Single Phase Nine Level Inverter with Reduced Number of Switches

D. Nageswari[1] R. Ramesh[2] G. Geethamahalaskhmi[3] R. Umadevi[4] J. Prince[5]
[1,3]Assistant Professor [2]EPD [4]Associate Professor [5]Student
[1,2,3,4,5]Department of Electrical Engineering
[1,3,4,5]R.M.K.College of Engineering and Technology [2]BGR Energy Systems

Abstract— Now a day's many industrial applications have begun to require high power. Some appliances in the industries however require medium or low power for their operation. The multilevel inverter has been used as alternative in high power and medium voltage situations. This paper deals with a single phase nine level inverter with reduced number of switches topology is developed. An experimental result shows that the total harmonic distortion is to be reduced with reducing the switches in topology.

Key words: Common-mode (CM) voltage, pulse width modulation (PWM), flexible AC transmission system

I. Introduction

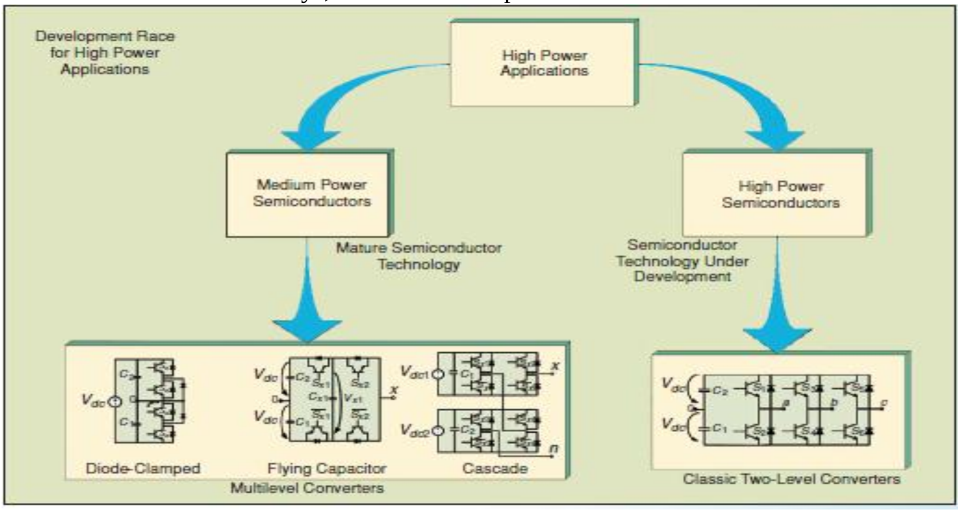
Multi-level inverter is an electronic device or circuitory that changes direct current (DC) to alternating current (AC) The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source. A single-phase inverter is usually used for residential or low-power applications of power ranges that are less than 10 kW. Types of single-phase multi level inverters have been investigated. 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 also the size of the filter used and the level of electromagnetic interference (EMI) generated by the inverter's switching operation. Multilevel inverters are promising, they have nearly sinusoidal output-voltage waveforms, output current with better harmonic profile, less stressing of electronic components owing to decreased voltages and lower EMI, all of which make them cheaper, lighter, and more compact. Various topologies for multilevel inverters have been proposed over the years. This paper recounts the development of a novel modified H-bridge single-phase multilevel inverter that has two diode embedded bidirectional switches and a novel pulse width modulated (PWM) technique. After grid connected photovoltaic system with considerations for a maximum-power-point tracker (MPPT) and a current-control algorithm. The topology was applied to a single phase nine level inverter in order to reduce the harmonics distortion level in the ac output voltage. Numerous industrial applications have begun to require higher power apparatus in recent years. Some medium voltage motor drives and utility applications require medium voltage and megawatt power level. For a medium voltage grid, it is troublesome to connect only one power semiconductor switch directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high A multilevel converter has several advantages over a conventional two-level converter that uses high switching frequency pulse width modulation (PWM). The attractive features of a multilevel converter can be briefly summarized as follows.

