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Design of Fuzzy Logic Controlling of a Single Phase 9-Level Grid-Connected Inverter for Photovoltaic system using Filter

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Abstract : The proposed system a fuzzy controller is employed for improving the overall performance of existed seven level multilevel inverter for grid connected photovoltaic system where we reduced total harmonic distortion(THD) and also improvised wave shaping as compared to traditional seven level inverter.In this paper we employed three identical reference signals (Vref1, Vref2, and Vref3) with offset value similar as amplitude of the triangular carrier (V carrier) signal to produce the PWM signals. PV based inverter providing seven levels of output voltage and its functionality is to recounts and enhancement of novel modified H-bridge single phase multilevel inverter, it has two diode bidirectional switches and a novel pulse width modulation technique. By supervisory the modulation index, the necessary number of levels of the inverter's output voltage can be accomplished. Also this topology had benefits in MPPT system. Multilevel inverter with FUZZY control implementation gains in better-quality output waveform, reduces the THD and fast error correction. The proposed system was verified through MATlab/Simulation program.

Keywords: Boost Converter, Boost Inverter, Fuzzy logic controller, Solar Photovoltaic, Total harmonic distortion

I. INTRODUCTION

Photovoltaic array system is likely recognized and widely utilized to the forefront in electric powerapplications. It can generate direct current electricity without environmental impact and contamination whenis exposed to solar radiation [1]. Among the renewable energy resources, the energy through the Photovoltaic(PV) effect can be considered the most essential and prerequisite sustainable resource because of theabundance, and sustainability of solar radiant energy.Generally solar power generation consists of a PV array, a dc-dc converter and an inverter [2].Maximum power is trapped using a boost converter to which fuzzy logic control is applied. The boostconverter used to boost the low voltage of solar photovoltaic array. The classical inverter gives outputvoltage lower than the dc link voltage due to this, the size of output transformer is increased thus the overallcost of the system increases and efficiency decreases. Here new voltage source inverter is proposed calledboost inverter [3]-[4] which naturally generates an output AC voltage larger than input voltage.Initially, the dc output voltage from the PV array is given to the boost dc-dc converter which booststhe output voltage of the PV array as well as it regulates its output voltage irrespective of the variation insolar radiation and temperature. Fuzzy logic controllers help to track the Maximum power from fluctuation inphotovoltaic array [11]-[12]. The PWM control is provided in order to regulate the output voltage of theboost converter [5]

Theobjective here is to identify and explain design choices forengineers as depicted in Fig.1. Generally solar power generation consists of a PV array, a dc-dc converter and an inverter [2].Maximum power is trapped using a boost converter to which fuzzy logic control is applied.

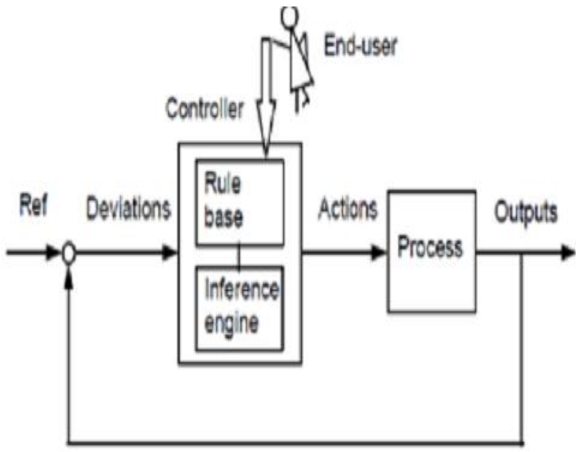

Fig 1. Fuzzy logic process

Design of an efficient fuzzy logic controller involves the optimization of parameters offuzzy sets (membership function) and proper choice of rule base. There are several techniquesreported in recent literature that use neural network architecture and genetic algorithms to learn andoptimize a fuzzy logic controller. The first step to build an efficient fuzzy inference system is toidentify the membership function from the experimental data. There is no pre defined rules forcalculating number of membership functions and range of membership functions. At this pointsystem identification comes in to act. With the help of system identification and estimation thedesigner can determine the number of membership functions and ranges of membership functions.After membership function is designed, rule base is created.

