A Seven-Level Grid Connected Inverter for Photovoltaic system

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Abstract: This paper proposes fuzzy logic controller based a single-phase seven-level inverter for grid-connected photovoltaic systems, with a novel pulse width-modulation (PWM) control scheme. Three reference signals produces from fuzzy logic controller which are identical to each other are going to compare with the amplitude of the triangular carrier signal. The inverter is capable of producing seven levels($V_{ab} = V_{dc}$ $V_{ab} = 2V_{dc}/3$ $V_{ab} = V_{dc}/3$ $V_{ab} = 0$ $V_{ab} = -V_{dc}/3$ $V_{ab} = -2V_{dc}/3$ $V_{ab} = -V_{dc}$)of output-voltage levels from the dc supply voltage. The total harmonic distortion is reduces by this control strategy. The proposed system was verified through simulation.

Keywords: Fuzzy logic Controller, Grid connected, modulation index, multilevel inverter, photovoltaic (PV) system, pulse width-modulated (PWM), total harmonic distortion (THD).

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1. INTRODUCTION

Fuzzy controllers are uses for controlling consumer products, such as washing machines, video cameras, and rice cookers, as well as industrial processes, such as cement kilns, underground trains, and robots. Fuzzy control is a control method based on fuzzy logic. Just as fuzzy logic can be described simply as ''computing with words rather than numbers''; fuzzy control can be described simply as ''control with sentences rather than equations''. A fuzzy controller can include empiric al rules, and that is especially useful in operator controlled plants [1]. The objective here is to identify and explain design choices for engineers.
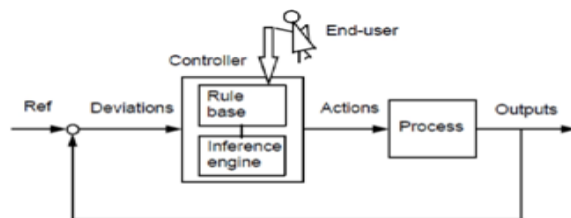

Fig 1. Fuzzy logic process

A single-phase grid-connected inverter is usually used for an engineering application which is controlled by a fuzzy system. Types of single-phase grid-connected inverters have been investigated [2]. A common topology of this inverter is full-bridge three-level. The three-level inverter can satisfy specifications through its very high switching, but it could also unfortunately increase switching losses, acoustic noise, and level of interference to other equipment. Improving its output waveform reduces its harmonic content and, hence, also the size of the filter used and the level of electromagnetic interference (EMI) generated by the inverter's switching operation [3]. The input for a seven level inverter is photo voltaic cells which reduces the pollution level due to generation [4].

II. FUZZY LOGIC CONTROLLERS

A. Introduction to fuzzy logic:

The logic of an approximate reasoning continues to grow in importance, as it provides an in expensive solution for controlling know complex systems. Fuzzy logic controllers are already used in appliances washing machine, refrigerator, vacuum

cleaner etc. Computer subsystems (disk drive controller, power management) consumer electronics (video, camera, battery charger) C.D. Player etc. and so on in last decade, fuzzy controllers have convert adequate attention in motion control systems. As the later possess non-linear characteristics and a precise model is most often unknown. Remote controllers are increasingly being used to control a system from a distant place due to inaccessibility of the system or for comfort reasons. In this work a fuzzy remote controllers is developed for speed control of a converter fed dc motor. The performance of the fuzzy controller is compared with conventional P-I controller.

B. Unique features of fuzzy logic

The unique features of fuzzy logic that made it a particularly good choice for many control problems are as follows, It is inherently robust since it does not require precise, noise – free inputs and can be programmed to fail safely is a feedback sensor quits or is destroyed. The output control is a smooth control function despite a wide range of input variations. Since the fuzzy logic controller processes user-define rules governing the target control system, it can be modify and tweakeseasily to improve or drastically alter system performance. New sensors can easily be incorporates into the system simply by generating appropriate governing rules.

C. Fuzzification and Normalization

Fuzzification is relate to the vagueness and imprecision in a natural language. It is a subjective valuation, which transforms a measurement into a valuation of an objective input space to fuzzy sets in certain input universes of discourse. In fuzzy control applications, the observed data are usually crisp. Since the data manipulation in a fuzzy logic controller is based on fuzzy set theory, fuzzification is necessary in an earlier stage.

