Neutral Point Clamped (NPC) Based Three-Phase Multilevel Converter

Sachin Lokhande[1], Prof. Ajeet Verma[2]

[1]M-Tech Research Scholar, [2]Research Guide

Department of Electrical Engineering, SCOPE College Bhopal

Abstract - Concept of the multilevel converter to optimize the system behaviour to work reliably and handle load efficiently. For that the system need to efficient upto the mark. So in order to improve the system stability, previous three phase conversion is equipped with the multi level converter system. In this modern technology, Power electronics is very important where it used in a great variety of product. With the high potential in high power for industry, multilevel converter will become most popular for so many applications. There have three main features by using multilevel converter. The most reason is ability to reduce the voltage stress on each power device due to the use of multiple levels on the DC bus. Even at low switching frequencies, smaller disturbance in the multiple level inverter AC side waveforms can be achieved with the step modulation technique. Such as in traction system, when voltage is imposed by an application is very important. Multilevel converter contains different power semiconductors and capacitor used as voltage source. Output voltages of multilevel converter consist of the inclusion of the capacitor voltages due to the commutation of the switches. This work is focused to work on the improvement in the efficiency of the three phase system with the utilization of Neutral Point Clamped (NPC) based multi level converter.

Keywords - NPC, Three Phase Conversion, Multilevel Converters.

I. INTRODUCTION

Grid integration of renewable resources poses a challenge to grid operators as the stochastic nature of renewables make it difficult to predict their output power. Thus, energy storage is becoming a necessity for future power grids, as it can quickly deliver active power to provide services such as spinning reserve, peak shaving, load levelling and load frequency control. These services increase reliability and stability of the grid.

Available energy storage technologies include hydro, battery, flywheel, superconducting magnetic energy storage, and supercapacitors. Excluding hydro, since it is limited by geography, batteries are the dominant solution for large scale energy storage with existing battery energy storage (BES) systems installed as early as the 1980s. These systems are the most cost effective when designed to provide less than 5 hours of service at rated output power. This allows the energy storage system to operate on time scales that complement generators rather than compete. Thus, the focus of this work is on large BES systems for medium voltage applications in the MW / MWh range.

A BES system has two major hardware components: a network of BES units and a power conversion system (PCS). The PCS is the focus of this work, but the employed battery technology must be selected in order to design a suitable PCS. Of the current battery technologies, the most mature batteries in the MW range applications are lead acid, sodium sulfur, lithium ion, and redox flow batteries. Lead acid batteries are the most mature with installations dating from 1980s, and redox flow batteries are the least mature of these four technologies. The four battery technologies can be subdivided into two categories, conventional sealed batteries and flow batteries. The fundamental difference is that flow batteries share electrolyte between all battery cells. This allows for a current path to exist between high and low potential cells, and isolation is required to mitigate circulating currents within the electrolyte. Conventional sealed batteries do not have this issue, thus do not require galvanic isolation. In this work, it is assumed that a mature battery technology is used, such as lead acid, sodium sulfur, or lithium ion batteries.

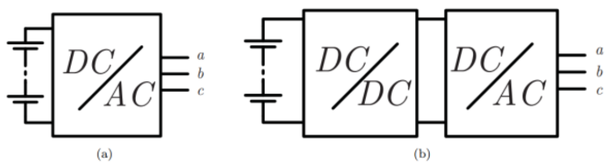

Figure 1.1 Generalized BES system structures: (a) Single stage, (b) Two-stage.

When choosing a PCS topology, the most important features are the reliability, and efficiency of the topology. Reliability is impacted by the arrangement of the BES units. In existing BES systems, the conventional configuration places the batteries in long series strings to create higher voltages. In this configuration, battery lifespan can be negatively affected by overcharging unless an equalization method is applied. Furthermore, if one battery cell faults or becomes dangerous to operate, an entire string must be disconnected for service.

Regarding efficiency, energy must be transferred into, and out of, the battery. Thus, the overall efficiency of the BES system, or round trip efficiency, is the square of the converter efficiency.

