ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

MODELLING AND SIMULATION OF LC SWITCHING VOLTAGE BOOST THREE LEVEL NPC INVERTER WITH FUZZY LOGIC CONTROLLER

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DOI: 10.5281/zenodo.995964

ABSTRACT
This paper presents a new control scheme for three levels NPC Inverter to boost up the input dc voltage and give three levels AC output voltage with less harmonic distortion in a single stage.Recently, Single stage high voltage pick up support inverter is getting ubiquity in applications like sun powered PV, energy component, UPS systems and so on. As of late, single stage voltage support multilevel Z-Source inverter (ZSI) and Quasi Z-source inverter (QZSI) have been proposed for DC-AC control transformation with enhanced power quality. Multilevel ZSI utilizes more number of high power inactive segments in the middle of the road arrange which increment the system measure furthermore, weight. Likewise its info current is irregular in nature which is not alluring in a portion of the applications like energy unit, UPS systems, hybrid electric vehicle and so forth. In this paper a consistent current info three level LC Switching based voltage help nonpartisan point clipped (NPC) inverter with fuzzy logic controller is proposed which utilizes similarly less number of high power detached segments at the same time holds every one of the benefits of multilevel QZSI/ZSI. It is ready to help the info DC voltageand give required three levels AC output voltage in a solitary stage. The fuzzy logic controller is incorporated to systematically control the time allocation for all the switching states based on instantaneous voltage. Using the fuzzy controller for a nonlinear systemallows for a reduction of uncertain effects in the system in the system control and improve the efficiency . Enduring state investigation of the proposed inverter is talked about to define the connection between the info DC voltage what's more, three level AC output voltage. The proposed converter with fuzzy logic controller has been verified by simulation in MATLAB Simulink

KEYWORDS: Boost Inverter, PWM, Shoot –through, three level inverter .Z-Source inverter, Fuzzy logic controller.

I. INTRODUCTION
Now-a-days The Multilevel inverter has drawn a tremendous interest in power industry .With the multilevel structure it may be easy to produce high power. High voltage inverter because of the way in which device voltage stress are controlled in the structure. Increasing the number of voltage levels in the inverter without requiring higher ratings on individual device can increase the power rating[1].The Multilevel voltage source inverter (VSI) is utilized as a part of an extensive variety of uses like photovoltaic (PV) system, continuous power supply (UPS), energy unit, wind control, cross breed electric vehicle (HEV) and so on [2]-[5]. Multilevel VSI gives advantages like better power quality, littler output AC channel prerequisites, reduction of stress over the inverter switches. Nonetheless, traditional multilevel VSI acts like buck converter [1] i.e. top AC output voltage is not as much as the information DC interfaces voltage. Inapplications like PV system, energy unit UPS and so forth the required AC output voltage level is accomplished by utilizing either a DC-DC converter some time before the VSI or a transformer after the VSI [6]. However, more number of energy converter stages expands system control many-sided quality and reductions the system proficiency [7]. So also, incorporation of line frequency transformer builds the system size and weight [8]. In multilevel VSI, shoot through (i.e. exchanging all the switches in the inverter leg) comes about dead short out of the source. Shoot-through is stayed away from by giving dead band between switching control signal fed to the correlative switches of inverter leg, whichpresents mutilation in the outputAC

Voltage. ZSI addresses the above issues and can help the info DC voltage to accomplish the required AC voltage in a solitary stage [9]– [10]. Traditional three level Z-Source Neutral point clasped (NPC) inverters are investigated for medium power and low power applications [11]-[12]. It gives better power quality in the meantime voltage stress across the switches and output filters necessity are less.