D. Membership functions

Fuzzy system uses ₋4'different shapes of MF's., those are Triangular, Gaussian, Trapezoidal, sigmoid, etc.,i.Triangular membership function The simplest and most commonly used membership

functions are triangular membership functions, which are Symmetrical and asymmetrical in shape Trapezoidal membership functions are also symmetrical or asymmetrical has the shape of truncated triangle

ii. Gaussian membership function

Two membership functions Triangular and Trapezoidal are built on the Gaussian curve and two sided composite of two different Gaussian curves.
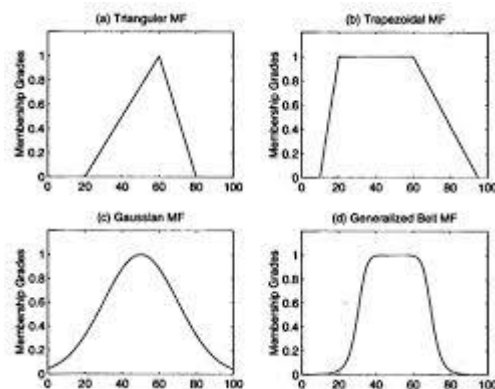

Fig 2. Membership functions

E. Fuzzy system

The fuzzy interface system Fuzzy system basically consists of a formulation of the mapping from a given input set to an output set using Fuzzy logic. The mapping process provides the basis from which the interference or conclusion can be made.

F. Steps for A Fuzzy interface process

i. Fuzzification of input variables.

ii. Application of Fuzzy operator.(AND, OR, NOT) In the IF (antecedent) part of the rule.

iii. Implication from the antecedent to the consequent (Then part of the rule).
iv. Aggregation of the consequents across the rules.

v. Defuzzification.

Generally there will be a matrix of rules similar tot eh ES rule matrix for Ex: There are 7MF for input

variables _x' and MF for input variable _y' then there will be all to get her35 rules.

G. Implication method

The implication step (3) introduces to evaluate the individual rules.

Methods:

1) MAMDANI

2) SUGENO

3) LUSING LARSON.

H. Defuzzification and Denormilization

The function of a defuzzification module (DM) is as follows:

Performs the so-called defuzzification, which converts the set of modified control output values into single point – wise values. Performs an output denormilization, which maps the point wise value of the control output onto its physical domain. This step in not needed if non normalized fuzzy sets is used. A defuzzification strategy is aim sat producing a non-fuzzy control action that best represents the possibility of an inferred fuzzy control action. Seven strategies in the literature, among the many that have been proposed by investigators, are popular for defuzziffying fuzzy output functions:

i. Max-membership principle

ii. Centroid method

iii. Weighted average method

iv. Mean-max member ship

v. Centre of sums.

vi. Centre of largest area

vii. First (or last) of maxima.

The best well-known defuzzification method is Centroid method.

III. PROPOSED MULTILEVEL INVERTER TOPOLOGY

The proposed single-phase seven-level inverter was developed from the five-level inverter in [15]–[18]. It comprises a single phase conventional H-bridge inverter, two bidirectional Switches, and a capacitor voltage divider formed by C1, C2,And C3, as shown in Fig. 1. The modified H-bridge topology is significantly advantageous over other topologies, i.e., less Power switch, power diodes, and less capacitor for inverters Of the same number of levels. Photovoltaic (PV) arrays were connected to the inverter via a Dc–dc boost converter. he power generated by the inverter is to be delivered to the power network, so the utility grid, rather than a load, was used. The dc–dc boost converter was required because the PV arrays had a voltage that was lower than the grid voltage. High dc bus voltages are necessary to ensure that power flows from the PV arrays to the grid. A filtering inductance was used to filter the current injected into the grid. Proper switching of the inverter can produce seven output-voltage levels (Vdc, 2Vdc/3, Vdc/3, 0,–Vdc,–2Vdc/3,–Vdc/3) from thedc supply voltage. The proposed inverter's operation can be divided into seven switching states, as shown in Fig. 3(a)–(g). Fig. 3(a), (d), and (g) shows a conventional inverter's operational states in sequence, while Fig. 3(b), (c), (e), and (f) shows additional states in the proposed inverter synthesizing one- and two-third levels of the dc-bus voltage. The required seven levels of output voltage were generated as follows.

1) Maximum positive output (Vdc): S1 is ON, connecting the load positive terminal to Vdc, and S4 is ON, connecting the load negative terminal to ground. All other controlled switches are 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 bidirectional switch S5 is ON, connecting the load positive terminal, and S4 is ON, connecting the load negative terminal to ground. All other controlled switches are OFF; the voltage applied to the load terminals is 2Vdc/3. Fig. 3(b) shows the current paths that are active at this stage.

3) One-third positive output (Vdc/3): The bidirectional switch S6 is ON, connecting the load positive terminal, and S4 is ON,connecting the load negative terminal to ground. All other controlled switches are OFF; the voltage applied to the load terminals is Vdc/3. Fig. 3(c) shows the current paths that are active at this stage.

