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Modeling and Simulation of NPC Inverter for Generation of Three Levels Based on LC Switching with ANN Controller

Narni Vijaya Kumar[1] | Mutyala Harini[2] | Chirla Ramesh Kumar Reddy[2] | Bobbili Naga Srinivas[2]

[1]Assistant Professor, Department of Electrical and Electronics Engineering, Godavari Institute of Engineering and Technology (A), Rajahmundry, Andhra Pradesh, India.

[2]UG Students, Department of Electrical and Electronics Engineering, Godavari Institute of Engineering and Technology (A), Rajahmundry, Andhra Pradesh, India.

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ABSTRACT

This paper presents a new control scheme for three levels NPC Inverter to boost up the input dc voltage and givethree levels AC output voltage with less harmonic distortion in a single stage.Recently, Single stage highvoltage 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 Zsourceinverter (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 whichincrement the system measure furthermore, weight. Likewise its info current is irregular in nature which is notalluring in a portion of the applications like energy unit, UPS systems, hybrid electric vehicle and so forth. Inthis paper a consistent current info three level LC Switching based voltage help nonpartisan point clipped (NPC)inverter with ANN logic controller is proposed which utilizes similarly less number of high power detachedsegments at the same time holds every one of the benefits of multilevel QZSI/ZSI. It is ready to help the infoDC voltageand give required three levels AC output voltage in a solitary stage. The ANN logic controller isincorporated to systematically control the time allocation for all the switching states based on instantaneousvoltage. Using the ANN controller for a nonlinear systemallows for a reduction of uncertain effects in thesystem in the system control and improve the efficiency . Enduring state investigation of the proposed inverter istalked about to define the connection between the info DC voltage what's more, three level AC output voltage.The proposed converter with ANN controller has been verified by simulation in MATLA Simulink

KEYWORDS: *Boost Inverter, PWM, Shoot –through, three level inverter .Z-Source inverter, ANN.*

I. INTRODUCTION

Recently the modern power electronics equipment has attracted the attention in many industrial applications. Most of the industrial applications need high power equipment, such as motor drives, hybrid electric vehicles, renewable energy system, etc.[1]. Some industries require medium voltage and high power, so for these purposes, the multilevel inverter has been introduced. The multilevel inverter provides high power rating and enables the use of renewable energy sources [2]. The multilevel inverter available with different topologies. Each of three main topologies provides some advantages over conventional two-level inverters such as the use of high switching frequency, improve efficiency and power quality of outputs with some limitations. The neutral point clamped (NPC) inverter topology can be applied to three level or higher-level inverters. Because of industrial developments over the past several years, now the three-level NPC inverter has been used extensively in industrial applications [3-5].

In conventional system, DC-DC boost converter was used before inverter or step up transformer after the inverter to get required AC output voltage from low input voltage. Due to this the power conversion stages increases, system efficiency decrease and the system becomes complex [6]. The Z-source converter identifies all the above limitation of conventional converter and to overcome these limitations providesa new power conversion method. Z-source converter which uses LC impedance network has been utilised for AC-DC, DC-AC, DC-DC power conversion. This Z source network is uses in between supply source and converter main circuit [7-9]. Conventional voltage source inverter (VSI) operated in active state and zero state while the Z-source Neutral point clamped (NPC) multilevel inverter can operates with one additional state i.e. active state, zero state and shoot through state. Shoot through state means turning on all the switches of one or all legs of inverter. Using this shoot through state the input DC voltage gets boosted and provides expected AC output voltage.

