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DESIGN AND ANALYSIS OF FIVE LEVEL CASCADED H-BRIDGE MULTILEVEL INVERTER USING LEVEL SHIFTED PWM

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Abstract: Nowadays, the industries demanding more power with low harmonics for the high power applications. Thus Multilevel Inverter concept is introduced. The concept of the Multilevel Inverters becoming trendier for the high power applications due to less harmonics and high power ratings. The importance of the multilevel converters has been increase since the last decade. The ability to synthesize waveforms for high voltage with better harmonic spectrum, these new types of multilevel converters is suitable for high power applications. Several topologies have been introduced, amongst these topologies, the Cascaded H-bridge Multilevel Inverter is proposed. Also the main concept is Harmonics. So to reduce the harmonics the modulation topologies (PWM techniques) for multilevel inverters are proposed. The proposed topologies are IPD (In-phase Disposition), POD (Phase Opposition Disposition) and APOD (Alternate Phase Opposition Disposition). The simulations for the same are carried out for single phase and three phase open loop and closed loop configurations in MATLAB/Simulink software. Also %THD will be measured for the same and compared also. %THD will give the how much harmonics are presented is the system. And the analysis of the same will be done for the single phase and three phase also.

Key Words: Cascaded H-Bridge Multilevel inverter, THD, SPWM

I. INTRODUCTION

Nowadays industry has begun to demand higher power equipment, which now reaches the megawatt level. Controlled ac drives in the megawatt range are usually connected to the medium-voltage network. Today, it is hard to connect a single power semiconductor switch directly to medium voltage grids (2.3, 3.3, 4.16, or 6.9 kV). Many industrial applications have begun to require higher power apparatus in recent years [1]. Some medium voltage motor drives and power utility applications require medium voltage and megawatt power level. In the medium voltage power utility system, 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. For these reasons, a new family of multilevel inverters has emerged as the solution for working with higher voltage levels. Multilevel inverters include an array of power semiconductors and capacitor voltage sources, the output of which generate voltages with stepped waveforms. The commutation of the switches permits the addition of the capacitor voltages, which reach high voltage at the output, while the power semiconductors must withstand only reduced voltages [1]. The term multilevel starts with the three-level inverter introduced by Nabae et al. By increasing the number of levels in the inverter, the output voltages have more steps generating a staircase waveform, which has a reduced harmonic distortion. However, a high number of levels increases the control complexity and introduces voltage imbalance problems. The results of a patent search show that multilevel inverter circuits have been around for more than 25 years [1]. The multilevel inverter using cascaded inverter with Separate DC Source synthesizes a desired voltage [8] from several independent sources of dc voltages, which may be obtained from batteries, fuel cells or solar cells [2]. Several patents were found for the use of cascade inverters in regenerative-type motor drive applications. The last entry for U.S. multilevel inverter patents, which were defined as the capacitor-clamped multilevel inverters, came in the 1990s. Today, multilevel inverters are extensively used in high-power applications with medium voltage levels. The field applications include use in laminators, mills, conveyors, pumps, fans, blowers, compressors, and so on. [1]Multilevel converter topologies are used for static power conversion systems in medium to high voltage applications (up to several kV) [5].

A. Concept of Multilevel Inverter

Basically Inverter is a device that converts DC power to AC power at desired output voltage and frequency. Demerits of inverter are less efficiency, high cost, and high switching losses. To overcome these demerits, we are going to multilevel inverter. The term Multilevel began with the three-level converter. The cascade multilevel inverter was first proposed in 1975. In recent years multi level inverters are used high power and high voltage applications. Multilevel inverter output voltage produce a staircase output waveform, this waveform look like a sinusoidal waveform. The multilevel inverter output voltage having less number of harmonics compare to the conventional bipolar inverter output voltage. If the multilevel inverter output increase to N level, the harmonics reduced to the output voltage value to zero [1]. Multilevel system is popular because of it advantages, the inverter can produce medium or high AC voltage by using low switching frequency. By using low switching frequency, switching losses is decreased so that the inverters efficiency is increased. For three-level inverter, every switch only withstand a half of total DC voltage, so dv/dt reduced and smaller rating of switch can be utilized.