II. UNIQUE FEATURES OF FUZZY LOGIC

A. Membership functions

Fuzzy system uses ‗4' different shapes of MF's., those areTriangular, Gaussian, Trapezoidal, sigmoid, etc.,i. Triangular membership functionThe simplest and most commonly used membership functionsare triangular membership functions, which are Symmetricaland asymmetrical in shape Trapezoidal membership functionsare also symmetrical or asymmetrical has the shape oftruncated triangle

ii. Gaussian membership function

Two membership functions Triangular and Trapezoidal arebuilt on the Gaussian curve and two sided composite of twodifferent Gaussian curves.

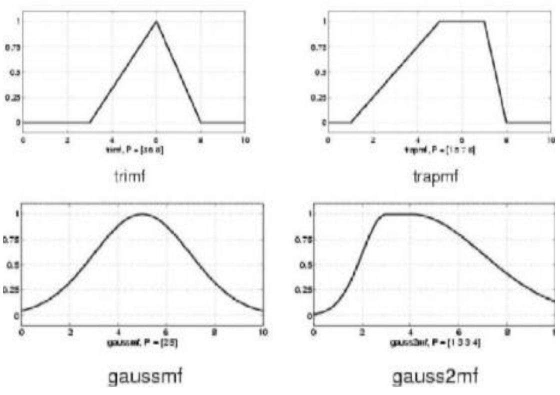

Fig 2. Membership functions

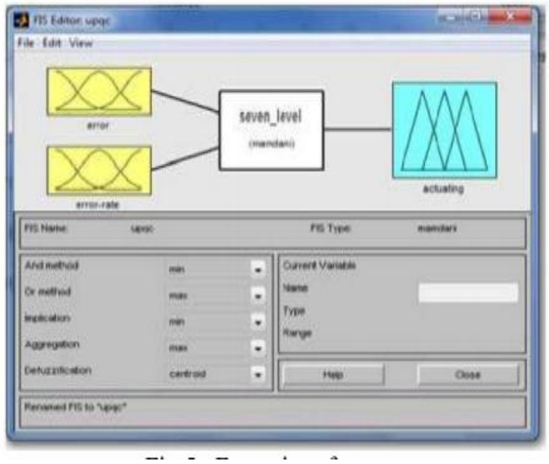

Fig 3 Fuzzy interface system

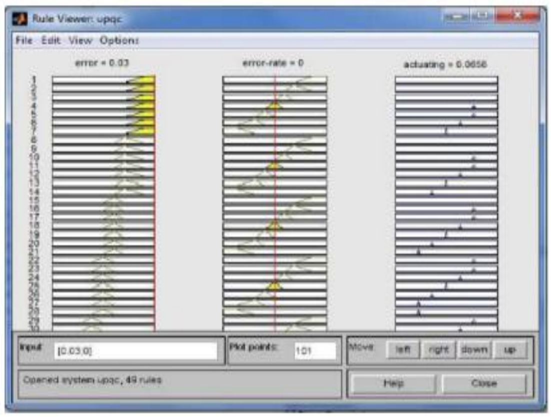

Fig 4. Fuzzy Rule Viewer

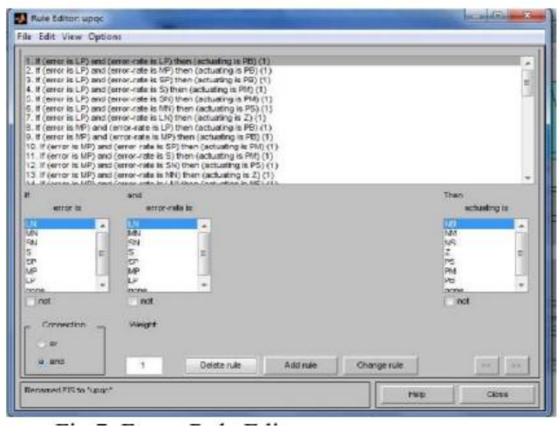

Fig 5. Fuzzy Rule Editor

There are fiveprimary GUI tools for building, editing, and observing fuzzy inference systems in the Fuzzy Logic Toolbox. The FuzzyInference System or FIS Editor, the Membership Function

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Editor, the Rule Editor, the Rule Viewer, and the SurfaceViewer.

