that uses high switching frequency pulse width modulation (PWM). Multilevel converters not only can generate the output voltages with very low distortion, but also can reduce the dv/dt stresses; therefore electromagnetic compatibility (EMC) problems can be reduced. Multilevel converters produce smaller common mode voltage; therefore, the stress in the bearings of a motor connected to a multilevel motor drive can be reduced. Multilevel converters can draw input current with low distortion. Multilevel converters can operate at both fundamental switching frequency and high switching frequency PWM. It should be noted that lower switching frequency usually means lower switching loss and higher efficiency. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. An increase in the number of levels in the inverter results in the output voltage having more steps generating a staircase waveform, which has a reduced harmonic distortion. However, more number of levels increases the control complexity and introduces voltage imbalance problems [2], [3].

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Three different topologies have been proposed for multilevel inverters: diode-clamped or neutral-clamped, capacitor-clamped or flying capacitors and cascaded multilevel inverter. Among the three topologies the cascaded H-bridge is the most efficient and convenient as compared to other topologies [4]-[7]. The cascaded H-bridge requires separate DC sources which is a very attractive feature in case of PV systems because solar cells can be arranged in a number of separate generators [8]-[12].

In addition, several modulation and control strategies have been developed or adopted for multilevel inverters including the following: multilevel sinusoidal pulse width modulation (PWM), multilevel selective harmonic elimination (SHE) and space-vector modulation (SVM). The Pulse Width Modulation (PWM) is a technique which is characterized by the generation of constant amplitude pulse by modulating the pulse duration by modulating the duty cycle. Analog PWM control requires the generation of both reference and carrier signals that are fed into the comparator and based on some logical output, the final output is generated. The reference signal is the desired signal output. It can be a sinusoidal or square wave, while the carrier signal is either a saw tooth or triangular wave at a frequency significantly greater than the reference. In sinusoidal PWM technique multiple number of output pulses per half cycle and pulses are of different width. The width of each pulse is varying in proportion to the amplitude of a sine wave evaluated at the centre of the same pulse. The gating signals are generated by comparing a sinusoidal reference with a high frequency triangular signal [13]-[17].

The fuzzy logic is used for intelligent controlling of multilevel in the inverter. The fuzzy logic controller is designed to vary the duty-cycle of the multi-level inverter automatically such that the load voltage is maintained constant. The decision making logic together with the knowledge base determines the output of each fuzzy IF THEN rules. The output crisp value can be calculated by the centre of gravity or the weighted average [18]-[20]. Hence, in this paper a fuzzy logic based MPPT technique is proposed. The fuzzy logic based MPPT can track the maximum power point faster and also it can minimize the voltage fluctuation after MPP has been recognized [21]-[24].

## 2. MULTILEVEL INVERTER

Multilevel inverters are becoming popular due to its ability of reducing the disturbances and operating at lower switching frequencies. In multilevel inverters, several voltage levels are added together to create a smoother stepped waveform with lower harmonic distortions. The Cascaded multi-level inverter has major advantages like giving twice the number of output steps as compared to the number of sources, generate output voltage with low distortion and lower harmonics, and operate with very less switching frequency.

## 3. CASCADED H-BRIDGE

In cascaded MLI, there are two topologies. They are T-topology and H-topology. In this paper, H-topology is used. The advantages of H Bridge are that the DC sources given to the bridges can be any natural

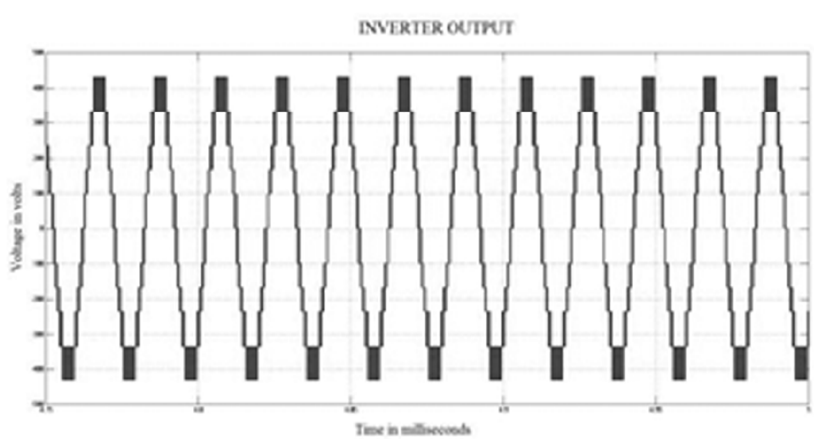


**Figure 1: Inverter Output Voltage**

resources such as solar or wind energy, etc. It does not need any capacitor or diode for clamping. The output waveform is more sinusoidal. The H Bridge can be more conveniently used for PV arrays as separate modules are used for each bridge and output will be the sum of all the bridges.