Output voltages of three-level inverter are built from three state voltage combination, so the voltage wave is more like sinusoidal form than two-level inverter. Hence, the output current ripple is lower at the same switching frequency [4].The main function of the multilevel inverter is to synthesize a desired voltage wave from several levels of dc voltages. Due to this reason, multilevel inverters provide the high power required of a large electric drive. Also, due to more steps are added to the waveform, the harmonic distortion of the output wave decreases, approaching zero as the number of levels increases. As the number of level increases, the voltage that can be extended by summing multiple voltage levels. Due to the structural property of the multilevel inverter no voltage sharing problems are encountered by the active devices. It exhibits several attractive features such as simple circuit layout, less components counts, modular in structure and avoid unbalance capacitor voltage problem. However as the number of output level increases, the circuit becomes bulky due to the increase in the number of power devices. So the multilevel inverter can be used to remove such demerits.

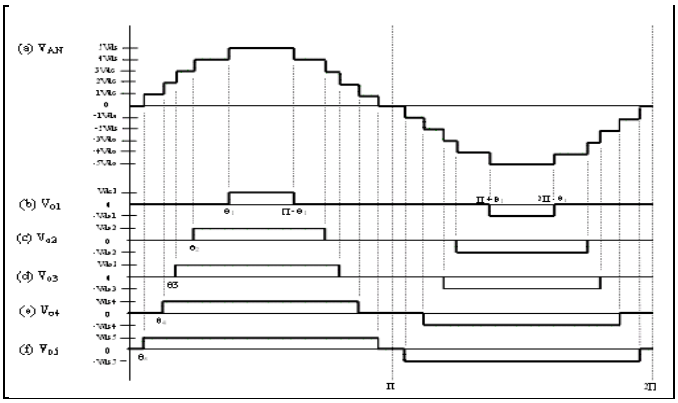

Fig 1. Multilevel inverter levels [16]

There are several types of multilevel inverter as discussed below:

- Diode-clamped multilevel inverter
- Flying capacitor multilevel inverter
- Cascaded H-bridge multilevel inverter

B. Cascaded H-bridge Multilevel Inverter

The one more topology for a multilevel inverter is the cascaded multilevel inverter or series H-bridge inverter. Cascaded multilevel inverter was not fully realized until two researchers, Lai and Peng. They patented it and presented its various advantages in 1996 [1]. Since then, the Cascaded H-bridge inverter has been utilized in a wide range of applications. With its modularity and flexibility, the Cascaded H-bridge inverter shows superiority in high-power applications. The Cascaded H-bridge inverter synthesizes its output nearly sinusoidal voltage waveforms by combining many isolated voltage levels. By adding more H-bridge converters, the amount of Voltage can simply increased without redesign the power stage and build-in redundancy against individual H-bridge inverter failure can be realized. A series of single-phase full bridges makes up a phase for the inverter.