This uses two secluded DC sources which may require seclusion transformer and extra rectifier circuits (in the event that secluded DC sources are not promptly accessible). It is fundamentally worked in three states i.e., Non- shoot through state, zero state, Shoot through state.In multilevel ZSI shoot-through state is used alongside passive reactive component to support the input DC voltage. It is like the zero condition of multilevel VSI where no power is exchanged to the load. In non-shoot through mode control is exchanged from DC source to AC load, which is like the dynamic condition of the multilevel VSI. Nevertheless, utilization of more number of high power passive reactive components in the middle of the network organizes and additionally confined DC control supply builds the system size, weight and cost. In writing [13]-[14] single LC impedance organize based three level ZSI is talked about which utilizes less number of high control passive elements (two capacitors and two inductors)and single split-DC source. But, in this multilevel inverter the voltage rating of the capacitor is about double than the traditional three levels Z-Source NPC inverter. The source/input current of the three level NPC ZSI is broken in nature which may expand the weight on source and is not alluring in a portion of the application like Fuel cell, UPS system, half and half electric vehicle (HEV) and so on.

Multilevel Quasi Z-Source inverter is an enhanced subordinate of multilevel Z-Source inverter, where the source current is constant in nature and voltage stress over the inverter switches are similarly less. Cascaded semiZ-source multilevel inverter utilizes at least two disengaged DC sources and more number of high power detached receptive components for better quality single stage control transformation [17]. Correspondingly, a three level NPC Quasi Z-Source inverter, where a Quasi Z-Source organizes is joined with customary NPC structure to give multilevel output. Notwithstanding, utilization of more number of high control latent receptive components and numerous disengaged DC control supply in multilevel Quasi Z-Source inverter[15]-[16], expands the system measure, cost and additionally weight. In this paper a three level LC-Switching based voltage help NPC inverter is proposed for boosting the information voltage and give required three levels AC output voltage in a solitary stage. It employments relatively less number of passive reactive components (as it were two inductors and two capacitors), two dynamic switches and four diodes in the halfway system between DC source also, inverter leg in the meantime it gives every one of the favorable circumstances of multilevel Quasi Z-Source inverter. Thus, system estimates what's more, weights are decreased. In spite of the fact that the cost of additional switches and diodes are very little not as much as the additional passive parts (inductors and capacitors) utilized as a part of multilevel Quasi Z-Source inverter however can be utilized as a part of low power or medium power applications where size and weight are fundamental requirements. The remaining paper is comprises as follows.Operation of the proposed converter with different operating modes and Mathematical validation is presented .PWM technique and Fuzzy logic controller [18], is alsopresented. Simulation results are discussed and the paper finally concluded with the main conclusion.

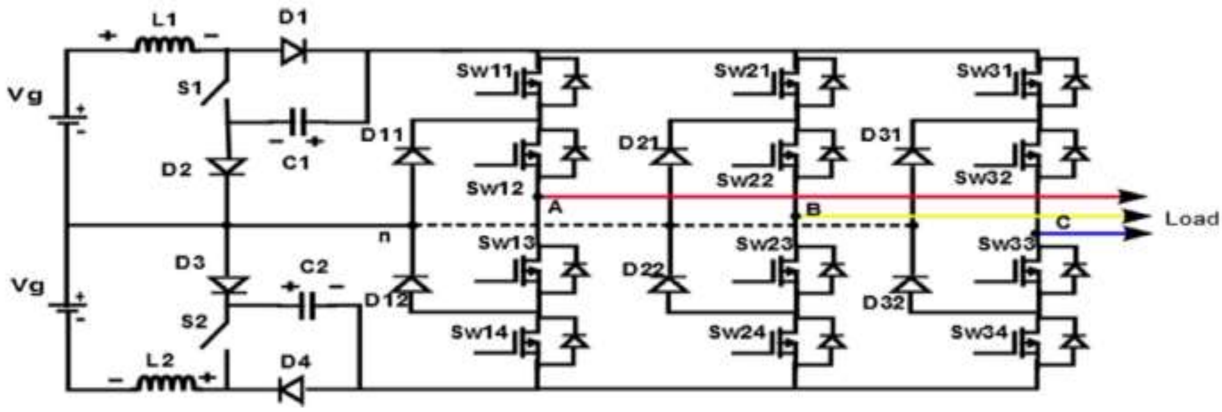

Fig.1.Circuit diagram of LC switching based voltage boost three levels NPC inverter.