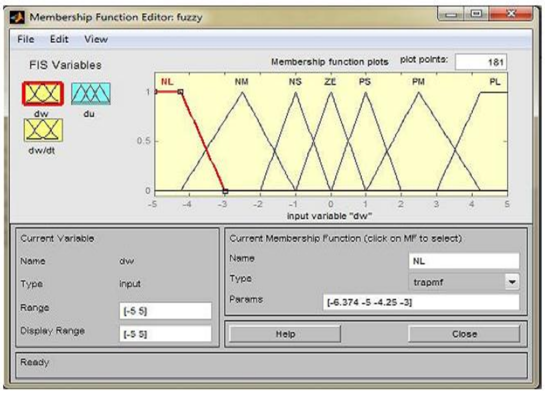

Fig. 6 Membership function of a fuzzy logic controller

III. FUZZY LOGIC CONTROLLERS

Fuzzy logic is a form of logic that is the extension of boolean logic, which incorporatespartial values of truth. Instead of sentences being "completely true" or "completely false," they areassigned a value that represents their degree of truth. In fuzzy systems, values are indicated by anumber (called a truth value) in the range from 0 to 1, where 0.0 represents absolute false and 1.0represents absolute truth.

Fuzzification is the generalization of any theory from discrete tocontinuous. Fuzzy logic is important to artificial intelligence because they allow computers toanswer 'to a certain degree' as opposed to in one extreme or the other. In this sense, computers areallowed to think more 'human-like' since almost nothing in our perception is extreme, but is trueonly to a certain degree. Through fuzzy logic, machines can think in degrees, solve problems whenthere is no simple mathematical model. It solves problems for highly nonlinear processes and usesexpert knowledge to make decisions.

The fuzzy logic controller provides an algorithm, which converts the expert knowledge into anautomatic control strategy. Fuzzy logic is capable of handling approximate information in asystematic way and therefore it is suited for controlling non linear systems and is used for modelingcomplex systems, where an inexact model exists or systems where ambiguity or vagueness iscommon. The fuzzy control systems are rule-based systems in which a set of fuzzy rules represent acontrol decision mechanism for adjusting the effects of certain system stimuli. With an effectiverule base, the fuzzy control systems can replace a skilled human operator. The rule base reflects thehuman expert knowledge, expressed as linguistic variables, while the membership functionsrepresent expert interpretation of those variables.

Fig.7 shows the block diagram of fuzzy control system. The crisp inputs are supplied tothe input side Fuzzification unit. The Fuzzification unit converts the crisp input in to fuzzy variable.The fuzzy variables are then passed through the fuzzy rule base.

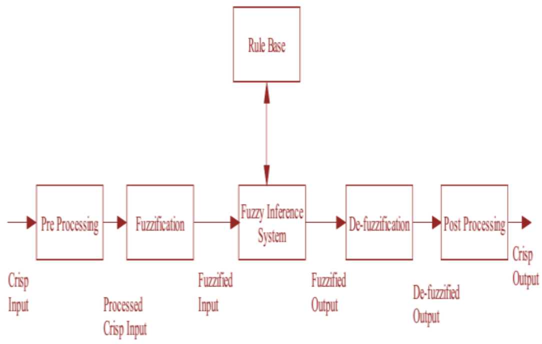

Fig.7fuzzy control system

The fuzzy rule base computes theinput according to the rules and gives the output. The output is then passed through de-fuzzificationunit where the fuzzy output is converted to crisp output.

IV. PROPOSED MULTILEVEL INVERTER TOPOLOGY

The proposed inverter‘s operation can be divided into sevenswitching states, as shown in Fig. 8(a)–(g). Fig. 8(a), (d), and(g) shows a conventional inverter‘s operational states insequence, while Fig. 8(b), (c), (e), and (f) shows additionalstates in the proposed inverter synthesizing one- and two-thirdlevels of the dc-bus voltage.The required seven levels of output voltage were generated asfollows.