1) Staircase waveform quality: Multilevel converters not only can generate the output voltages with very low distortion, but also can reduce the dv/dt stresses; therefore electromagnetic compatibility (EMC) problems can be reduced.
2) Common-mode (CM) voltage: Multilevel converters produce smaller CM voltage; therefore, the stress in the bearings of a motor connected to a multilevel motor drive can be reduced. Furthermore, CM voltage can be eliminated by using advanced modulation strategies such as that proposed in.
3) Input current: Multilevel converters can draw input current with low distortion.
4) Switching frequency: Multilevel converters can operate at both fundamental switching frequency and high switching frequency PWM. It should be noted that lower switching frequency usually means lower switching loss and higher efficiency.

Unfortunately, multilevel converters do have some disadvantages. One particular disadvantage is the greater number of power semiconductor switches needed. Although lower voltage rated switches can be utilized in a multilevel converter, each switch requires a related gate drive circuit. This may cause the overall system to be more expensive and complex.

Plentiful multilevel converter topologies have been proposed during the last two decades. Contemporary research has engaged novel converter topologies and unique modulation schemes. Moreover, three different major multilevel converter structures have been reported in the literature: cascaded H-bridges converter with separate dc sources, diode clamped (neutral-clamped), and flying capacitors (capacitor clamped). Moreover, abundant modulation techniques and control paradigms have been developed for multilevel converters such as sinusoidal pulse width modulation (SPWM), selective harmonic elimination (SHE-PWM), space vector modulation (SVM), and others. In addition, many multilevel converter applications focus on industrial medium-voltage motor drives, utility interface for renewable energy systems, flexible AC transmission system (FACTS), and traction drive systems.

The most commonly used multilevel topology is the diode clamped inverter, in which the diode is used as the clamping device to clamp the dc bus voltage so as to achieve steps in the output voltage. Thus, the main concept of this inverter is to use diodes to limit the power devices voltage stress. The increase of the world energy demand has entailed the appearance of new power converter topologies and new semiconductor technology capable to drive all needed power. In this way, the last-generation devices are suitable to support high voltages and currents (around 6.5 kV and 2.5 kA). The Fig 1.1 shows multilevel converters built using mature medium-power semiconductors are fighting in a development race with classic power converters using high-power semiconductors that are under continuous development and are not mature. Nowadays, multilevel converters are a good solution for power applications due to the fact that they can achieve high power using mature medium-power semiconductor technology. Multilevel converters present great advantages compared with conventional and very well-known two-level converters. These advantages are fundamentally focused on improvements in the output signal quality and a nominal power increase in the converter.



. Fig. 1.1: Classic Two-Level Power Converters versus Most Common Multilevel Power Converters.

In order to show the improved quality of the output voltages of a multilevel converter, the output voltage of a single-phase two-level converter is compared to three- and nine-level voltage multilevel waveforms in Fig 1.2. The power converter output voltage improves its quality as the number of levels increases reducing the total harmonic distortion (THD) of the output waveforms. These properties make multilevel converters very attractive to the industry and, nowadays, researchers all over the world are spending great efforts trying to improve multilevel converter performances such as the control simplification and the performance of different optimization algorithms in order to enhance the THD of the output signals, the balancing of the dc capacitor voltage, and the ripple of the currents. The most common multilevel converter topologies are the neutral-point clamped converter (NPC), flying capacitor converter (FC), and cascaded H-bridge converter (CHB).

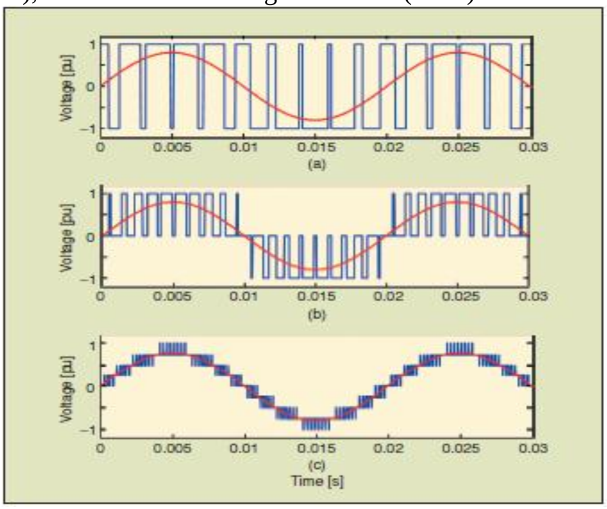


Fig. 1.2: Comparison of Output Phase Voltage Waveforms: (A) Two-Level Inverter, (B) Three-Level Inverter, And (C) Nine-Level Inverter.