The output waveform of the eleven level cascaded H bridge inverter is in Fig 1.

## 4. PULSE-WIDTH MODULATION

The Pulse Width Modulation (PWM) is a technique for the generation of constant amplitude pulse by varying the duty cycle through modulation. There are various types of PWM techniques and so we get different output and the choice of the inverter depends on cost, noise and efficiency.

There are three basic PWM techniques: 1. Single Pulse Width Modulation 2. Multiple Pulse Width Modulation 3. Sinusoidal Pulse Width Modulation

In sinusoidal pulse width modulation technique there are multiple number of output pulses per half cycle and pulses are of different width. The width of each pulse is varying in proportion to the amplitude of a sine wave evaluated at the centre of the same pulse. The gating signals are generated by comparing a sinusoidal reference with a high frequency triangular signal. The above waveform in Fig.2 shows the PWM waveform as obtained after simulation.

## 5. FUZZY LOGIC CONTROLLER

Fuzzy logic is a form of many-valued logic. It deals with reasoning that is regaining approximate rather than fixed and exact value. Compared to traditional binary sets fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. The Fuzzy logic controller consists of three main blocks. They are fuzzification, inference engine and defuzzification. The process of converting input/output variable to linguistic levels is termed as Fuzzification. The behaviour of the control surface which relates the input and output variables of the system is governed by a set of rules present in the inference engine. Defuzzification is the process of conversion of fuzzy quantity into crisp quantity. There are several methods available for defuzzification. They are centroid method, weighted average method, centre of sums etc.

To operate PV system properly within its Maximum Power Point, since the solar irradiation and module temperature varies, fuzzy logic MPPT is certainly needed to find its MPP and maintain the peak power. So this Strategy provides the values of voltage and current at which it will provide the maximum output power. In this paper, mamdani type fuzzy logic is used. The input has five variables and output has 9 variables to give a set of 45 rules. The FAM table which is used to write these 45 rules is given in table -I.

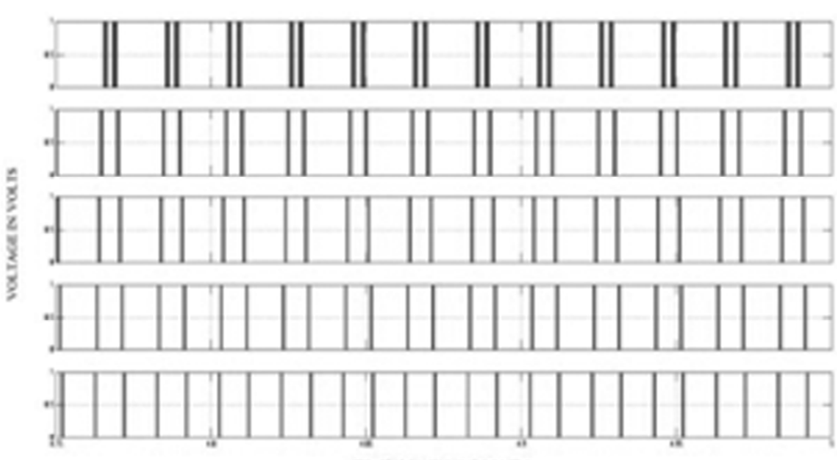


**Figure 2: PWM output**

**Table 1**
**FAM Table**

| Vn | ΔVdiff | | | | |
|---|---|---|---|---|---|
| | PB | PS | ZE | NS | NB |
| IV+ | IV+ | IV+ | IV+ | III+ | III+ |
| III+ | IV+ | IV+ | III+ | II+ | II+ |
| II+ | III+ | III+ | II+ | I+ | I+ |
| I+ | II+ | II+ | I+ | ZE | ZE |
| ZE | I+ | I+ | ZE | I- | I- |
| I- | ZE | ZE | I- | II- | II- |
| II- | I- | I- | II- | III- | III- |
| III- | II- | II- | III- | IV- | IV- |
| IV- | III- | III- | IV- | IV- | IV- |