1) Maximum positive output (Vdc): S1 is ON, connecting theload positive terminal to Vdc, and S4 is ON, connecting theload negative terminal to

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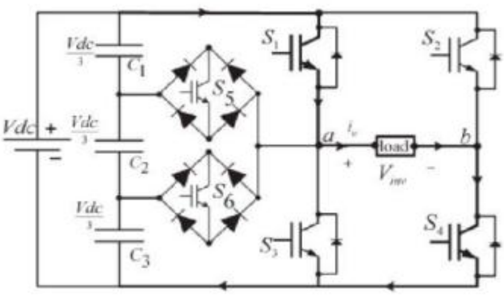
ground. All other controlled switchesare OFF; the voltage applied to the load terminals is Vdc. Fig.1.12. Shows the current paths that are active at this stage.

2) Two-third positive output (2Vdc/3): The bidirectionalswitch S5 is ON, connecting the load positive terminal, and S4is ON, connecting the load negative terminal to ground. Allother controlled switches are OFF; the voltage applied to theload terminals is 2Vdc/3. Fig. 8(b) shows the current paths thatare active at this stage.

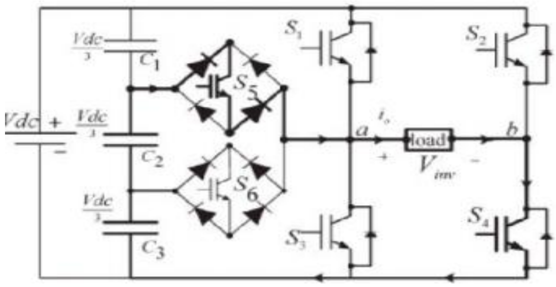
3) One-third positive output (Vdc/3): The bidirectional switchS6 is ON, connecting the load positive terminal, and S4 isON, connecting the load negative terminal to ground. All othercontrolled switches are OFF; the voltage applied to the loadterminals is Vdc/3. Fig. 8(c) shows the current paths that areactive at this stage.

4) Zero output: This level can be produced by two switchingcombinations; switches S3 and S4 are ON, or S1 and S2 areON, and all other controlled switches are OFF; terminal ab is ashort circuit, and the voltage applied to the load terminals iszero. Fig. 8(d) shows the current paths that are active at thisstage.

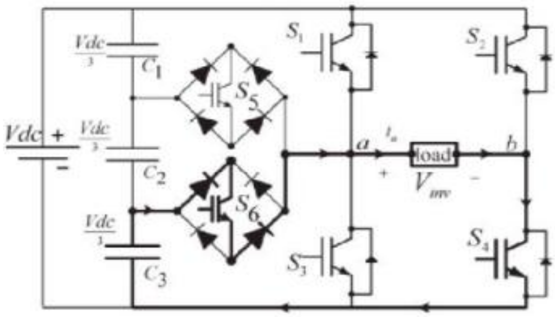
5) One-third negative output (−V dc/3): The bidirectionalswitch S5 is ON, connecting the load positive terminal, and S2is ON, connecting the load negative terminal to Vdc. All other



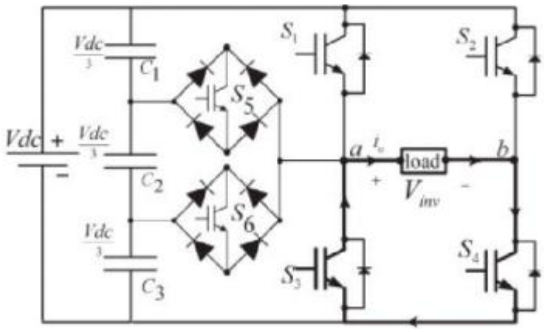
(a)