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II. OPERATION OF LC SWITCHING BASED VOLTAGE BOOST THREE LEVEL NPC INVERTER

Fig.1 demonstrates the schematic outline of LC Switching based voltage boost three level NPC inverter, which can support the info DC voltage source ('Vg') and give required three levels AC voltage not at all like traditional NPC VSI. Here the info source can be either two equivalent DC sources or single split DC source. This single split DC can be made by nourishing a DC source parallel to two arrangement associated capacitors where, the interconnection point between these capacitors can be taken as nonpartision point. The network between DC source and inverter leg is comprises of two inductors (L1, L2), two capacitors (C1, C2), two dynamic switches (S1, S2) and four diodes (D1, D2, D3 and D4). Conventional NPC three level VSI is fundamentally worked in two states i.e. dynamic state (or non-shoot through state) and zero stateto give three particular voltage levels (i.e. +Vdc, 0, - Vdc). Though, the proposed inverter utilizes extra one more state i.e. shoot through state to boost up the input dc voltage and produces three distinct voltage levels (+Vdc,0,-Vdc) in a single stage. Shoot through state is placed inside the conventional zero state, without interfering the active state

Modes Of Operation

A. In non -shoot through state(or active state):

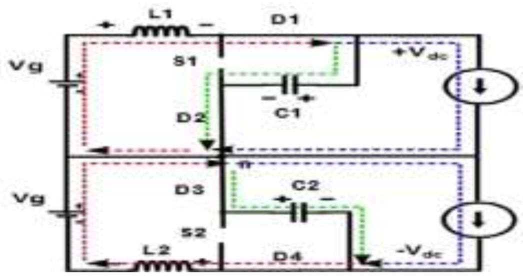

Fig.2.Equivalent circuit of non- shoot through state

It is like the dynamic condition of traditional NPC VSI where control is exchanged from DC source to AC load. In this mode of operation the AC load accomplishes either "+Vdc" or '– Vdc' voltage level crosswise over AC load as for nonpartisan point 'n'. The switches Swx1, Swx2 (where, x=1, 2, 3) are exchanged "ON" and switch "S1" is exchanged "OFF" to accomplish "+Vdc" crosswise over AC load as for nonpartisan point 'n', which thusly forward biases the diodes "D1" and 'D2'. Subsequently, both source "Vg" and inductor "L1" stimulate the capacitor "C1" and additionally supply energy to the load as appeared in Fig.2. Thus, the switches Swx3, Swx4 are exchanged "ON" and switch "S2" is exchanged "OFF" to accomplish '- Vdc'crosswise over AC load regarding impartial point 'n', which thusly forward biases the diodes "D3" and 'D4'. Subsequently, both source "Vg" what's more, inductor "L2" stimulate the capacitor "C2" and also supply energy to the load as appeared in Fig.2. Here for simple understanding the load has been spoken to by current source with respect to little span the load current is thought to be consistent.

B. During Zero State

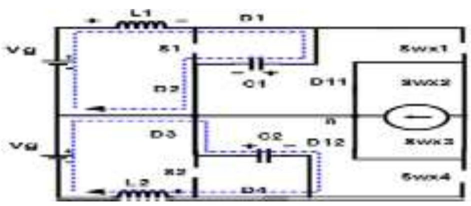

Fig.3.Equivalent circuit of zero state

In this mode of operation, no power is exchanged to AC load from DC source like zero condition of ordinary NPC VSI. The switches Swx2, Swx3 are exchanged "ON" and switch'S1','S2', 'Swx1', "Swx4" are exchanged "OFF" to accomplish "0" voltage over load, which thusly forward biases the diodes 'D1', 'D2',"D3" what's more, 'D4'.Thus, upper source "Vg" and inductor "L1" empower the capacitor "C1" and also bring down source "Vg" and inductor "L2" to empower the capacitor "C2" as appeared in fig.3.