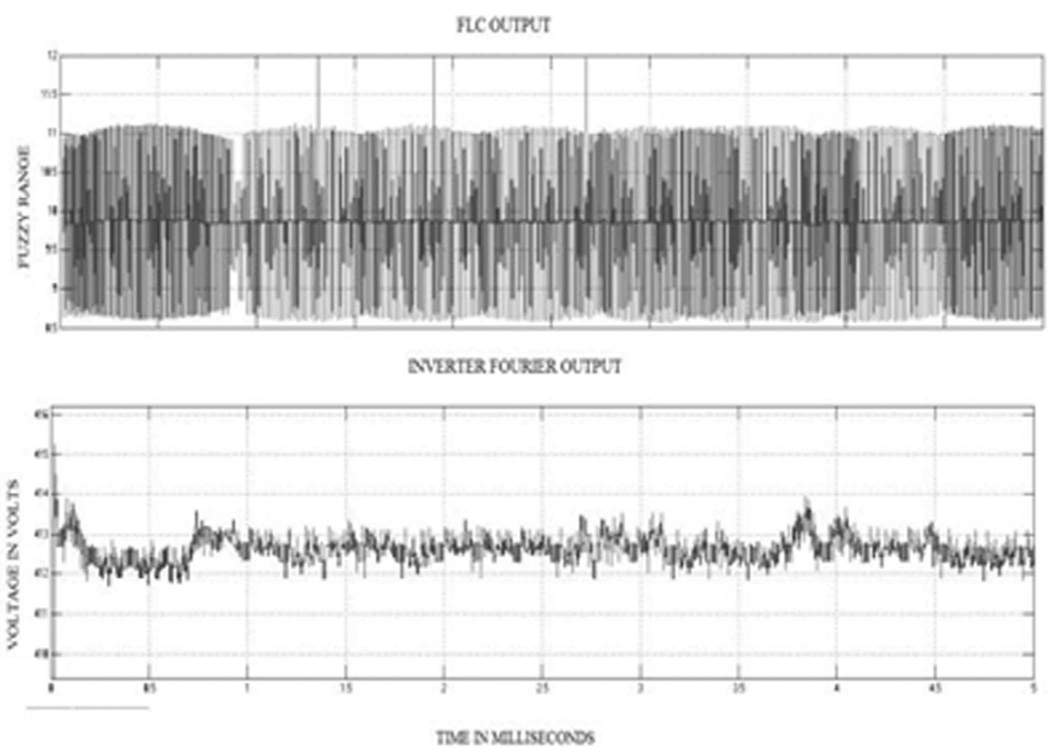


**Figure 3: FLC Output**

The output of the fuzzy logic controller, where the values are varying near the zero error is shown in the following Fig 3.

In the surface view of fuzzy logic controller formed by the two inputs and the output is shown in Fig 4 below.

The THD comes out to be 14.12% as shown in the FFT analysis in Fig 5 and the output is near sinusoidal.

## 6. HARDWARE DESCRIPTION

The proposed system consists of five IRF840 Power MOSFETs connected in an H manner instead of the conventional system consisting of 20 MOSFETs forming 5 H-bridges. The proposed system has the advantage of lesser switching losses compared to the conventional system. The H-bridge provides the 11 level pulsating DC. There are 4 more MOSFETs which form the single phase inverter and convert the pulsating DC to AC. The MOSFETs are driven by the driver circuit consisting of the driver TLP250.

There is a control circuit consisting of Microcontroller. DSPIC30F2010 which provides the PWM for the MOSFETs and also provides fuzzy control for the MPPT techniques used for the solar panel.