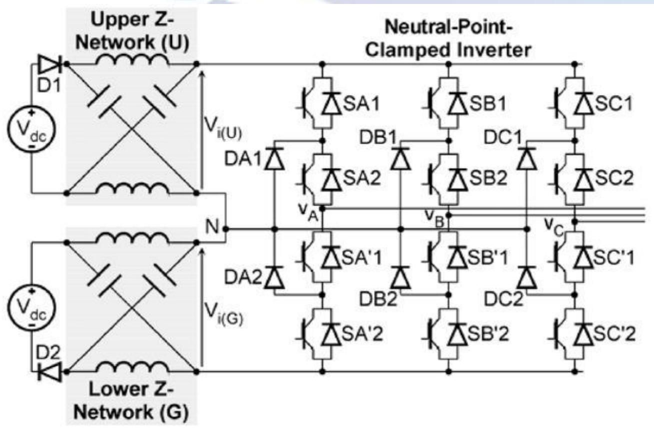

Fig -1: Conventional three level NPC Z-source inverter

Conventional NPC Z-source inverter utilizes four inductors, four capacitors, two diodes in its LC impedance network as shown in figure-1. This conventional inverter needs two isolated DC voltage sources to get expected output [10]. Similarly, the three-level dual Z-source inverter uses one diode, two inductors, two capacitors and open end winding line frequency transformer to get desired output. But the use of open-end winding line frequency transformer and more number of passive elements makes system complex and bulky. The input current of this Z-source inverter is discontinuous and making it continuous requires equal inductor and capacitor pair in its LC impedance network. It has been difficult to get the equal value of inductor and capacitor pair while making this system in practice [11]. Quasi Z-source multilevel inverter provides continuous input current, but it also required more number of passive elements and isolated DC source supply [12]. Similarly, a cascaded three-level NPC Quasi Z-source multilevel inverter utilizes more number of passive elements and two or more isolated dc sources supply for better quality. But the use of more number of passive elements and multiple isolated dc power supply increases the system size, weight so the overall cost [13-14].

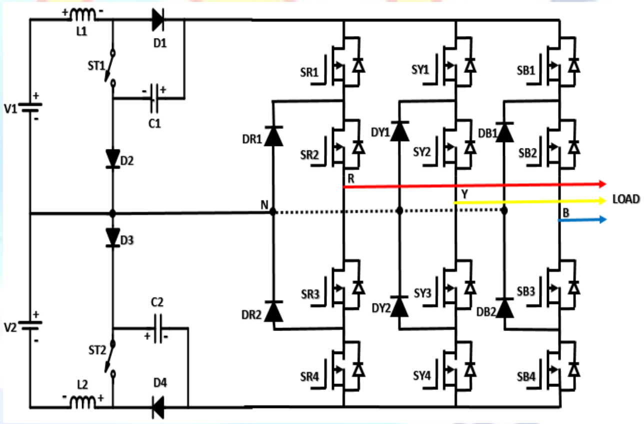

Fig -2: Proposed voltage boost NPC multilevel inverter using LC impedance network

This paper presents proposed work on a voltage boost NPC multilevel inverter using LC impedance network. This inverter uses impedance network comprises of two inductors, two capacitors, four diodes, and two intermediate switches (shoot through switches) between NPC inverter legs and DC source supply. It requires comparatively less number of passive elements while providing all the advantages of conventional available inverter. These features of this proposed inverter making it reliable and system weight and size are reduced. This inverter can be used in medium or low power application where weight and size are main constraints.

II. PROPOSED VOLTAGE BOOST NPC INVERTER AND OPERATIONAL PRINCIPLE

The proposed voltage boost NPC inverter is able to boost the input DC source supply (V) and provide required multilevel AC voltage. The schematic circuit diagram of proposed voltage boost NPC inverter using minimal count of L and C in impedance network is as shown in figure-2. Here input to this inverter is a simple dc input voltage source. This DC source supply can be fed from the dual power supply as two DC source. Another way is DC source can be split into two by proving required DC voltage in parallel to two series connected capacitor, where the center point between two capacitors considered as a neutral point. This input is then provided to upper and lower part of this proposed inverter. The inverter is consists of three legs, one per phase, each containing two series connected high-side switches and two series connected low-side switches. The center of each device pair is clamped to the neutral through clamping diodes.

In this inverter, the impedance network comprises of one inductor (L1), two capacitors (C1 and C2), four diodes (D1, D2, D3, and D4) and two active intermediate switches (ST1 and ST2). This impedance network is placed between input DC source supply and NPC inverter legs. As compared to the conventional three-level Z-source inverter this proposed inverter utilizes almost half of the number of passive elements. Hence the size and the weight is reduced, so overall cost also reduces. Conventional VSI operated in only in two states while the proposed inverter can operate in three states i.e. active state, zero state, and the shoot through state. Using this third additional state the input voltage has boosted The detail working of all possible mode of this inverter is discussed as follows.

A. Active state (Non-shoot through state)

In this mode of operation, the power is transferred from DC supply side to AC load side. It is same as the active state of traditional NPC VSI. In this state, the AC load gets either "+Vdc" or "-Vdc" voltage level with respect to a neutral point "N". Here for simple understanding, only one leg from three legs of three-phase NPC inverter is considered as the normal constant current flowing through it.