II. SYSTEM MODEL

Power electronics is a technology that facilitates electrical energy conversion between source and load based on the combined knowledge of energy systems, electronics and control. Due to the different in nature of supply voltage and frequency (source) and the varying requirements of modern applications (loads), power conversion is essential in order to ensure a proper and energy efficient operation of equipment. As shown in Figure 1.1, a power electronic interface consists of a converter and a controller. The converter is an electronic circuit that is formed with high power handling semiconductor devices, energy storage elements and magnetic transformer. The conversion process begins when the controller, which is a low-power digital or analog electronic circuit, operates the switching devices in the converter according to a strategy that is specifically derived to control the stability and response characteristics of the overall system.

The development of power electronics has been closely related to the development of power semiconductor devices that capable of handling higher powers. The invention of the thyristor or silicon-controlled rectifier (SCR) by Bell laboratory in 1956, which was later commercially introduced by General Electric in 1958, marked the beginning of the modern power electronic era. The rapid development of solid-state devices in terms of power rating, improved performance, cost and size has triggered the transition of power electronic from a 'device-driven' field to an 'application-driven' field. This transition facilitates the extensive use of power electronics in a variety of electrical applications in industrial, commercial, residential, aerospace, military, utility, communication and transportation environments.

The three-level neutral-point-clamped Multilevel Converter (NPC VSI) was introduced by Nabae in 1981 [10] and is probably the most popular among the multilevel converter topologies for high voltage, high power applications. As shown in Figure 2.2, the NPC VSI is supplied by two series-connected capacitors (C1 and C2), where both capacitors are charged to an equal potential of VDC, with the DC-link middle point 'o' as a zero DC voltage neutral point.

In order to generate the three-level output, the switching devices in each phase leg are controlled according to the switching combinations presented.

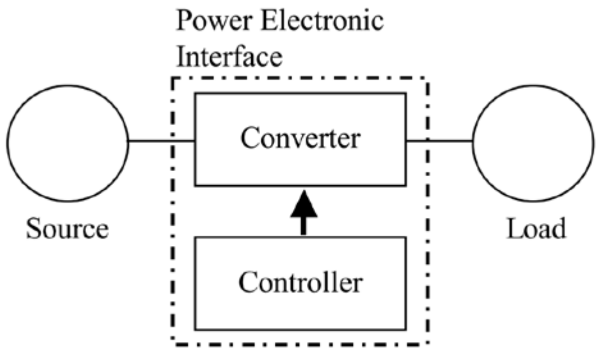

Figure 2.1 The power electronic interface between the source and the load.

At any time, only two of the four switching devices are turned on and the output terminal can be connected to any of the DC-link points (p, o or n), which can be represented by a switching state (P, O or N); for example switching state P represents the connection of the output terminal to the DC-link point 'p'. Using the DC-link middle point 'o' as a reference, the NPC VSI is obviously able to generate three distinct voltage levels at the output terminal of each phase leg, Vxo.

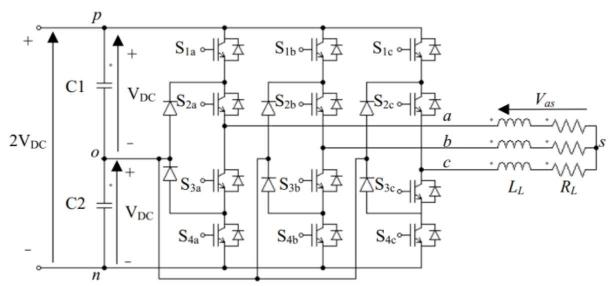

Figure 2.2 the schematic diagram of a conventional three level neural point clamped voltage source inverter using IGBT switches.

III. PROPOSED SYSTEM

In proposed work in order to improve the efficiency of the three phase system Neutral Point Clamped (NPC) based multi level converter has been utilized. Multilevel converter contains different power semiconductors and capacitor used as voltage source. Output voltages of multilevel converter consist of the inclusion of the capacitor voltages due to the commutation of the switches. Figure 3.1 shows the proposed four series connected switching device and two clamped diodes. The proposed system NPC system consists of four series-connected switching devices and two clamping diodes. As demonstrated in figure 3.1 there are following sub blocks in proposed system such as a three phase source connected to NPC system, Two NPC blocks, a NPC control system interfaced with power grid, and load. The modelling of proposed system has done on Matlab.