These converters can be classified among the power converters for high-power applications according to Fig 1.3. Several surveys on multilevel converters have been published to introduce these topologies. In the 1980s, power electronics concerns were focused on the converter power increase (increasing voltage or current). In fact, current source inverters were the main focus for researchers in order to increase the current. In order to achieve the idea of increasing the voltage instead of the current the idea of NPC pulse width modulation (PWM) converter, also named the diode-clamped converter was presented. This converter was based on a modification of the classic two-level converter topology adding two new power semiconductors per phase. Using this new topology, each power device has to stand, at the most, half voltage compared with the two level case with the same dc-link voltage. So, if these power semiconductors have the same characteristics as the twolevel case, the voltage can be doubled. The NPC converter was generalized in order to increase the number of output levels.Other multilevel converter topologies such as the FC or CHB appeared. These multilevel converters present different characteristics compared with NPC, such as the number of components, modularity, control complexity, efficiency, and fault tolerance.

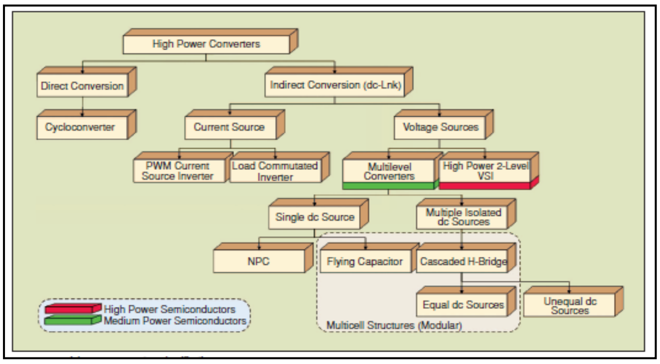


Fig. 1.3: High-Power Converters Classification

Depending on the application, the multilevel converter topology can be chosen taking into account these factors as shown in Table 1.1.

TABLE 1—COMPARISON OF MULTILEVEL CONVERTER TOPOLOGIES DEPENDING ON IMPLEMENTATION FACTORS.

	NPC	FC	CHB
Specific requirements	Clamping diodes	Additional capacitors	Isolated dc sources
Modularity	Low	High	High
Design and implementation complexity	Low	Medium (capacitors)	High (input transformer)
Control concerns	Voltage balancing	Voltage setup	Power sharing
Fault tolerance	Difficult	Easy	Easy

Table 1.1: Comparison of Multilevel Converter Topologies Depending On Implementation Factors

Nowadays, there are several commercial multilevel converter topologies that are sold as industrial products for high-power applications. However, although the advantages of using multilevel converters have been demonstrated, there has not been an industrial boom in the application of these power systems in the electrical grid in spite of their demonstrated good features to be used as medium-voltage drives. Maybe technological problems such as reliability, efficiency, the increase of the control complexity and the design of simple and fast modulation methods have been the barrier that has slowed down the application of multilevel converters all over the world. Finally, the effort of researchers has overcome this technical barrier and it can be affirmed that multilevel converters are prepared to be applied as a mature power system in the electric energy arena. This work is devoted to review and analyze the most relevant characteristics of multilevel converters, to motivate possible solutions, and to show that we are in a decisive instant in which energy companies have to bet on these converters as a good solution compared with classic two-level converters. This article presents a brief overview of the actual applications of multilevel converters and provides an introduction of the modeling techniques and the most common modulation strategies. It also addresses the operational and technological issues. In [1] Quasi two level operation of a five level inverter. In [2] Capacitor Balance Issues of the Diode-Clamped Multilevel Inverter Operated in a Quasi Two-State Mode. A new operational mode for diode-clamped multilevel inverters termed quasi two-level operation is proposed.