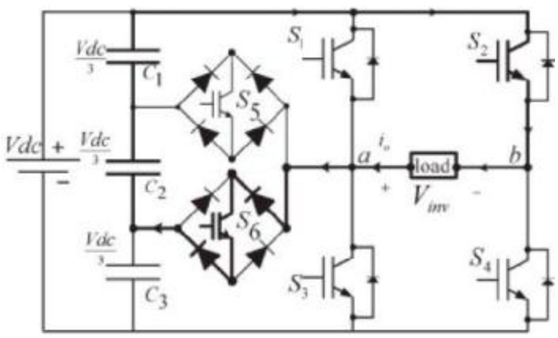
(b)



(c)



(d)



(e)

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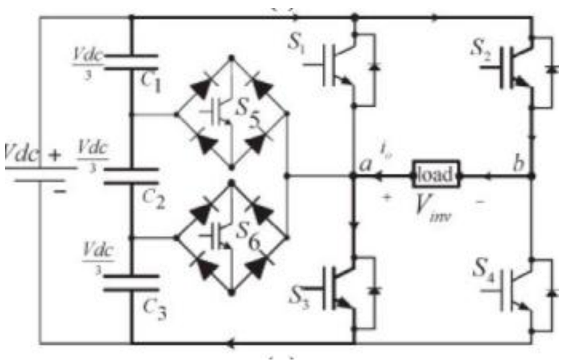

(f)

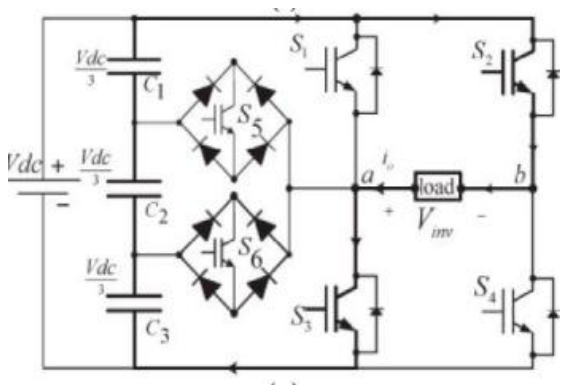

Fig. 8. Switching combination required to generate theoutput voltage (Vab).(a) Vab = Vdc. (b) Vab = 2Vdc/3. (c) Vab = Vdc/3. (d) Vab = 0.(e) Vab = −V dc/3. (f)Vab= − 2Vdc/3. (g)Vab = −V dc.