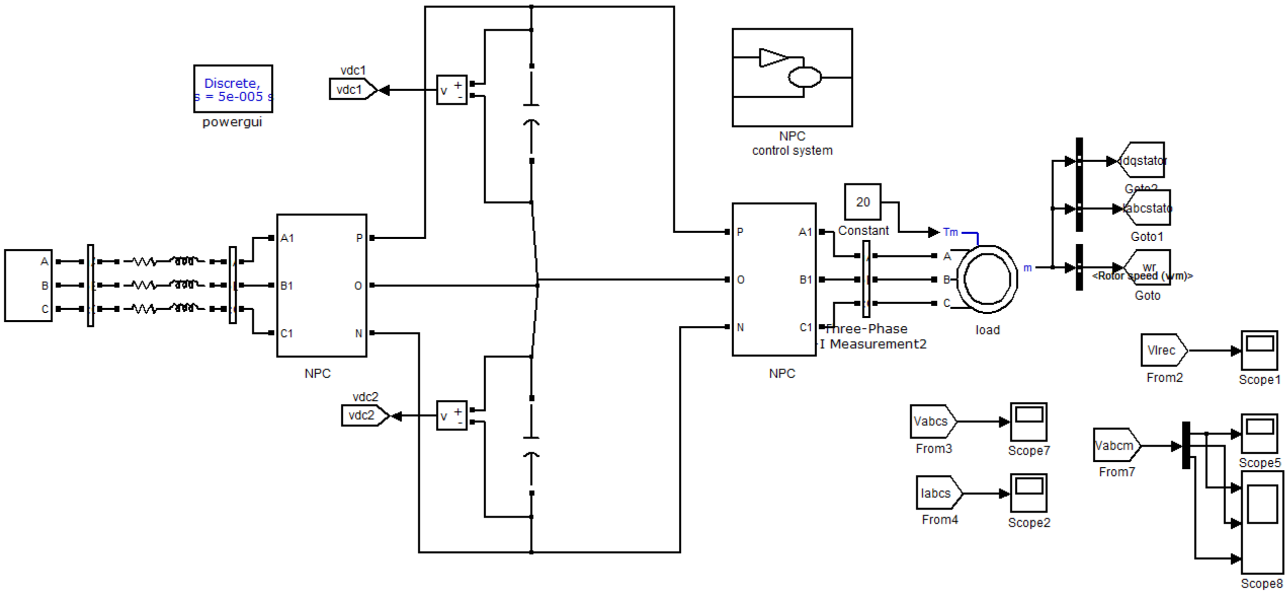

Fig.3.1 Proposed Neutral Point Clamped (NPC) Based Three-Phase Multilevel Converter System.

A Neutral Point Clamped (NPC) Multi-Level Converter is a sub block of proposed system illustrated in figure 3.2 implementation of neutral point clamped three phase converter in Matlab. A control system for proposed NPC system has been shown in figure 3.3