II. BLOCK DIAGRAM

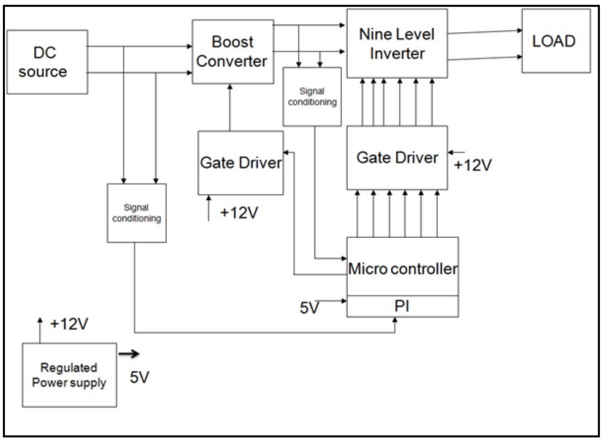


Fig. 4: Block Diagram

III. EXPLANATION ABOUT SIMULATION RESULT

In this paper, the hardware implementation of multilevel inverter is proposed. The total harmonic distortion gets reduced in order to produce the ac waveform. Input supply of 11 voltages is given to the boost converter through RPS. Boost converter is a DC to DC converter with an output voltage greater than its input voltage. It is a class of switched mode power supply containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.Input voltage gets boosted up to 150 voltage. An inverter can produce a square wave, modified sine wave, pulsed sine wave, or sine wave depending on circuit design. The two dominant commercialized waveform types of inverters as of 2007 are modified sine wave and sine wave. There are two basic designs for producing household plug-in voltage from a lower-voltage DC source, the first of which uses a switching boost converter to produce a higher-voltage DC and then converts to AC. The second method converts DC to AC at battery level and uses a line-frequency transformer to create the output voltage. A power inverter device which produces a multiple step sinusoidal AC waveform is referred to as a sine wave inverter. To more clearly distinguish the inverters with outputs of much less distortion than the "modified sine wave" (three step) inverter designs, the manufacturers often use the phrase pure sine wave inverter. Almost all consumer grade inverters that are sold as a "pure sine wave inverter" do not produce a smooth sine wave output at all, just a less choppy output than the square wave (one step) and modified sine wave (three step) inverters. In this sense, the phrases "Pure sine wave" or "sine wave inverter" are misleading to the consumer. However, this is not critical for most electronics as they deal with the output quite well where power inverter devices substitute for standard line power, a sine wave output is desirable because many electrical products are engineered to work best with a sine wave AC power source. The standard electric utility power attempts to provide a power source that is a good approximation of a sine wave. Sine wave inverters with more than three steps in the wave output are more complex and have significantly higher cost than a modified sine wave, with only three steps, or square wave, (one step), types of the same power handling. Switch-mode power supply devices, such as personal computers or DVD players, function on quality modified sine wave power. AC motors directly operated on non-sinusoidal power may produce extra heat, may have different speed-torque characteristics, or may produce more audible noise than when running on sinusoidal power. The output voltage, output current and output power will be produced across the load with total harmonic distortion of 15.39%.