4) Zero output: This level can be produced by two switching combinations; switches S3 and S4 are ON, or S1 and S2 are ON, and all other controlled switches are OFF; terminal ab is ashort circuit, and the voltage applied to the load terminals is zero. Fig. 3(d) shows the current paths that are active at this stage.

5) One-third negative output (−V dc/3): The bidirectional switch S5 is ON, connecting the load positive terminal, and S2is ON, connecting the load negative terminal to Vdc. All other controlled switches are OFF; the voltage Applied to the load terminals is −V dc/3. Fig. 3(e) shows the current paths that are active at this stage.

6) Two-third negative output (− 2Vdc/3): The bidirectional switch S6 is ON, connecting the load positive terminal, and S2 is ON, connecting the load negative terminal to ground. All other controlled switches are OFF; the voltage applied to the load terminals is − 2Vdc/3. Fig. 3(f) shows the current paths that are active at this stage.
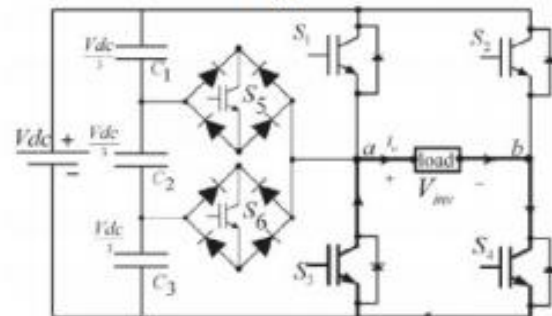
7) Maximum negative output (−V dc): S2 is ON, connecting the load negative terminal to Vdc, and S3 is ON, connecting the load positive terminal to ground. All other controlled switches are OFF; the voltage applied to the load terminals is −V dc. Fig. 3(g) shows the current paths that are active at this stage.
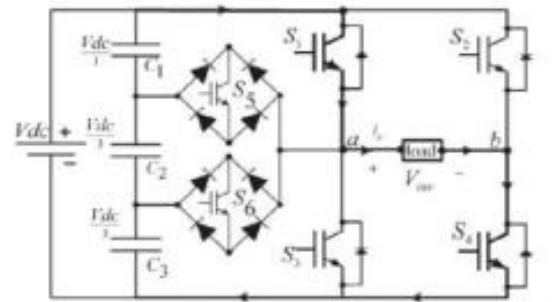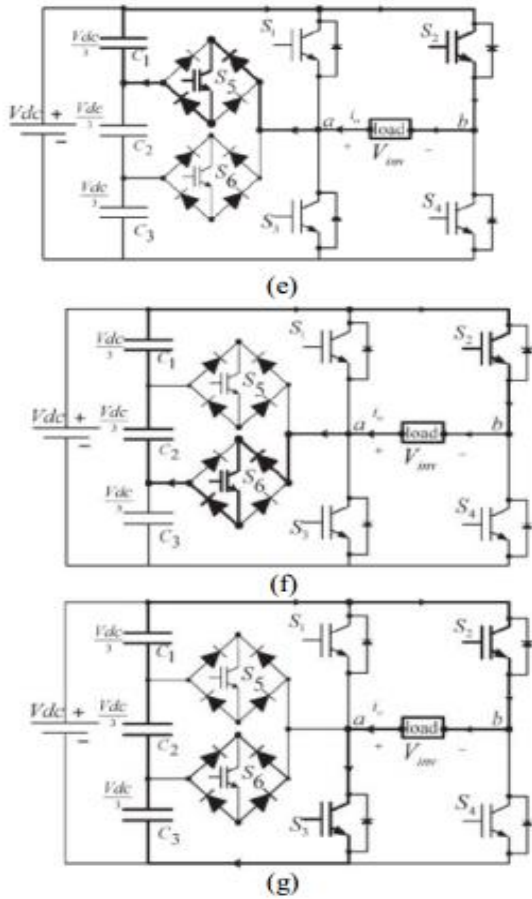

(a)
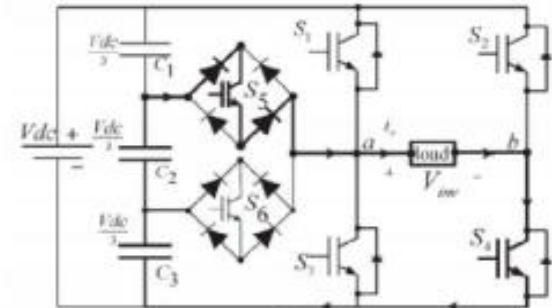
(b)
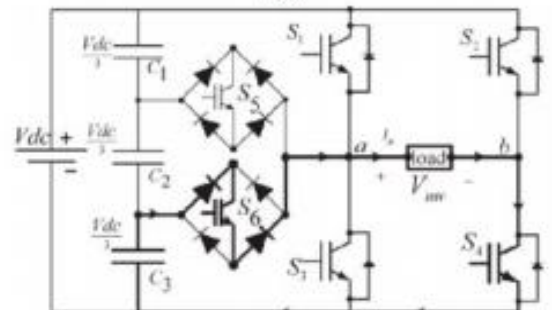
(c)

(d)

Fig. 3. Switching combination required to generate the output 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.