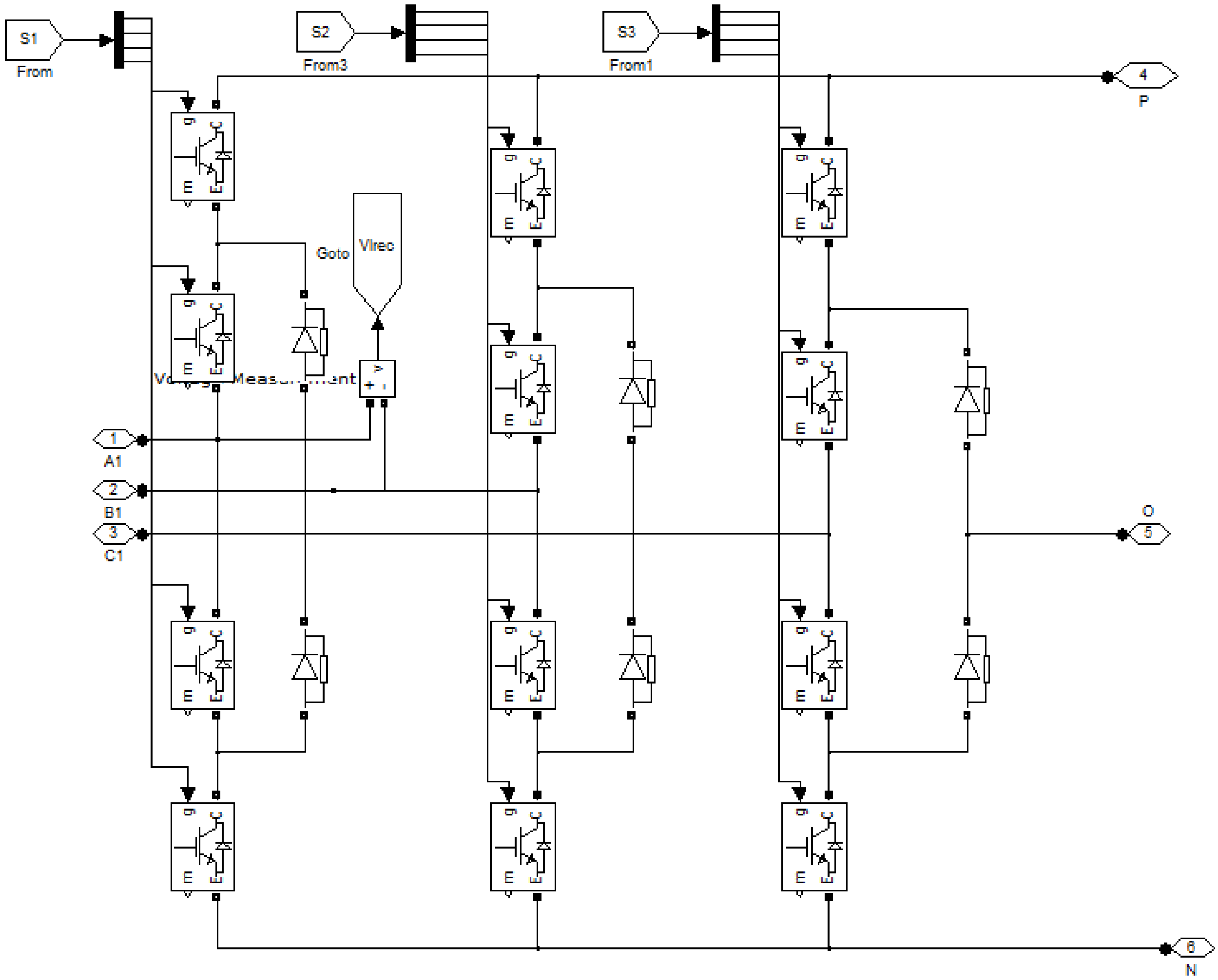

Fig.3.2 Neutral Point Clamped (NPC) Multi-Level Converter.