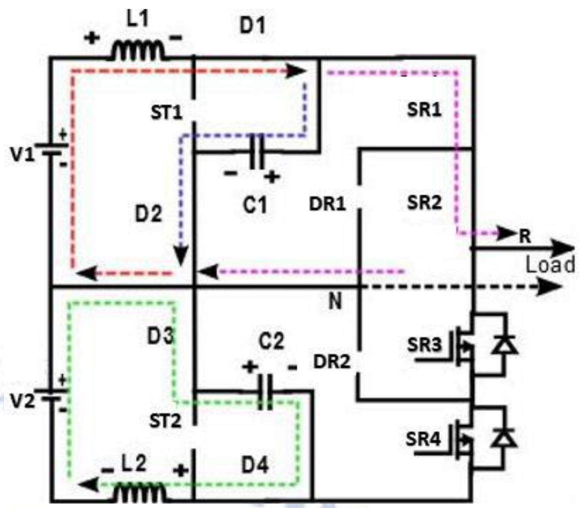

Fig-3: Operating circuit of proposed inverter to get "+Vdc"

For attaining the "+Vdc" (positive half cycle) across the load the switches Sx1 and Sx2 are turned „ON" while switches Sx3, Sx4, ST1, and ST2 are turned „OFF". As a result diodes D1, D2, D3 and D4 are getting forward biased while Dx1 and Dx2 (where x = R, Y, and B) are get reversed biased, as shown in figure-3. In this mode of operation both upper DC voltage source „V1" and energy stored in inductor „L1" supplies the power to the AC load as well as energizing the capacitor „C1". Similarly lower DC voltage source „V2" and energy stored in inductor „L2" energizing the capacitor „C2" to „+VC1" as shown in the figure above. So, the voltage appears across the AC load in this period is „+VC1".

Similarly, for attaining the "-Vdc" (negative half cycle) across the load the switches Sx3 and Sx4 are turned „ON" while switches Sx1, Sx2, ST1, and ST2 are turned „OFF". As a result diodes D1, D2, D3, and D4 are getting forward biased whereas diodes Dx1 and Dx2 (where x = R, Y, and B) are get reversed biased, as shown in figure-4. In this mode of operation both lower DC voltage source „V1" and energy stored in inductor „L2" supplies the power to the AC load and energizing the capacitor „C1". Similarly lower DC voltage source „V1" and energy stored in inductor „L1" energizing the capacitor „C1" to „+VC2". So, the voltage appears across the AC load in this period is „+VC2".

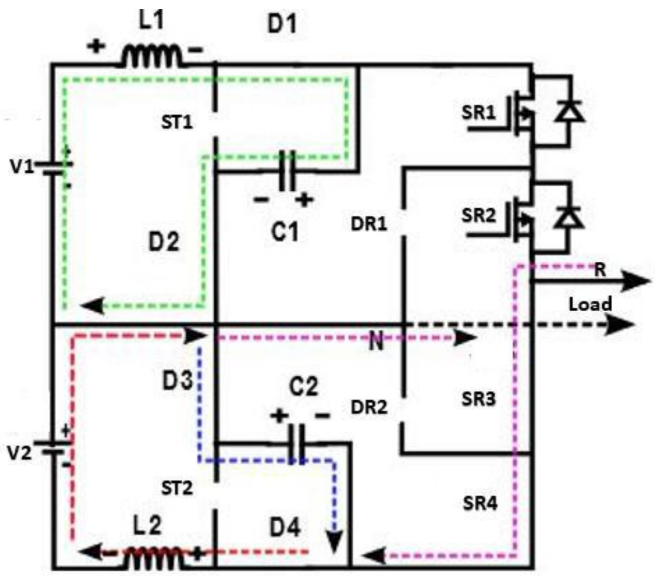

Fig -4: Operating circuit of proposed inverter to get "-Vdc"

B. Zero state

Figure-5 shows the zero state of the proposed inverter. In this mode of operation, switches Sx2, Sx3 are turned „ON", whereas switches ST1, ST2, Sx1 and Sx2 (where x = R, Y, and B) are turned „OFF", and diodes D1, D2, D3, and D4 are forward biased. So voltage appears across the load is zero. It simply means that no power is transferred to load from DC source to load side. Here upper DC voltage source „V1" and energy stored in inductor „L1" energizing the capacitor „C1", whereas lower DC voltage source „V2" and energy stored in inductor „L2" energizing the capacitor „C2", same as in case of the active state operation.