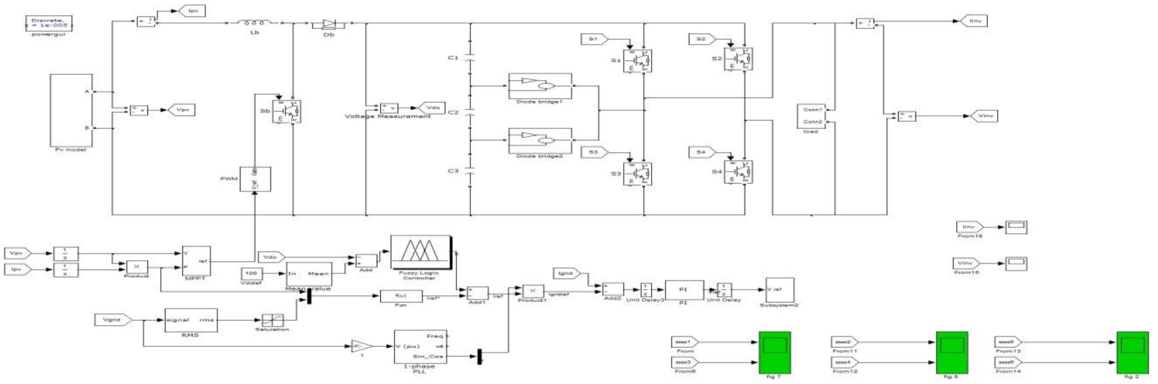

Fig. 9

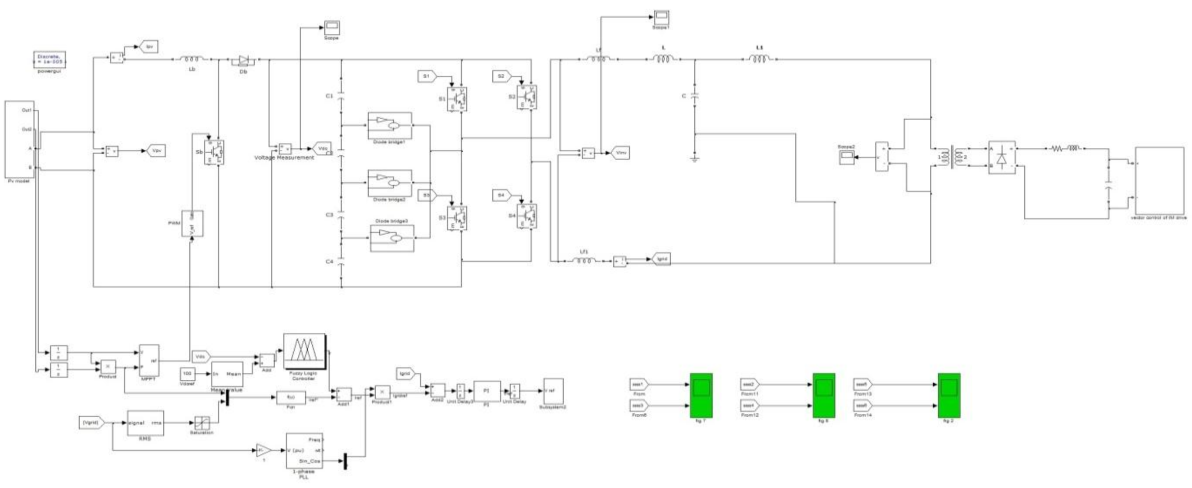

Fig. 10

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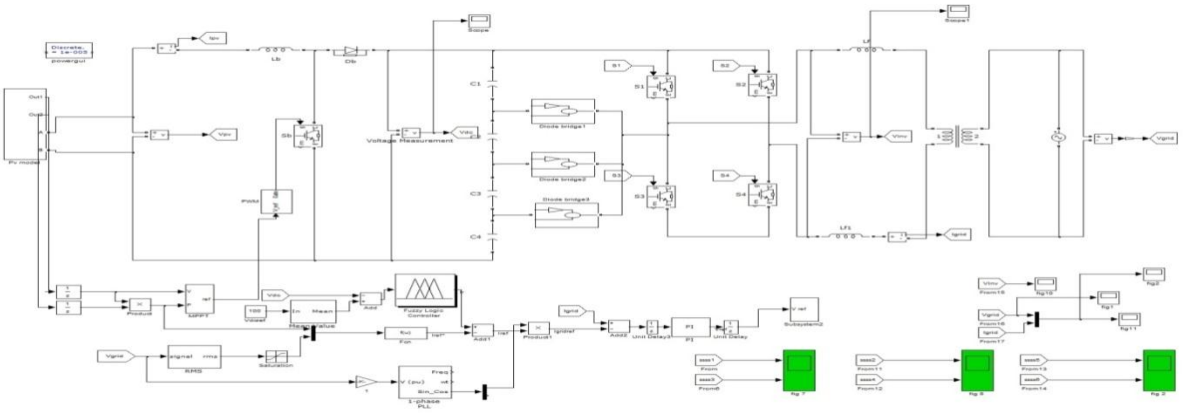

Fig. 11

V. SIMULATION RESULTS

MATLAB SIMULINK simulates the inverter operates at ahigh switching rate that was equivalent to the frequency of thecarrier signal, while the other leg operates at the rate of thefundamental frequency (i.e., 50 Hz). Switches S5 and S6 alsooperates at the rate of the carrier signal. Fig. 12 shows thesimulation result of inverter output voltage Vinv. The dc-busvoltage was set at 300 V (>√2Vgrid; in this case, Vgrid was120 V). The dc-bus voltage must always be higher than √2 ofVgrid to inject current into the grid, or current injects from thegrid into the inverter. Therefore, operation is recommendbetween M_a = 0.66 and M_a = 1.0. V_{inv} comprises sevenvoltage levels, namely, Vdc, 2Vdc/3, Vdc/3, 0, −V dc, −2Vdc/3, and −V dc/3. The current flowing into the grid wasfilters to resemble a pure sine wave in phase with the gridvoltage.