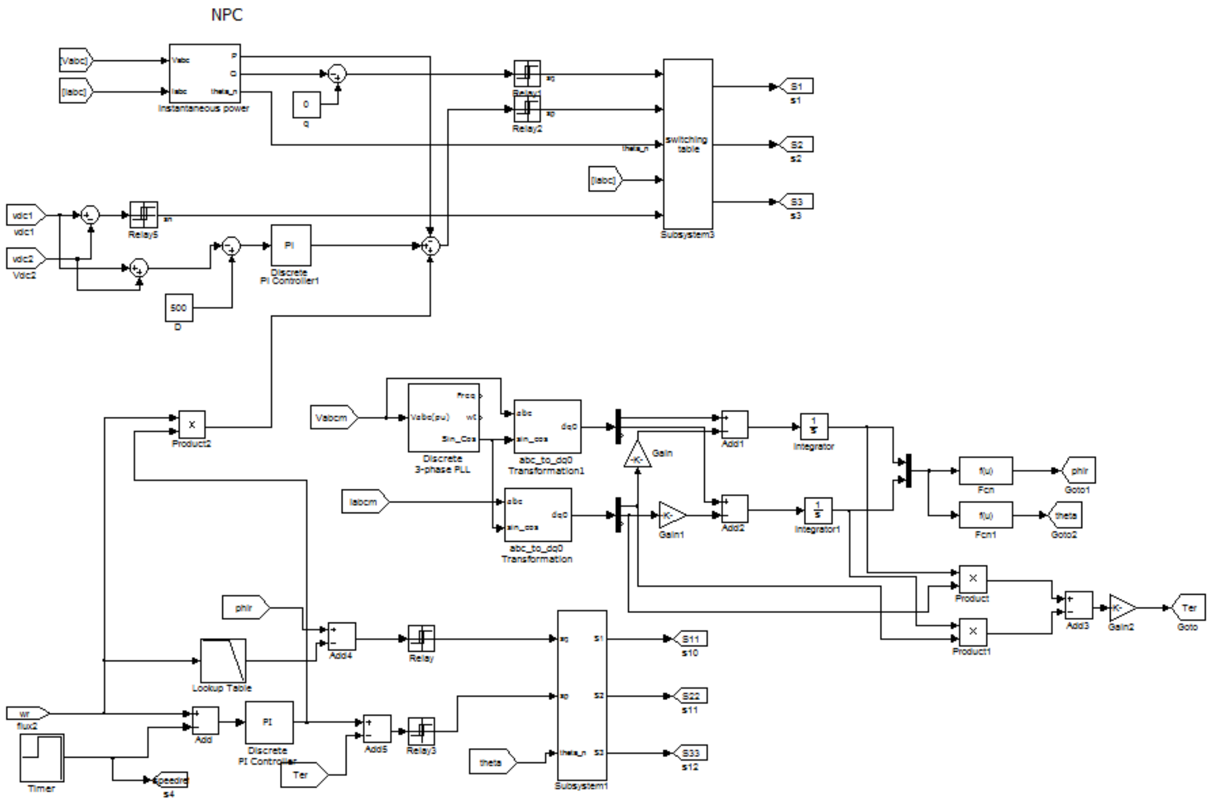

Fig. 3.3 Control System for NPC.

IV. SIMULATION OUTCOMES

The neutral point clamped Based Three-Phase Multilevel Converter is a multilevel neutral-point-clamped matrix converter topology that incorporates the simplified multi-level neutral-point- clamped voltage source inverter concept in an indirect matrix based topology. In order to facilitate an explanation of the operating principles and modulation schemes for the indirect three-level sparse matrix converter. Simulation results are presented to prove the ability of this topology to generate multilevel outputs and the effectiveness of the modulation scheme in controlling the balance required for neutral point.

Compared to existing work, the ability of multilevel neutral- point-clamped voltage source inverter to generate higher quality output voltages is well recognised. However, the high number of power semiconductor devices requirement is undoubtedly a drawback. To overcome this downside, a simplified three-level neutral-point-clamped multi level converter was proposed, which is able to generate the multi level outputs but requires far fewer power semiconductor devices. The Matlab Simulink based Simulation waveform of proposed work has been shown in figure as follows.

Source Voltage Waveforms of the proposed neutral point clamped based three-phase multilevel converter system has been shown in figure 4.1 and figure 4.2.