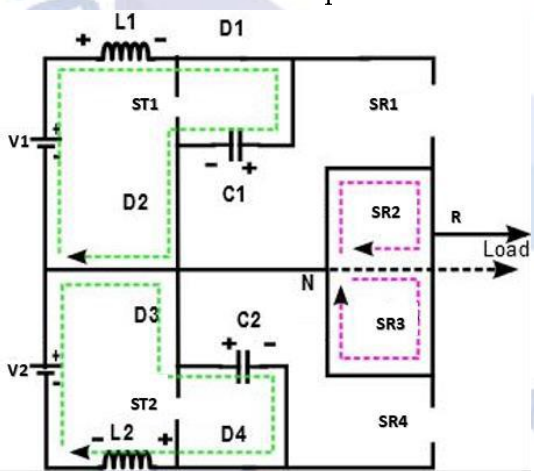

Fig -5: Operating circuit of proposed inverter during zero state "0 V"

C. Shoot through state

In the multilevel inverter, the shoot-through means switching on all the switches in the inverter leg results in the dead short circuit of the source in the conventional inverter, which can be avoided by using the proper dead band. Here the shoot-through state is utilized to get an additional level along with passive reactive element to boost the input dc voltage.

In this state of operation, all the switches of one or more inverter leg i.e. Sx1, Sx2, Sx3, and Sx4 as well as switches ST1 and ST2 are turned „ON". Due to this, diodes D1, D2, D3, and D4 are reverse biased as shown in figure-6. During this state stored energy in the capacitor „C1" along with upper DC voltage source „V1" energizes the inductor „L1". Similarly, stored energy in the capacitor „C2" along with lower DC voltage source „V2" energizes the inductor „L2".

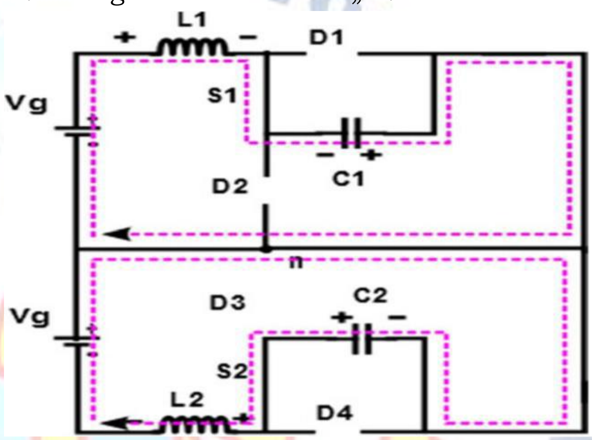

FIg-6: Operating circuit of proposed inverter during shoot through state

III. ARTIFICIAL NEURAL NETWORK

Artificial Neural Networks, also known as "Artificial neural nets", "neural nets", or ANNfor short, are a computational tool modeled on the interconnection of the neuron in the nervoussystems of the human brain and that of other organisms. Biological Neural Nets (BNN) are thenaturally occurring equivalent of the ANN. Both BNN and ANN are network systemsconstructed from atomic components known as "neurons". Artificial neural networks are verydifferent from biological networks, although many of the concepts and characteristics ofbiological systems are faithfully reproduced in the artificial systems. Artificial neural nets are atype of non-linear processing system that is ideally suited for a wide range of tasks, especiallytasks where there is no existing algorithm for task completion. ANN can be trained to solvecertain problems using a teaching method and sample data. In this way, identically constructedANN can be used to perform different tasks depending on the training received. With propertraining, ANN are capable of generalization, the ability to recognize similarities among differentinput patterns, especially patterns that have been corrupted by noise.ANNs have been found to be effective systems for learning discriminates for patternsfrom a body of examples5. Activation signals of nodes in one layer are transmitted to the nextlayer through links which either attenuate or amplify the signal. ANNs are trained to emulate afunction by presenting it with a representative set of input/output functional patterns. The backpropagation training technique adjusts the weights in all connecting links and thresholds in thenodes so that the difference between the actual output and target output are minimized for allgiven training patterns1.In designing and training an ANN to emulate a function, the only fixed parameters arethe number of inputs and outputs to the ANN, which are based on the input/output variables ofthe function. It is also widely accepted that maximum of two hidden layers are sufficient to learnany arbitrary nonlinearity4. However, the number of hidden neurons and the values of learningparameters, which are equally critical for satisfactory learning, are not supported by such wellestablished selection criteria. The choice is usually based on experience. The ultimate objectiveis to find a combination of parameters which gives a total error of required tolerance areasonable number of training sweepsThe network consists of several "layers" of neurons, an input layer, hidden layers, andoutput layers. Input layers take the input and distribute it to the hidden layers (so-called hiddenbecause the user cannot see the inputs or outputs for those layers). These hidden layers do all thenecessary computation and output the results to the output layer, which (surprisingly) outputs thedata to the user.