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The voltage across Inductors' L1'and 'L2' in non-shoot through and zero state ((1-D)Ts) (from fig.2.andfig.3.) can take as

$$VL1=Vg-Vc1 \qquad (1) \quad VL2=Vg-Vc2 \quad (2)$$

Similarly current through the Capacitors' C1'and 'C2' are taken as

$$Ic1=iL1-Iac \qquad (3) \qquad\qquad Ic2=iL2-Iac \qquad (4)$$

C. During Shoot-Through State

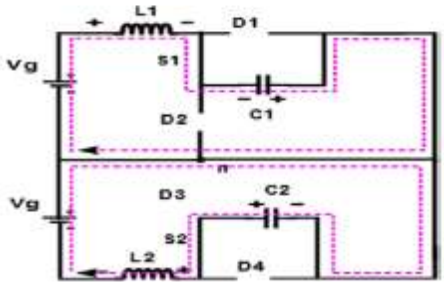

Fig.4.Equivalent circuit of shoot through state

Amid this method of operation, the switches 'S1', "S2" and all the switches of the one or more inverter legs are turned 'ON', which in turn reverse biases the diodes 'D1', 'D2', "D3" and'D4'. Thus, upper DC voltage source "Vg" and capacitor "C1" empower the inductor 'L1'. In the meantime bring down DC voltage source "Vg" and capacitor "C2" to empower the inductor "L2" as shown in fig.4.

The voltage across Inductors 'L1' and 'L2' are found to be (from fig.4.)

$$VL1=Vg+Vc1 \quad (5) \qquad\qquad VL2=Vg+Vc2 \qquad (6)$$

The current through the Capacitors'C1' and 'C2' are found to be

$$Ic1=-iL1 \quad (7) \qquad\qquad ic2=-iL2 \qquad (8)$$

Applying charge-second balance in steady state equilibrium across the capacitors 'C1' and'C2' respectively

$$(Vg-Vc1)(1-D)+(Vg+Vc1)D=0 \qquad (9)$$
$$(Vg-Vc2)(1-D)+(Vg+Vc2)D=0 \qquad (10)$$

From (9) and(10) ,the voltage gains at Capacitors 'C1' and 'C2' can be given as

$$Vc1=Vc2=\frac{Vg}{(1-2D)} \quad (11)$$

Similarly, applying charge- second balance across the capacitors 'C1' and'C2' respectively

$$(iL1-iac)(1-D)-DiL1=0 \qquad (12)$$
$$(iL2-iac)(1-D)-DiL2=0 \qquad (13)$$

By solving (12) and (13) ,we get the Input current as,

$$I1=IL1=IL2=\frac{(1-D)ias}{(1-2D)} \qquad (13)$$

From the equivalent circuit (Fig.2), it can be observed that the DC voltage fed to the inverter leg'Vdc' during active state is equal to the capacitor voltages.

The peak output ac phase voltage is found to be

$$Vm = MVdc = \frac{MVg}{(1-2D)} \qquad (14)$$

The boost factor of the converter is found to be,

$$B=\frac{1}{1-2D} \qquad (15)$$

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The voltage gain factor of the inverter can be expressed as.

$$G = \frac{M}{(1-2D)} \quad (16)$$

From the above equation(16),we can notice that the LC-Switching boost NPC inverter can be operated as Buck-Boost inverter by choosing the suitable values of M and D to get the required output AC load voltage. From (11), it can be seen that the converter can't be worked with shoot-through obligation proportion (D) more than 0.5 like ZSI. For ensuring shoot-through state not to overlap non-shoot through state (or dynamic state) in any exchanging cycle, the shoot-through period can be taken most extreme up to zero state, i.e.,