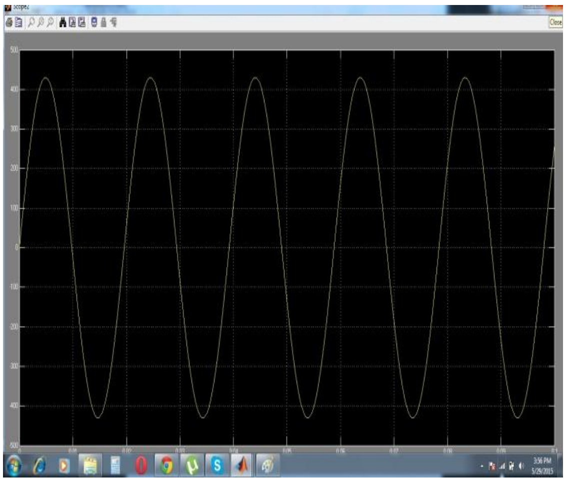

Fig. 11 Load voltage

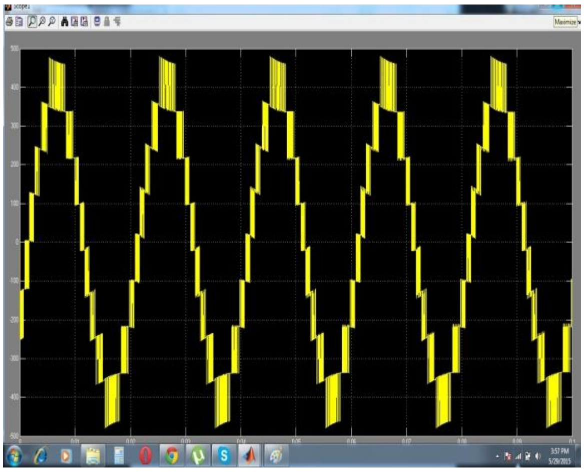

Fig. 12Nine level

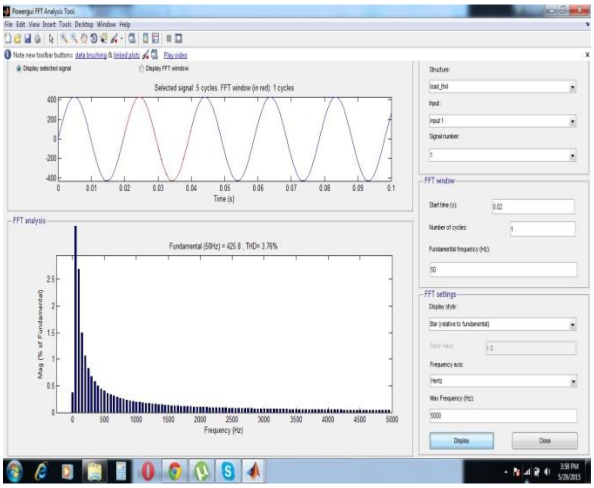

Figure 13. THD under Machine load

After analyzed, Total Harmonic Distortion of the proposed system provides 3.76 % for inductive load shown in Figure 13. This will provide better economic andtechnical advantages. The simulation results show that this system is able to adapt the fuzzy parameters forfast response, good, transient performance, insensitive to variations in external disturbances. This system canprovide energy to a utility with low harmonics. It is also evident from the results, that the total harmonicdistortion of the output inverter current waveform at different solar panel voltage levels can be maintainedclose to the specified regulation limits of the utility.

VI. CONCLUSION

Fuzzy logic controller to multilevel inverters improvesoutput waveforms and lower THD. This paper has presented anovel FUZZY PWM switching scheme for the proposedmultilevel inverter. It utilizes three reference signals and atriangular carrier signal to generate PWM switching signals.The three reference signals are obtained by fuzzy controller.The behavior of the proposed fuzzy logic controller multilevelinverter was analyzed in detail.

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