IV. SIMULATION RESULTS

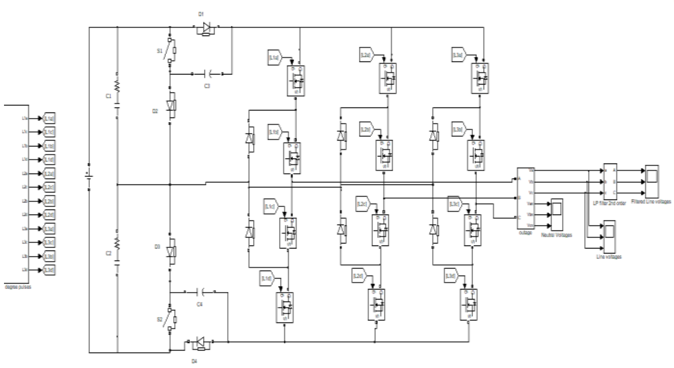

Fig.8. Simulation circuit.

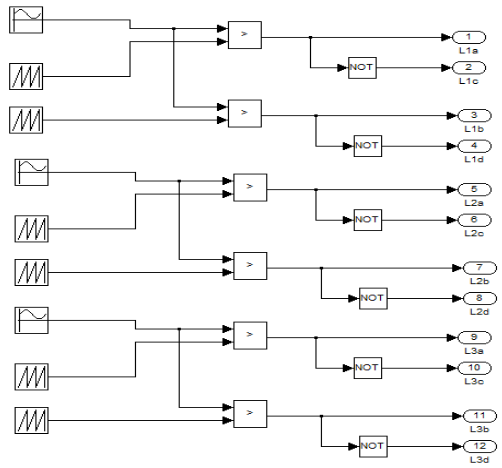

Fig.9. Controller circuit with PWM.

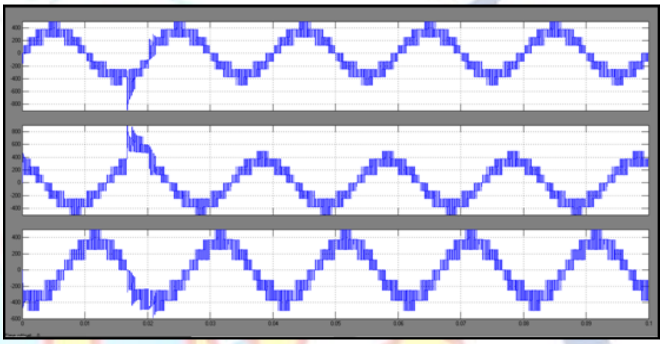

Fig.10. Output voltage with multi level voltage.

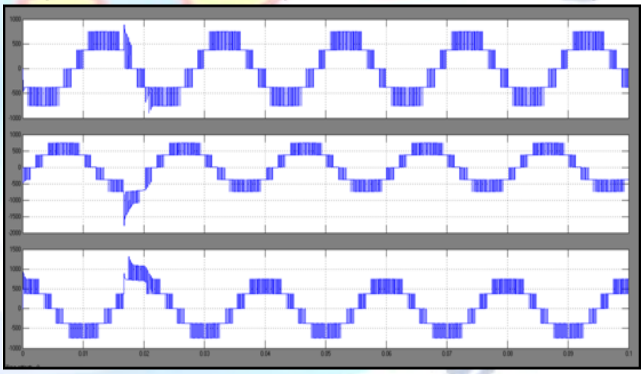

Fig.11. Line voltage at output side.