$$M + D \leq 1 \quad (17)$$

III. PWM CONTROL OF LC-SWITCHING BOOST NPC INVERTER

The gate control motion for the inverter leg switches are produced utilizing unipolar PWM procedure in each stage for disposing of first center band harmonics and also to accomplish three level pole voltages. Here, for each stage two modulating sine influxes of 180 degrees phase displacement (Va(t) and –Va(t)) are compared with high recurrence triangular carrier signal (Vtri(t)) as appeared in Fig.6. For three phases these modulating signals (Va(t) and –Va(t)) are phase displaced by 120 degrees and compared with triangular carrier signal to produce entryway control signal for the inverter leg switches. The shoot through door flag is created by contrasting two settled reference signals (Vst and - Vst) with the transporter flag (Vtri(t)). The voltage pick up factor (G) chooses the abundancy of settled signals (Vst and - Vst) and also adjusting signals (Va(t) and –Va(t)). For guaranteeing shoot-through state not to obstruct dynamic state (or non-shoot through state), shoot-through state is set inside the zero state in each exchanging cycle as appeared in Fig.6. To guarantee voltage adjust over the capacitors a shoot throughcounterbalance is included by utilizing the control rationale displayed. The shoot through door flag is sustained to the switches in the middle of the road organizes ('S1' and 'S2'). Though, entryway flag encouraged to the inverter leg switches are the mix of shoot through flag and additionally flag created from the correlation of tweaking signals and bearer flag.

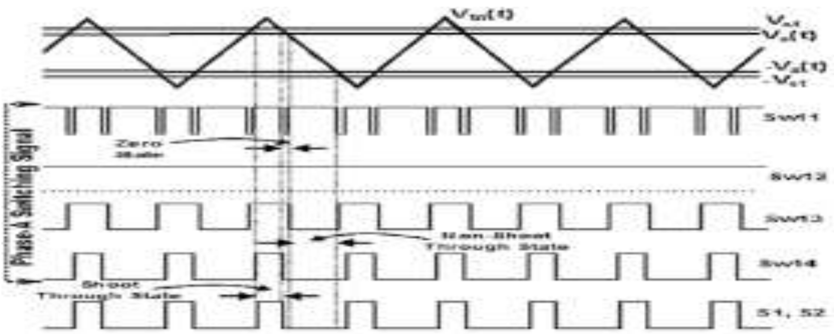

Fig.5.PWM control of LC-Switching voltage boost NPC inverter

IV. FUZZY LOGIC CONTROLLER

Fuzzy Logic control (FLC) has proven effective for complex, non-linear and imprecisely defined processes for which standard model based control techniques are impractical or impossible. Fuzzy Logic, unlike Boolean or crisp logic, deals with problems that have vagueness, uncertainty and use membershipfunctions with values varying between 0 and 1.In fuzzy logic a particular object has a degree of membership in a given set, which is in the rangeof 0 to 1. The essence of fuzzy control algorithms is a conditional statement between a fuzzy input variable A and fuzzy output variable B. In general a fuzzy variable is expressed through a fuzzy set, which in turn is defined by a membership function. The complete block diagram of the fuzzy logic controller is shown in figure 9.

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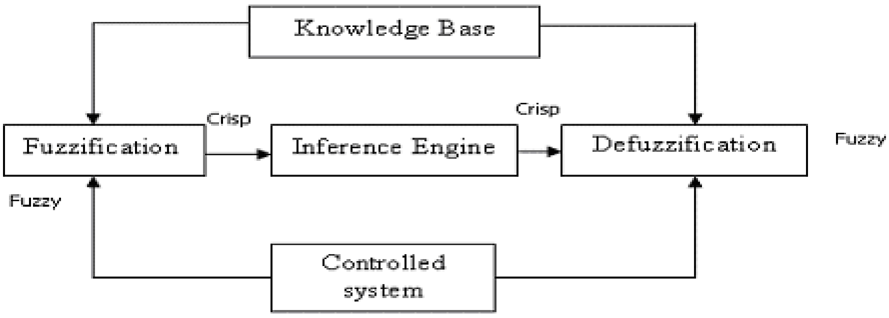

Fig.6. Internal Structure of The Fuzzy Logic Controller

The fuzzy controller is considered as follows:
1. Seven fuzzy sets are used for e (n) and **δ**e (n).
2. Nine fuzzy sets are used for V (n).
3. Fuzzification using continuous universe ofDiscourse.
4. Defuzzification using the „„centroid"" method.
5. Mamdani"s minimum fuzzy implication.
6. Triangular membership functions