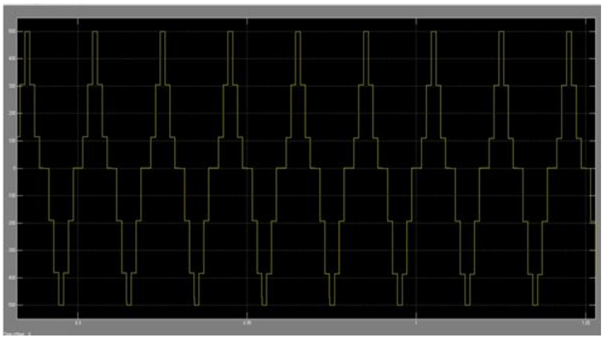


Fig. 3.1: Output Voltage

Fig. 3.2: Input Supply

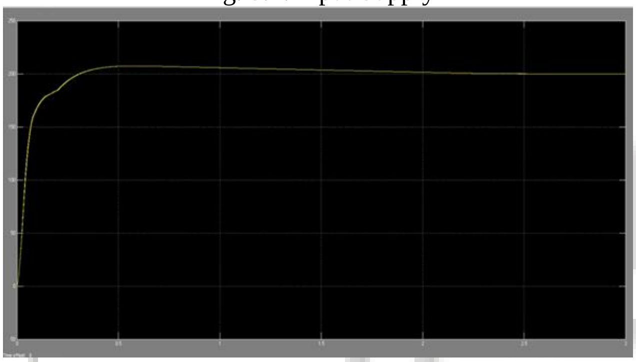


Fig. 3.3: Output of the Boost Converter

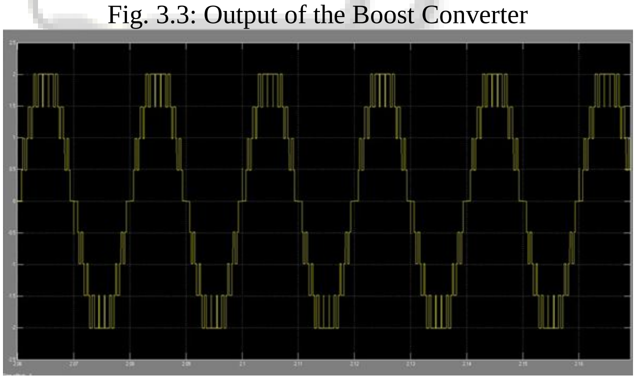


Fig. 3.4: Output Current

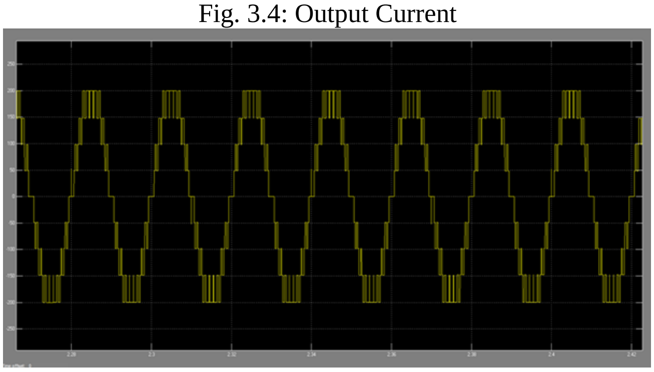


Fig. 3.5: Output Voltage

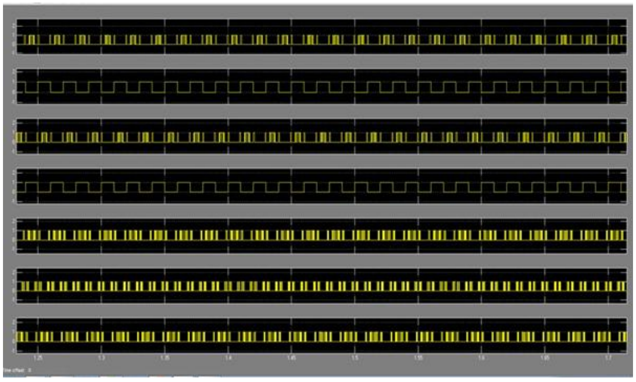


Fig. 3.6: Pulses

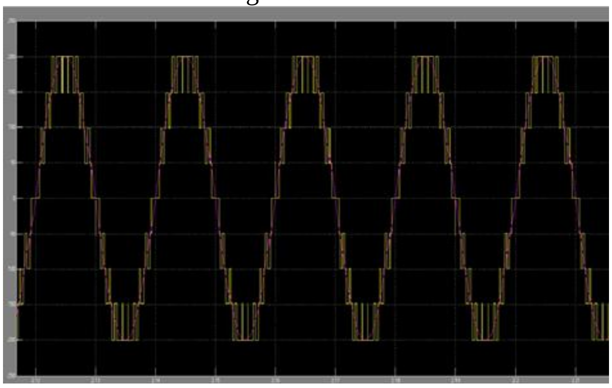


Fig. 3.7: Comparison with Sinusoidal Waveform

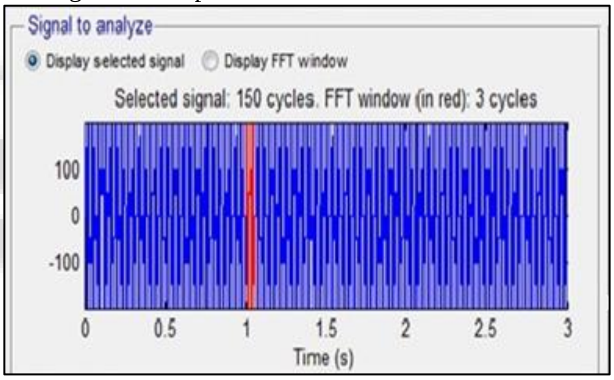


Fig. 3.8: THD Analysis – Frequency Range

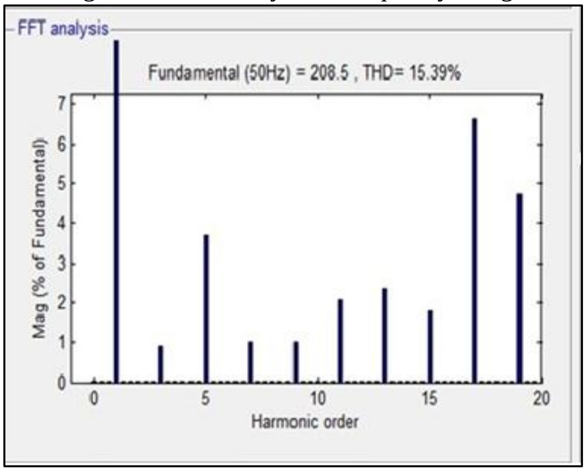