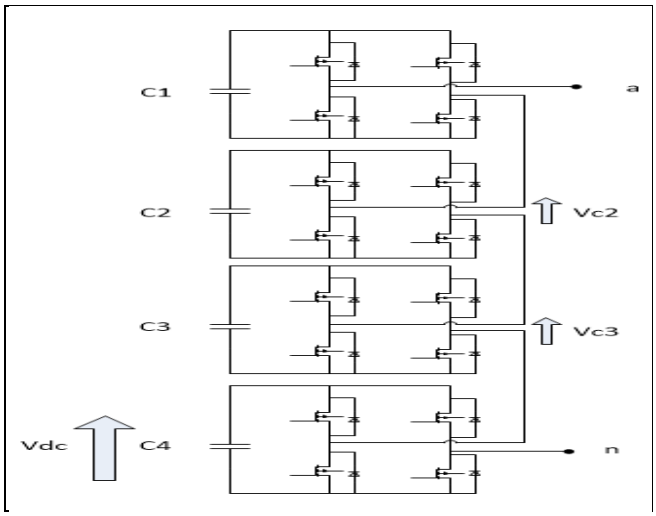

Fig 2. Cascaded inverter circuit topology

Fig. shows the power circuit for one phase leg of a nine-level inverter with four cells in each phase. The resulting phase voltage is synthesized by the addition of the voltages generated by the different cells. Each single-phase full-bridge inverter generates three voltages at the output: +Vdc, 0, and -Vdc. This is made possible by connecting the capacitors sequentially to the ac side via the four power switches. The resulting output ac voltage swings from -4Vdc to 4Vdc with nine levels, and the staircase waveform is nearly sinusoidal, even without filtering.

C. Classification of Modulation Topologies for Multilevel Inverter

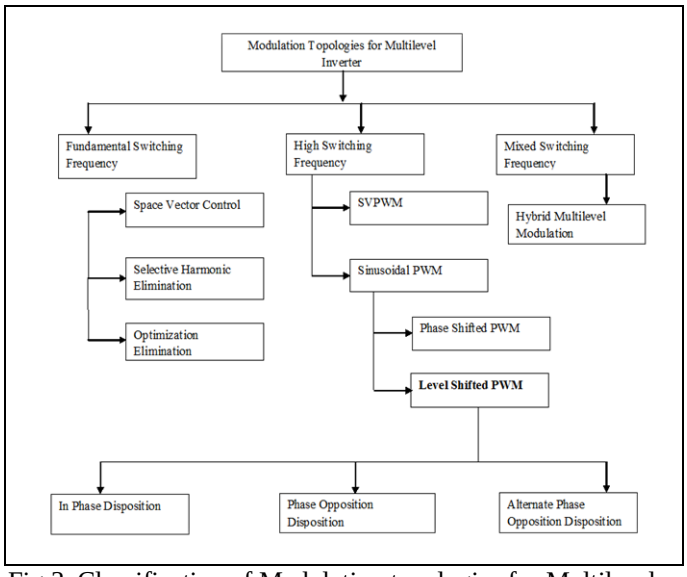

Fig 3. Classification of Modulation topologies for Multilevel Inverter

D. Level Shifted PWM

The Level shifted pulse width modulation have three types named as In-phase Disposition (IPD), Phase opposition disposition (POD) and Alternate phase opposition disposition (APOD).

E. Block Diagram of Proposed system

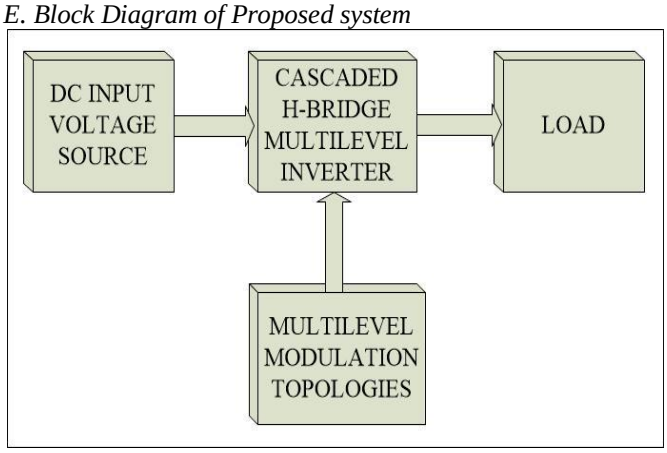

Fig 4. Basic block diagram of proposed system

II. SIMULATION WORK

Simulink model and results of Single phase Five level inverter by Cascading of Multilevel Inverters.