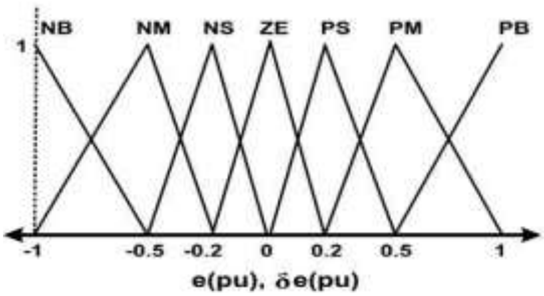

Fig. 7.Input Membership Functions

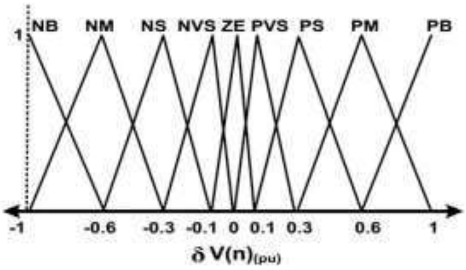

Fig. 8. Output Membership Functions

e / δe	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NS	NVS	ZE
NM	NB	NB	NM	NS	NVS	ZE	PVS
NS	NB	NM	NS	NVS	ZE	PVS	PS
ZE	NM	NS	NVS	ZE	PVS	PS	PM
PS	NS	NVS	ZE	PVS	PS	PM	PB
PM	NVS	ZE	PVS	PS	PM	PB	PB
PB	ZE	PVS	PS	PM	PB	PB	PB

Fig. 9. Rule Base for Fuzzy Logic Controller

Triangular Membership function are used to represent input variables such as NB (negative big),NM (negative medium),NS (negative small), ZE(zero), PS (positive small), PM (positive medium),PB (positive big) and output variables such as NB(negative big), NM (negative medium),NS (negative small), NVS (negative very small), ZE (zero), PVS(positive very small),PS (positive small), PM(positive medium), PB (positive big) Here, Membership functions should -1 to +1.The Fuzzy Rules are represented using IF-THEN form [11,14]. MAX-MIN Inference algorithm and Center of Gravity Defuzzification Approach is used to get Crisp output from Fuzzy Logic Controller. The fuzzy rules were designed based on the dynamic behavior of the error signal

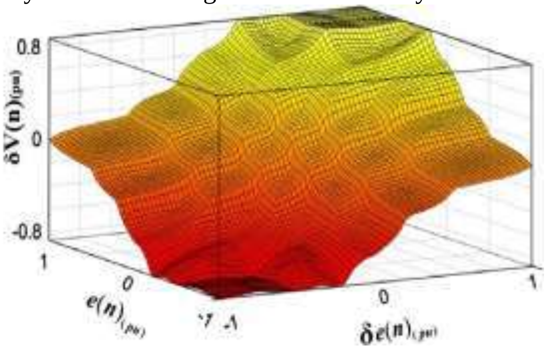

Fig.8.Fuzzy logic controller surface

The fuzzy logic controller surface is the output plotted against the two inputs.It is the effect of the interpolation of the 49 rules of table.1.

Simulation model:
The block diagram of proposed system consists of unipolar PWM technique ,fuzzy logic controller as shown in fig.9.
Simulation model:
The simulation model of the proposed inverter with fuzzy logic controller as shown in fig.10 .