Fig. 3.9: Total Harmonics Distortion – 15.39%

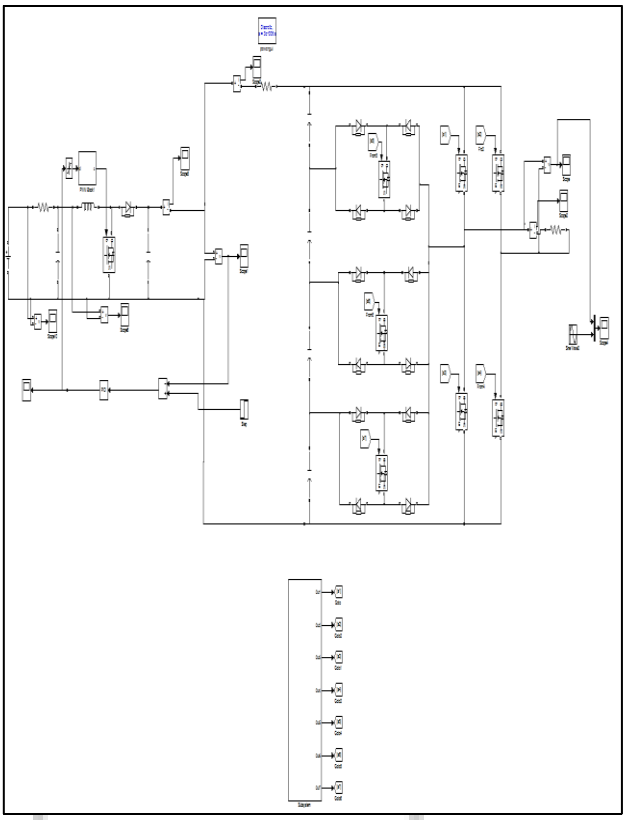


Fig. 3.10: Simulation Circuit

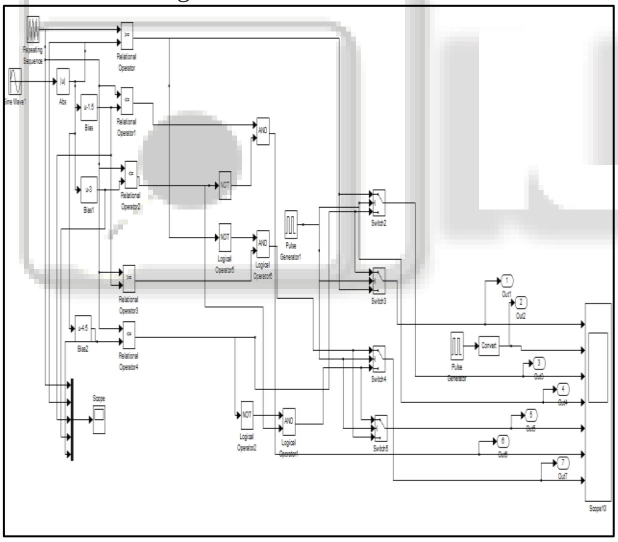


Fig. 3.11: Nine Level Inverter Simulation Circuit – PWM Generation

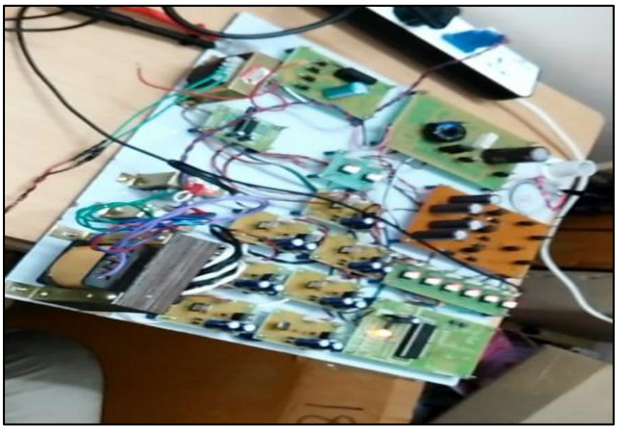


Fig. 3.12: Hard Ware Circuit of 9 Level Inverter

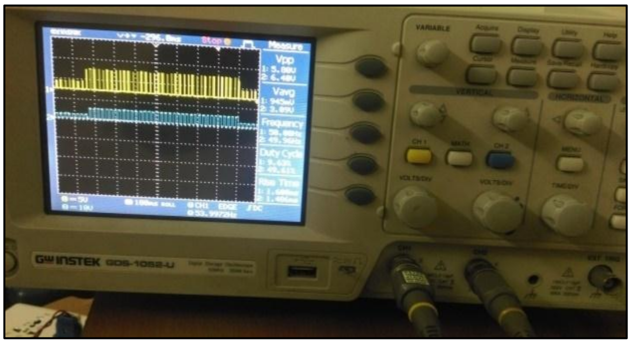


Fig. 3.13: Pulses Given To Boost Converter

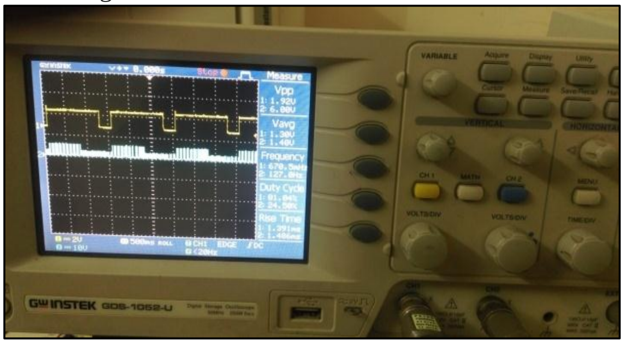


Fig. 3.14: Pulses 1 and 2 Given To Converter

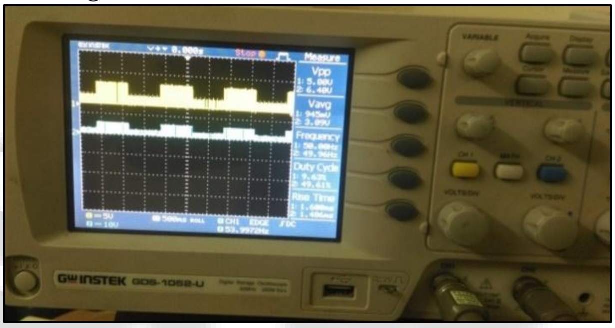


Fig. 3.15: Pulses 1 and 3 Given To Converter

Fig. 3.16: Output Voltage Waveform

IV. CONCLUSION

To conclude this paper, quasi operation shows better settling time and lesser peak values can be obtained. Whereas seven level operation requires larger settling time and hence results in peak values with larger magnitudes. In order to apply this methods in industrial areas, quasi operation is more desirable. The output voltage, output current and output power will be produced across the load with total harmonic distortion of 15.39%.

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