IV. SIMULATON RESULTS

MATLAB SIMULINK simulates the inverter operates at a high switching rate that was equivalent to the frequency of the carrier signal, while the other leg operates at the rate of the fundamental frequency (i.e., 50 Hz). Switches S5 and S6 also operates at the rate of the carrier signal. Fig. 6 shows the simulation result of inverter output voltage Vinv. The dc-bus voltage was set at 300 V (>√2Vgrid; in this case, Vgrid was 120 V). The dc-bus voltage must always be higher than √2 of Vgrid to inject current into the grid, or current injects from the grid into the inverter. Therefore, operation is recommend between Ma = 0.66 and Ma = 1.0. Vinv

comprises seven voltage levels, namely, Vdc, 2Vdc/3, Vdc/3, 0, −V dc, −2Vdc/3, and −V dc/3. The current flowing into the grid was filters to resemble a pure sine wave in phase with the grid voltage
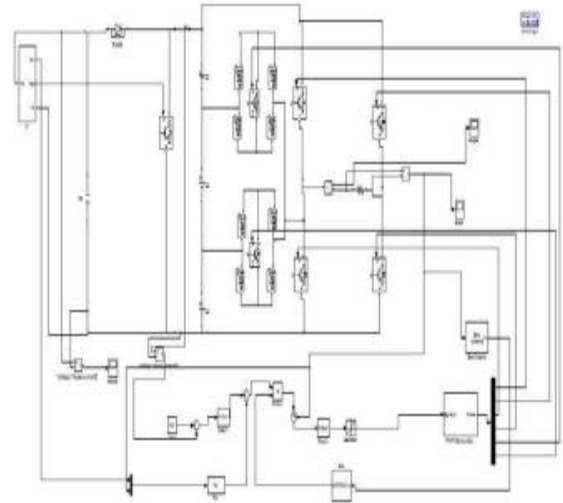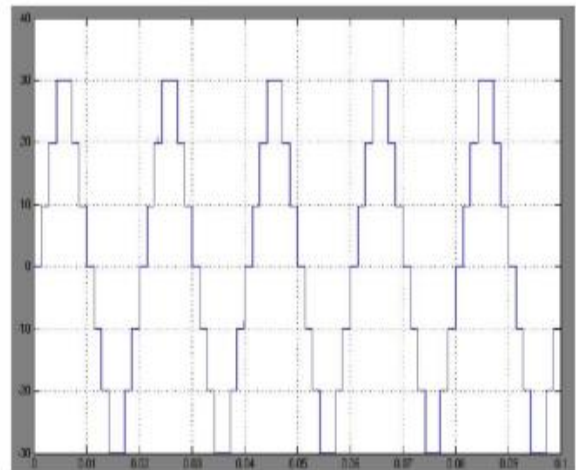

Fig 4. 7 level fuzzy
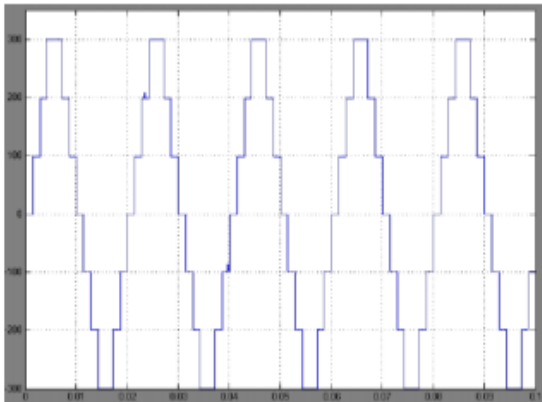

Fig 5: Current waveform with fuzzy

Fig 6. Voltage waveform with fuzzy

V. CONCLUSION

Fuzzy logic controller to multilevel inverters improves output waveforms and lower THD. This paper has presented a novel FUZZY PWM switching scheme for the proposed multilevel inverter. It utilizes three reference signals and a triangular carrier signal to generate PWM switching signals. The three reference signals are obtained by fuzzy controller. The behavior of the proposed fuzzy logic controller multilevel inverter was analyzed in detail. By controlling the modulation index, the desired number of levels of the inverter's output voltage can be achieved.

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