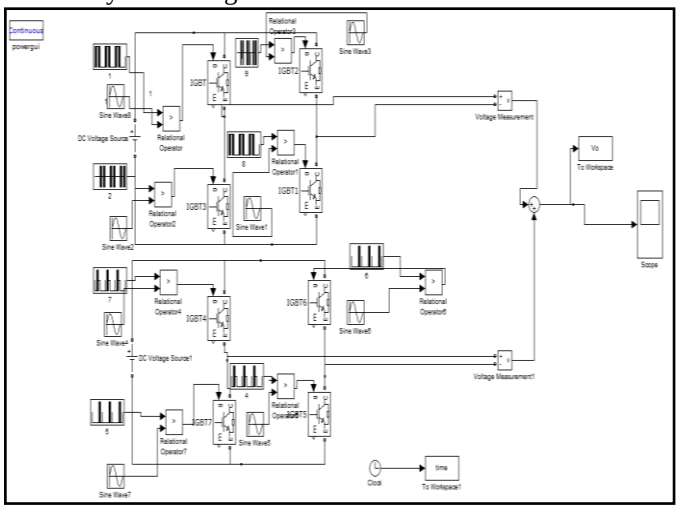

Fig 5. Simulink model of Single phase Five level inverter by Cascading of Multilevel Inverters

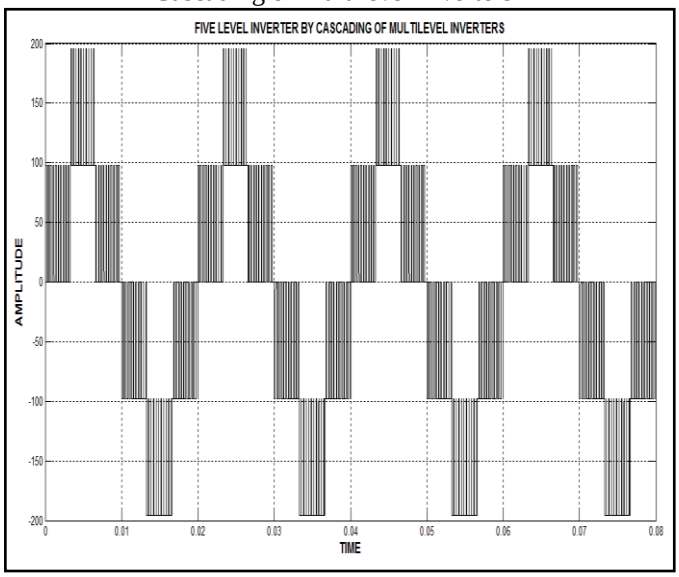

Fig. 6. Output of Single phase Five level inverter by Cascading of Multilevel Inverters

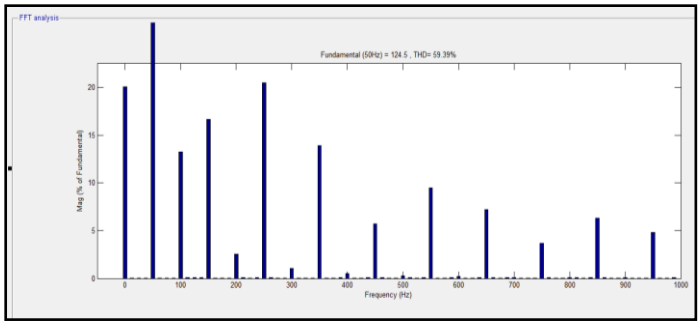

Fig 7. THD spectrum

Simulink model and results of comparison of reference and carrier waves of IPD.