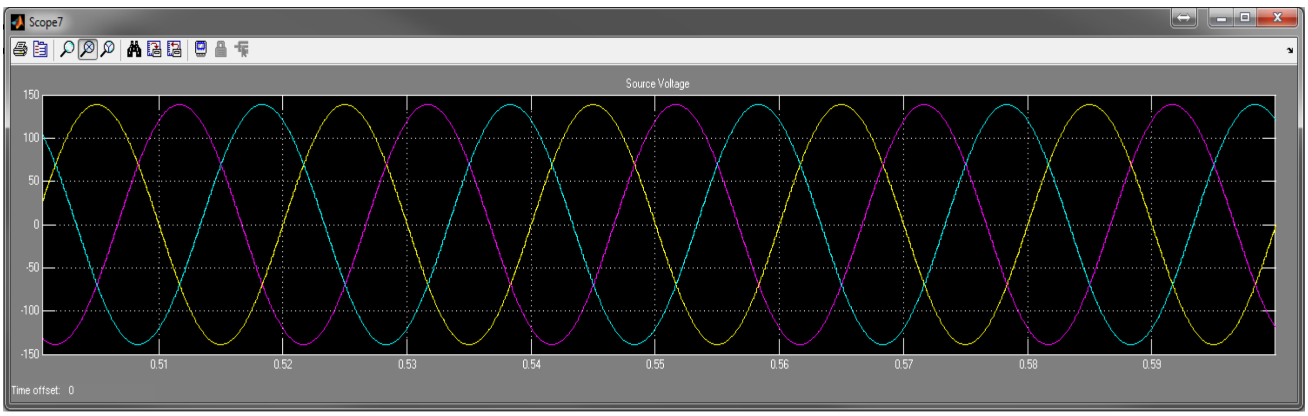

Fig. 4.1 Source Voltage Waveforms of the Proposed System.

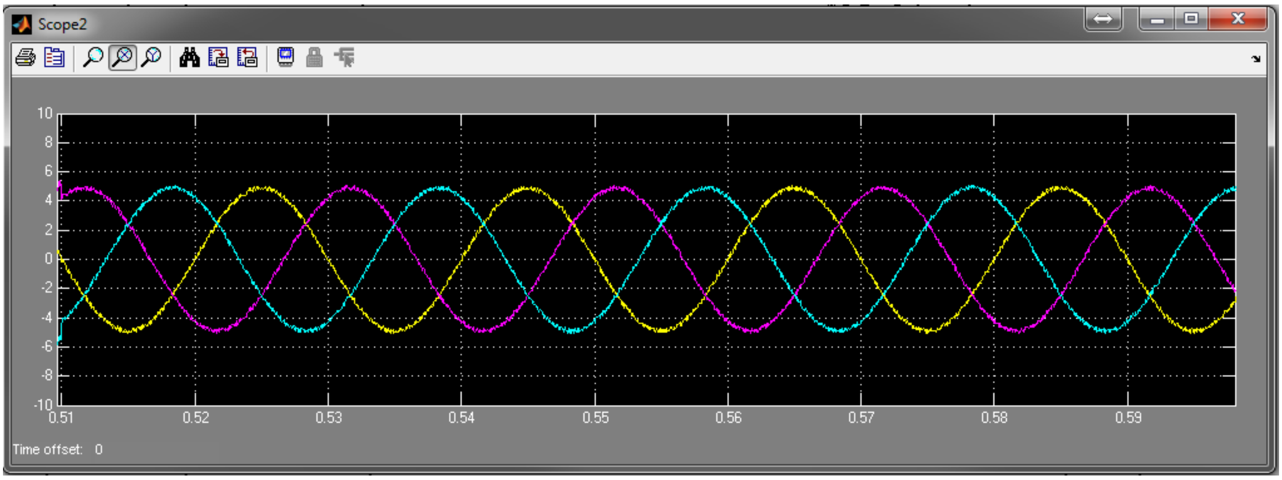

Fig.4.2 Source Voltage Waveforms of the Proposed System.

A line voltage wave form of proposed Source NPC system has been shown in figure 4.3 has taken from Matlab Simulink scope1. The load voltage waveform of proposed multilevel converter system has been shown in figure 4.4 taken from scope5.