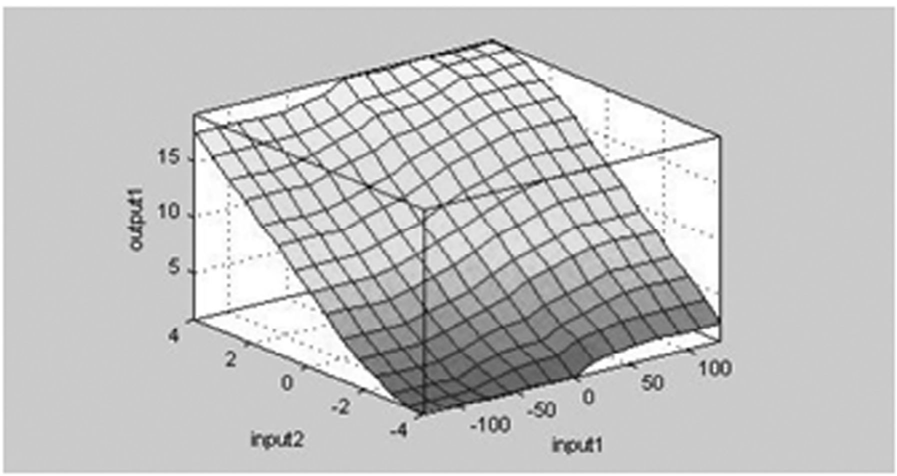


**Figure 4: FLC Surface View**

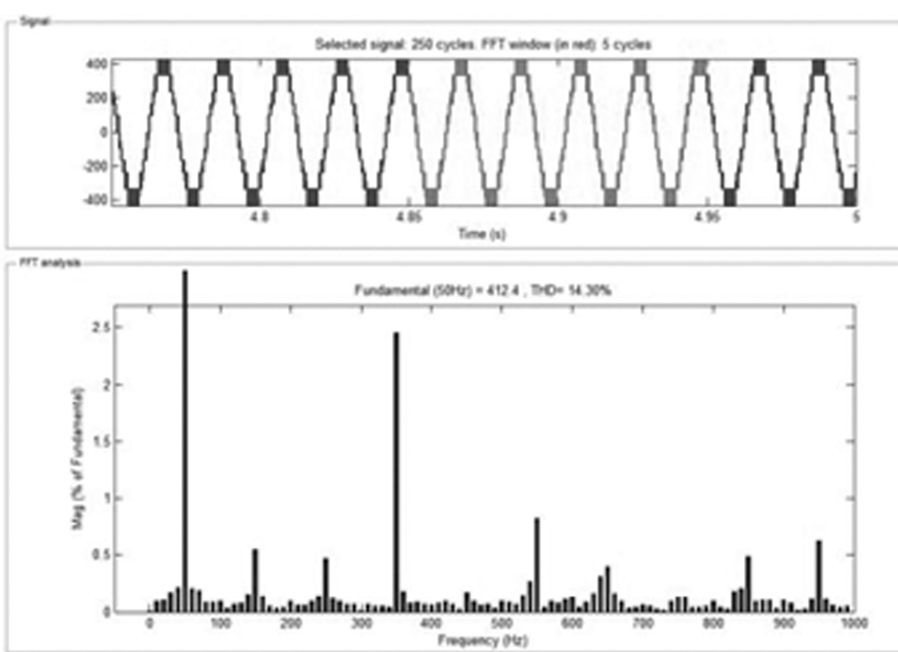


**Figure 5: FFT Analysis**

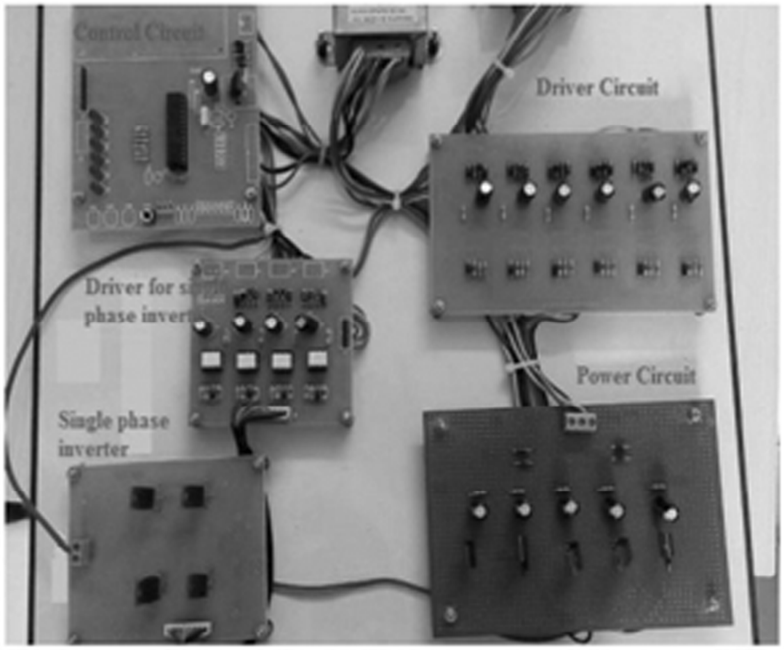


**Figure 6: Hardware Prototype of MLI**

### 6.1. Power MOSFET IRF840

The inverter employs low-voltage MOSFETs which are cheaper, faster and more efficient than IGBTs. Power MOSFETs provide the best combination of fast switching, ruggedized device design, low on-resistance and cost-effectiveness.