Extension circuit With ANN:

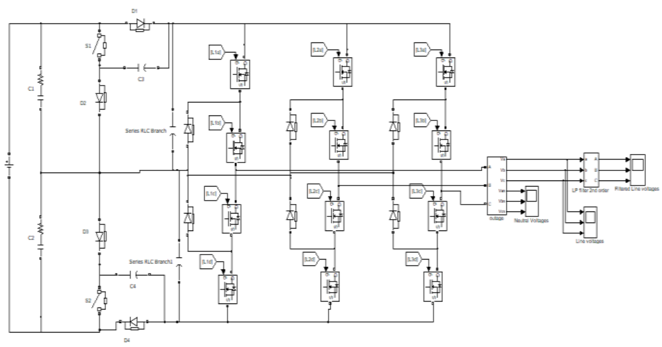

Fig.12. Simulink circuit.

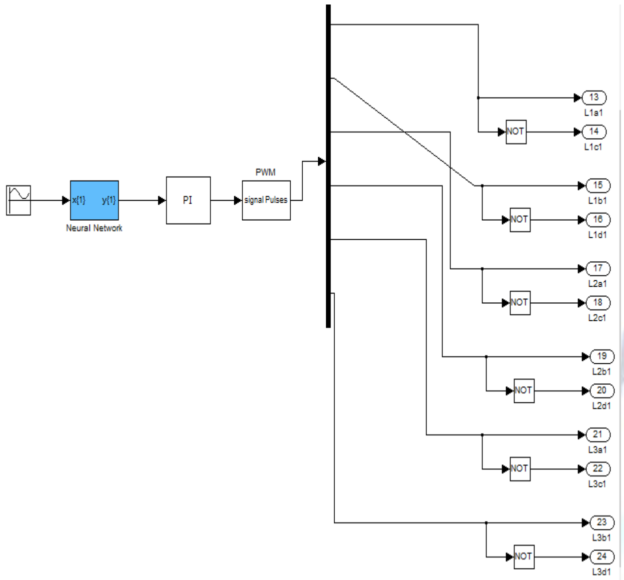

Fig.13. Controller design with ANN circuit.

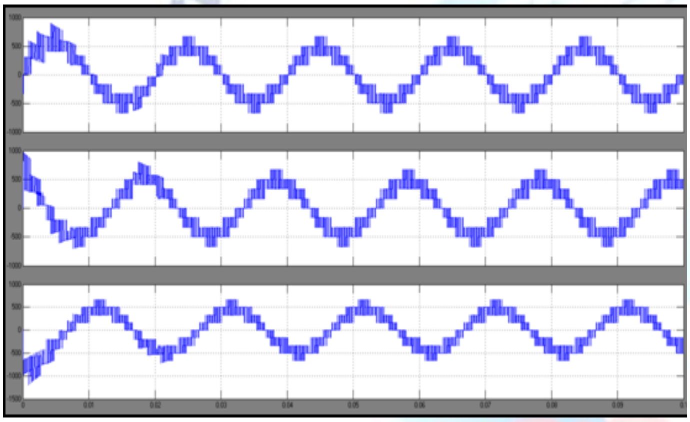

Fig.14. Output voltage with three level.

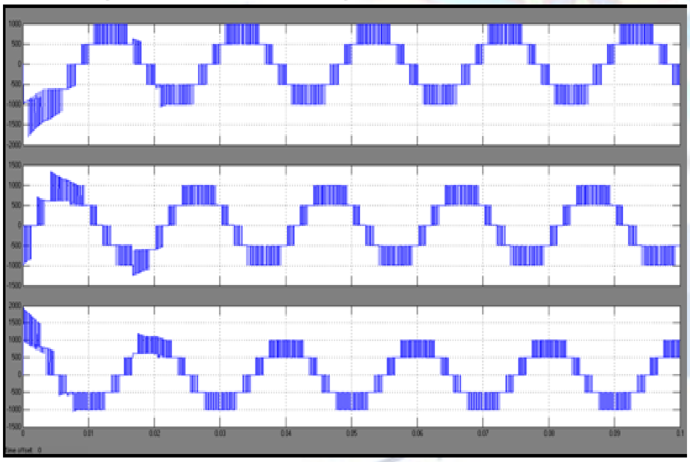

Fig.15. Output voltage with ANN circuit at different voltage.

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 NPCinverter without fuzzy controller. The output phase voltage(Vph) is 260volts with the DC input of 48 volts. Thetotal harmonic distortion (THD) for the phase voltage for the aboveload condition is found to be 21.53%, byusing fuzzy controller, which is lower than the THD of normal LC-switching NPC inverter.

V. CONCLUSION

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

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