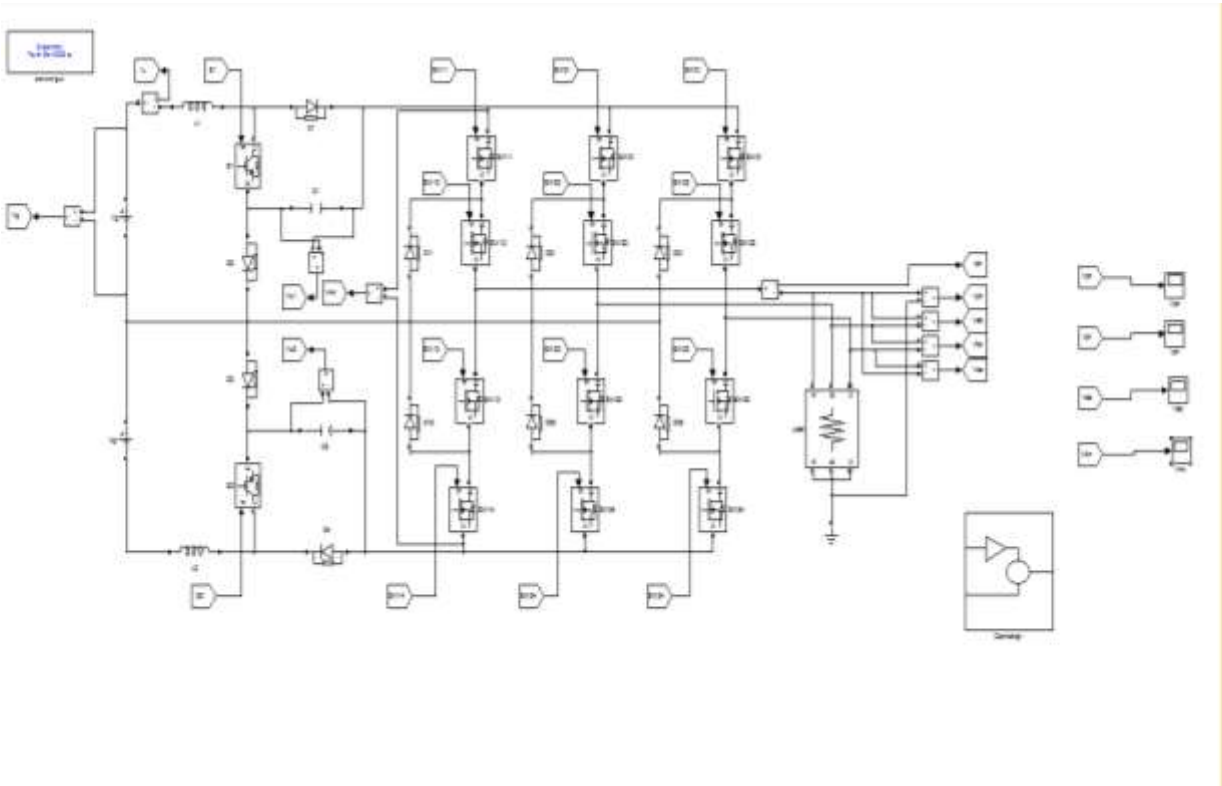

Fig.10.simulation model of LC-switching voltage based boost NPC inverter with fuzzy logic controller.

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ISSN: 2277-9655
Impact Factor: 4.116
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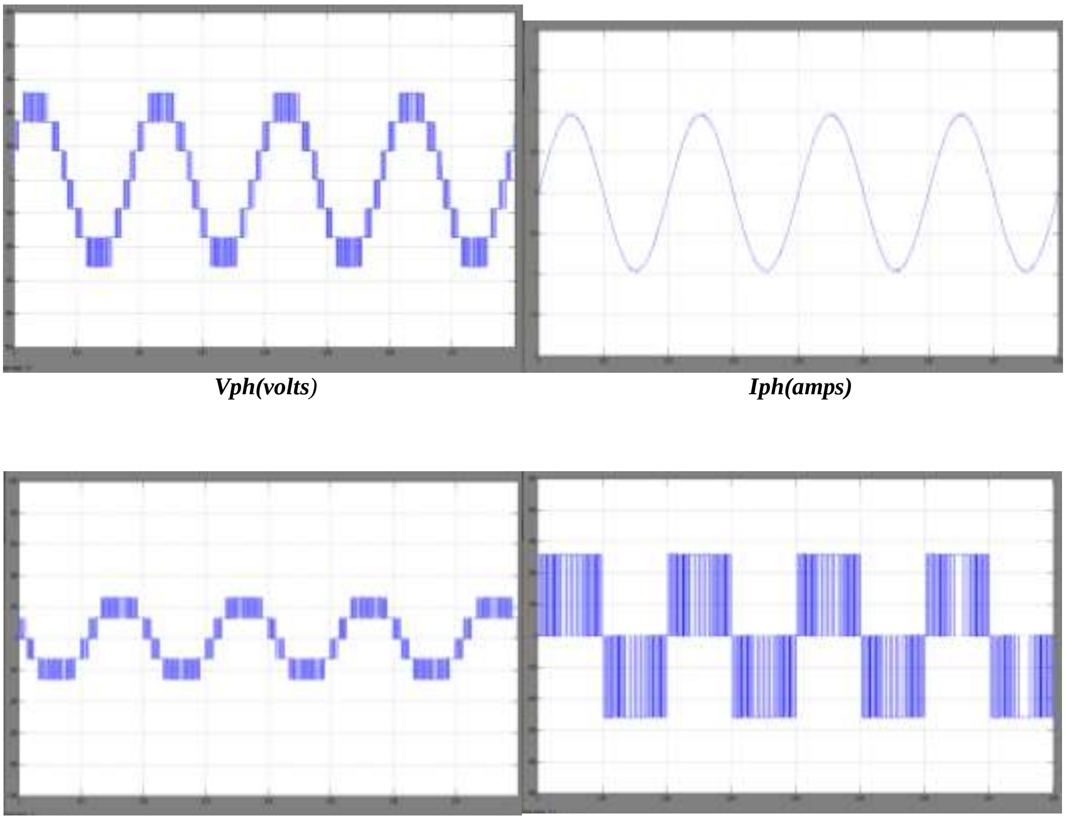
Simulation results:

The proposed inverter has been analyzed and verified by performing simulation in MATLAB Simulink. The simulation results of the proposed inverter with fuzzy logic controller are as shown in figure.

B.LC-switching NPC inverter with fuzzy logic controller:



Vph(volts) *Iph(amps)*

Vab(volts) *Van (volts)*

Fig.12.phase voltage(Vph),phase current(Iph),line voltage(Vab),pole voltage(Van) of LC-switching voltage boost NPC inverter with fuzzy controller.

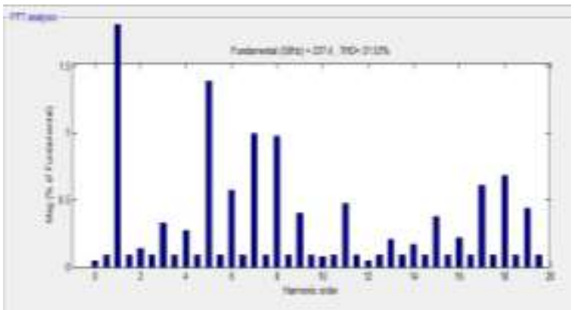


Fig.14.Harmonic spectrum of LC- switching boost NPC inverter with fuzzy logic controller.

From the above analysis we can observe that the ripple content in the phase voltage (Vph), phasecurrent (Iph), linevoltage (Vab), polevoltage (Van) is reduced by the use of the fuzzy logic controller compared to the NPC inverter without fuzzy controller. The output phase voltage(Vph) is 260volts with the DC input of 48 volts. The total harmonic distortion (THD) for the phase voltage for the aboveload condition is found to be 21.53%, by using fuzzy controller, which is lower than the THD of normal LC-switching NPC inverter.

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V. CONCLUSION

A complete analysis and implementation is done regarding the application of unipolar PWM technique with FUZZY LOGIC control scheme on the LC-switching based voltage boost three level NPC inverter is presented by using MATLAB/SIMULINK.The proposed inverter is able to boost up the voltage with less number of ripple content in the output voltage in a single stage compare to the conventional LC-switching voltage boost NPC inverter, the THD is decreases by incorporating the fuzzy control . The fuzzy logic controller is best suited for the human decision –mechanism. The proposed inverter using less number of high power passive elements which in turn reduces size and weight.In addition to the advantages the continuous current with less distortion makes it applicable for various applications. The fuzzy logic controller is incorporated to systematically control the time allocation for all switching states based on instantaneous voltage. In order to make the output voltage constant irrespective of the load conditions a feedback also provided using fuzzy controller with PWM generator to provide gating signal to controlling switches.

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CITE AN ARTICLE

Pragathi, K., & Reddy, N. P. (2017). MODELLING AND SIMULATION OF LC SWITCHING VOLTAGE BOOST THREE LEVEL NPC INVERTER WITH FUZZY LOGIC CONTROLLER. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, *6*(9), 484-493.