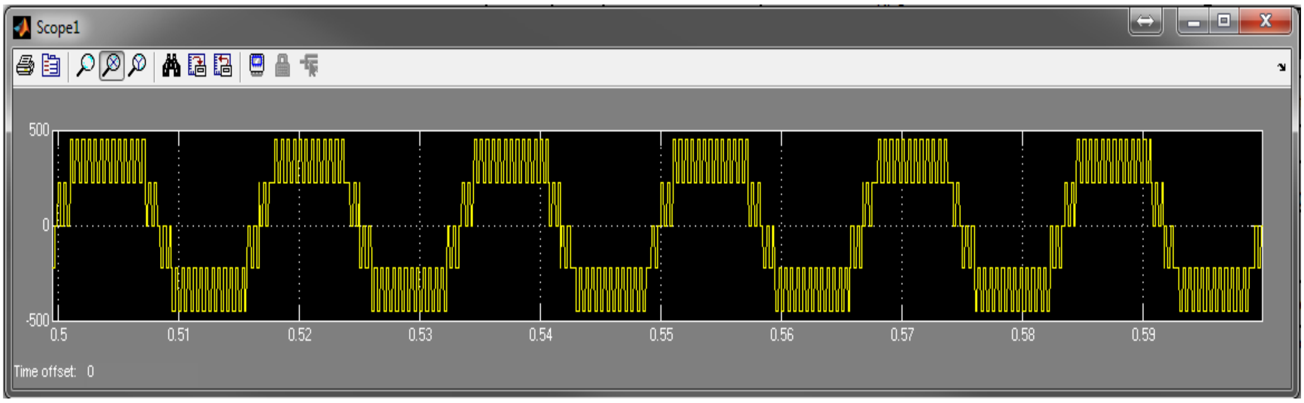

Fig. 4.3 Source NPC Line Voltage.

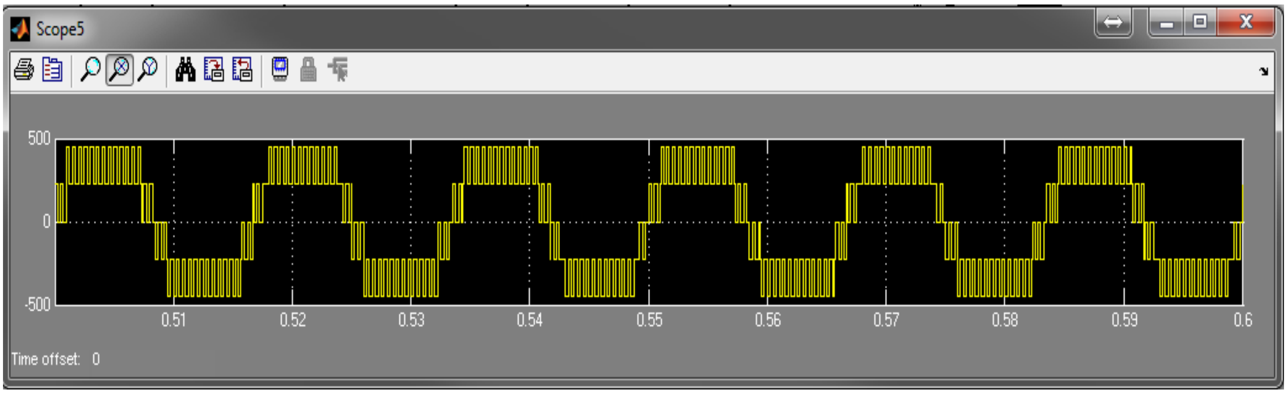

Fig.4.4 Load Voltage Waveforms of the Proposed System.

V. CONCLUSION AND FUTURE SCOPES

The multi level NPC converter is one of three major categories and offers the advantages of lower common-mode and differential-mode dv/dt, greater power capacity, and lower harmonic distortion in the output waveforms in comparison to VSIs. In this work neutral point clamped based three-phase multilevel converter topology, the indirect multilevel converter, has been proposed. This multilevel converter topology is the simplified multi - level neutral point clamped voltage source inverter topology. Despite having a simpler circuit configuration the converter is able to generate multilevel output voltages. The implementation has done on Matlab IDE and verification of proposed system has done based on

Simulation in Malab Simulink simulation environment. The simulation outcome shows that the performance of proposed system is batter as compared to existing work.