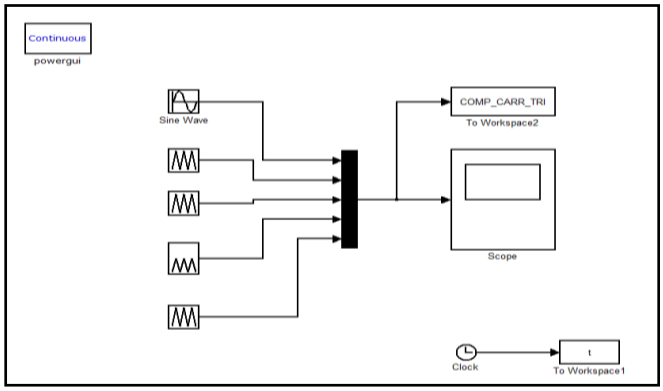

Fig 8. Comparison of reference (sine) and carrier (triangular) waves for IPD

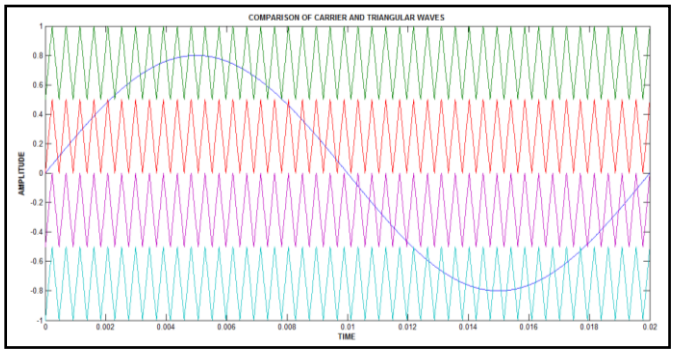

Fig 9. Output of carrier and reference waves for IPD

Simulink model and the results of gate pulses for the Switches.

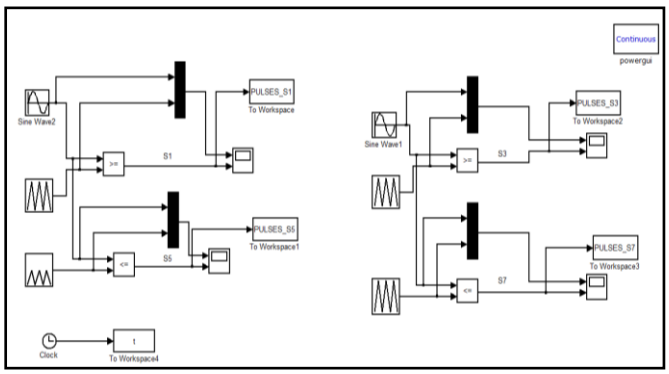

Fig 10. Gate pulses for switches

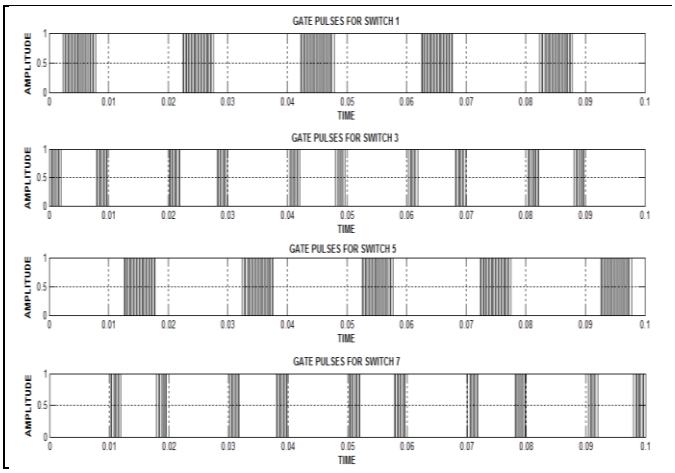

Fig 11. Output for switches

Simulink model and results of the Single phase Five Level Open loop In-phase Disposition (IPD)