### 6.2. Driver TLP250

The TOSHIBA TLP250 consists of a GaAlAs light emitting diode and an integrated photo detector. This unit is 8"lead DIP package. TLP250 is suitable for gate driving circuit of IGBT or power MOSFET. TLP250 MOSFET driver is optically isolated. Input and output of TLP250 MOSFET driver is isolated from each other. Its works like an optocoupler. Input stage has a light emitting diode and output stage has a photo diode. Whenever input stage LED light falls on output stage photo detector diode, output becomes high. In the proposed system, a 12V DC supply is provided to the driver for its functioning. The driver amplifies the 5V signal provided to it by the control circuit to a 12V signal, for the proper switching of the MOSFETs.

### 6.3. MICROCONTROLLER

### DSPIC30F2010

The dsPIC30F2010 devices contain extensive Digital Signal Processor (DSP) functionality within high-performance 16-bit microcontroller (MCU) architecture. In the proposed model, it is used as a controller of fuzzy logic algorithm and pulse width modulation.

## 7. OPERATION

The prototype model shown in Fig 6 of the eleven level multilevel inverter is given the maximum DC input received from the solar panels. The variable DC power from the solar panel is fed to the circuit after the dsPIC30F2010 controller dumped with fuzzy logic MPPT algorithm tracks the maximum power. The control circuit is also programmed to produce pulses so as to trigger the MOSFET switches for a predefined duration.

The maximum power fed by the solar panel based on the fuzzy logic algorithm is given to the driver circuit which in turn triggers the MOSFETs in the sequence T1, T4, T3, T2, T5, T1. The loop is programmed

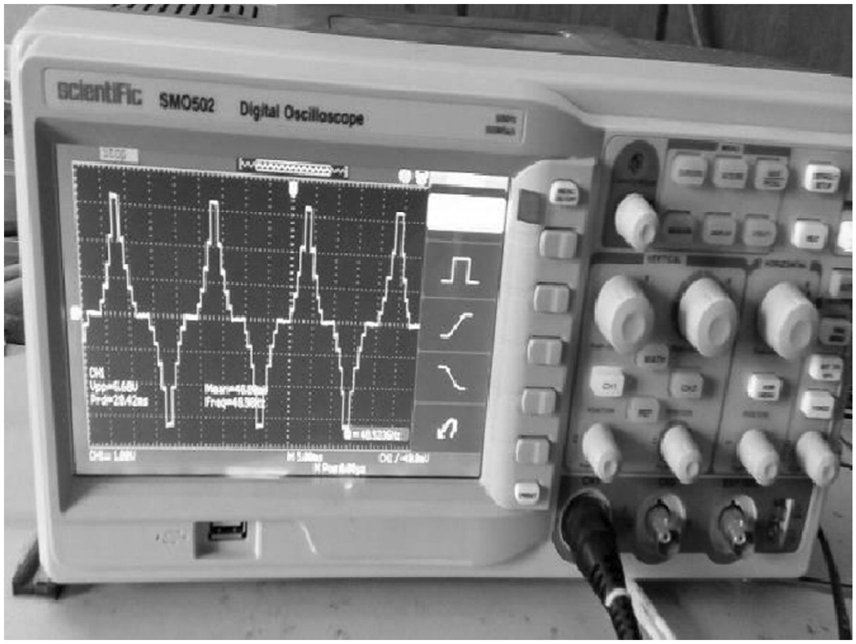


**Figure 7: Prototype Inverter Output**

to operate till the time an eleven level stepped output is obtained. The number of switches used is reduced by programming a looping operation among the five MOSFETs in order to minimize the switching losses. Such a loop operation of the switches resembles the operation of a five stage cascaded H-Bridge multilevel inverter with reduced number of switches and hence is much more efficient and cost effective. The output of the MLI is a stepped waveform. There is another single phase inverter bridge consisting of four MOSFET switches with a separate driver circuit which on receiving triggering pulses from the control circuit inverts the stepped DC output of the MLI into stepped AC.

The stepped AC output obtained has reduced harmonics content which in turn is fed to drive loads like induction motor, capacitive loads, etc.

This inverter output shown in Fig 7 demonstrates the good quality of the obtained voltage waveforms, confirming simulation results.

The following output has been obtained from the testing of the prototype model for an input of 12V DC:

Output Voltage (Peak to Peak): 6.6V AC, 50Hz.

## 8. CONCLUSION

A novel single-phase multilevel cascaded H-bridge inverter for photovoltaic applications with fuzzy logic control has been proposed. The hardware model was also implemented using various components and an eleven level stepped output is obtained. Its performance satisfies the demand of flexible and accurate electric power generation and reduces both the output filter dimensions and the influence of perturbations caused by cloud darkening or seasonal variations. Due to its modularity, the proposed system can be improved by increasing the number of levels, further reducing its harmonic content.

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