In order to verify the effectiveness of the proposed system, it is recommended that the necessary code be developed and implemented into the hardware of the developed multilevel NPC converter. Moreover, experimental analysis would be beneficial because the data acquired using software mitigation strategies could be benchmarked against data acquired when using hardware mitigation strategies.

REFERENCES

[1] A. M. Eltamaly, "Harmonic injection scheme for harmonic reduction of three-phase controlled converters," in IET Power Electronics, vol. 11, no. 1, pp. 110-119, 1 12 2018.

[2] Z. Zhang, A. Mallik and A. Khaligh, "A High Step-Down Isolated Three-Phase AC-DC Converter," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 6, no. 1, pp. 129-139, March 2018.

[3] J. Wang, F. Hu, J. Weidong, W. Wang and Y. Gao, "Investigation of Zero Sequence Circulating Current Suppression for Parallel Three-Phase Grid-Connected Converters Without Communication," in IEEE Transactions on Industrial Electronics, vol. PP, no. 99, pp. 1-1.

[4] S. Öztürk, "Design of three phase interleaved DC/DC boost converter with all SiC semiconductors for electric vehicle applications," 2017 10th International Conference on Electrical and Electronics Engineering (ELECO), Bursa, Turkey, 2017, pp. 355-359

[5] S. H. Hosseini, M. Maalandish, T. Jalilzadeh and S. Ghasemzadeh, "Three-phase interleaved boost DC/DC converter with high voltage gain and reduced nominal value on power devices," 2017 10th International Conference on Electrical and Electronics Engineering (ELECO), Bursa, Turkey, 2017, pp. 254-258.

[6] R. J. Vince and H. S. Manjula, "A three phase high frequency link PWM converter using soft switching techniques," 2017 Third International Conference on Science Technology Engineering & Management (ICONSTEM), Chennai, India, 2017, pp. 611-615.

[7] R. Velasco-Reyes, R. Loera-Palomo, M. A. Rivero-Corona, F. S. Sellschopp-Sánchez and J. A. Morales-Saldaña, "Three-phase converter based on reduced redundant power processing concept," 2017 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC), Ixtapa, Mexico, 2017, pp. 1-6.

[8] D. C. Morais, F. J. M. de Seixas, L. S. C. e Silva and C. P. João, "Three-phase bridgeless boost PFC converter with variable duty cycle control," 2017 Brazilian Power Electronics Conference (COBEP), Juiz de Fora, 2017, pp. 1-6.

[9] N. B. de Freitas, C. B. Jacobina, A. C. N. Maia, and A. C. Oliveira, “Six-leg single-phase to three-phase converter,” in 2016 IEEE Energy Conversion Congress and Exposition (ECCE), pp. 1–8, Sept 2016.

[10] S. Chiang, T.-S. Lee, and J. Chang, “Design and implementation of a single phase three-arms rectifier inverter,” Electric Power Applications, IEE Proceedings -, vol. 147, pp. 379–384, Sep 2000.

[11] C. Jacobina, T. Oliveira, and E. da Silva, “Control of the single-phase three-leg ac/ac converter,” Industrial Electronics, IEEE Transactions on, vol. 53, pp. 467–476, April 2006.

[12] J. Chang, W. Chang, and S. Chiang, “Multilevel single-phase recti- fier inverter with cascaded connection of two three-arm converters,” Electric Power Applications, IEE Proceedings, vol. 153, pp. 719–725, September 2006.

[13] C. B. Jacobina, M. B. de Rossiter Correa, A. M. N. Lima, and

[14] D. R. C. da Silva, “Ac motor drive systems with a reduced-switch- count converter,” IEEE Transactions on Industry Applications, vol. 39, pp. 1333–1342, Sept 2003.

[15] C. Jacobina, M. Correa, T. Oliveiro, A. Lima, and E. Cabral da Silva, “Current control of unbalanced electrical systems,” Industrial Electronics, IEEE Transactions on, vol. 48, pp. 517–525, Jun 2001.