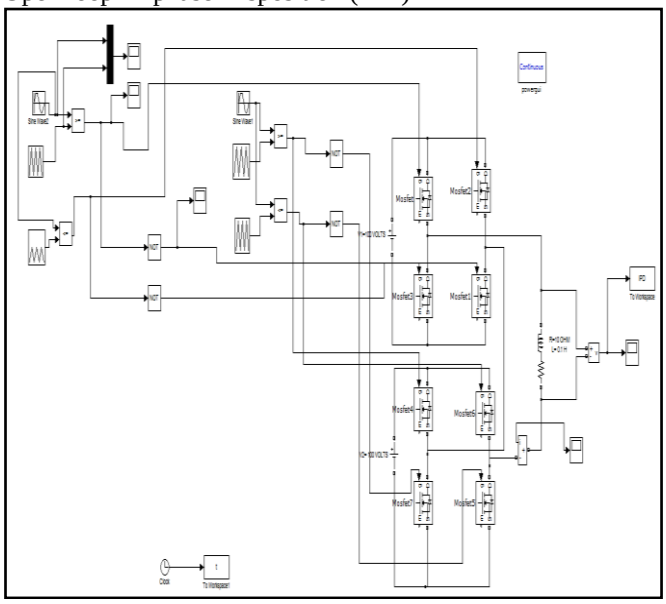

Fig 12. Simulink model of Single phase Five Level Open loop In-phase Disposition (IPD)

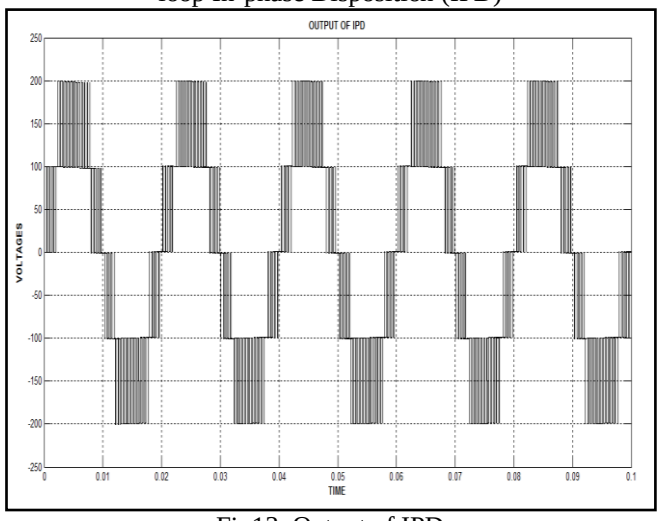

Fig13. Output of IPD

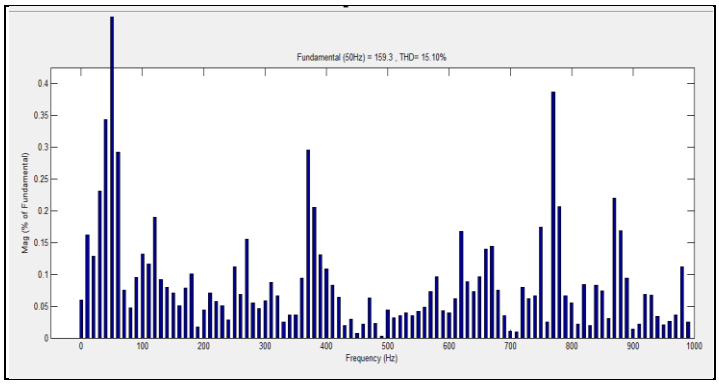

Fig14. 10 THD spectrum for IPD

III. CONCLUSION

The simulation of the five levels inverter is successfully done using with conventional inverter and In-phase disposition (IPD) method. Also %THD calculated for both and compared. Various topologies for multilevel inverter are described and modulation topologies are used to reduce the harmonics. Among all these topologies Cascaded H-bridge multilevel inverter proposed. It's having fewer components to get desired output. Also various modulation topologies like IPD, POD and APOD described to eliminate the harmonics.

IV. FUTURE WORK

To simulate the Five levels cascaded H-bridge inverter with Single phase POD and APOD. Results analysis of POD and APOD and to calculate %THD and comparison of the same.

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