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Study of Total Harmonic Distortion in Multilevel Inverter Topologies

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Abstract: **Nowadays, multilevel inverters have gained much popularity in PV systems. Multilevel inverter promises a lot of advantages over conventional inverter especially for high power applications. One of the advantage is that the output waveform is improved since multilevel inverter produce nearly sinusoidal output voltage waveform, hence the total harmonic distortion is low. The switching losses also become less. And, the filter needed to smooth the output voltage is small; hence, the system is compact, lighter and much cheaper.**

Keywords: MLI-multi level inverter, THD-Total harmonic distortion.

1. INTRODUCTION

Basically Inverter is a device which converts DC power to AC power with desired voltage and frequency. Multilevel inverters are used in every field. It has become quite famous in Energy and Power systems. The demerits of inverter are less efficiency, high cost and high switching losses. To overcome these demerits multilevel inverter is preferred. The concept of multilevel converters has been introduced since 1975. Some of the widely used multilevel inverters are diode clamped, flying capacitor and cascaded H-bridge. In diode clamped MLI as number of levels increases, diodes required for inverter also increase. In flying capacitor topology as number of levels increase capacitor required also increase which makes this topology heavy and cumbersome. The cascaded multilevel control method is very easy as compared to other multilevel inverters because it doesn't require any clamping diodes and flying capacitors. The attractive features of multilevel inverter are, they can generate the output with very low THD, it is much suitable for high voltages, High power applications than that of conventional inverter, it can switch each device only once per cycle and generate Multistate stair case waveform approaching pure sinusoidal output voltage.

2. RELATED WORK

The different multilevel inverter topologies have been explained in various articles with different control system with modifications. Sridhar R. Pulikanti, et al [1] have worked on hybrid 7 level cascaded active neutral point clamped based multilevel converter under selective harmonic elimination pulse with modulation (SHE-PWM) technique with minimum switching frequency with provided the elimination of low order harmonic and the results have been validated through simulation results and low power laboratory prototype. Jose Rodriguez, et al [2] have reviewed a survey of topologies, with controls and applications of multilevel inverters. The soft switched multilevel inverters with sinusoidal pulse with modulation, multilevel selective harmonic elimination and space vector modulation have been explained. Javier Chivite-Zabalza, et al [3] have demonstrated the applications of combining three level neutral point clamped power electronics building blocks for a large power voltage source converter for FACTS. The analysis of system has been carried out with elimination of third harmonic component by the modulation, high quality output which eliminated the need of filters and also the results have been verified with experimental results for several modulation strategies. Jia-Min Shen, et at [4] have implemented five level inverter for a renewable power generation system. The five level inverter has been developed and applied for injecting real power of the renewable power into the grid to reduce the switching power loss, harmonic distortion and electromagnetic interference caused by switching operation of power electronics devices. The system is analysed with output current of five level inverter controlled to generate a sinusoidal current in phase with utility voltage inject into the grid and verified the results with hardware setup. Hossein Sepahvant, et al [5] have designed a single dc source cascaded H-bridge multilevel converters for capacitor voltage regulation using phase shift modulation control strategy. The issues of voltage balancing have been solved with this modulation technique in which converter is fed with only one independent dc source. The constraints involved in selecting the voltage source level of auxiliary H-bridge cell is discussed.

3. MULTILEVEL INVERTER

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. Using a high power source for all industrial loads may prove beneficial to some motors requiring high power, while it may damage the other loads. Some medium voltage motor drives and utility applications require medium voltage. The multi-level inverter has been introduced since 1975 as an alternative in high power and medium voltage situations. The Multilevel inverter is like an inverter and it is used in industrial applications as an alternative to high power and medium voltage situations.

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❖ **Types of Multilevel Inverter:**

Multilevel inverters are of three types.

A. Diode clamped multilevel inverter

The main concept of this inverter is to use diodes and provides the multiple voltage levels through the different phases to the capacitor banks which are in series. A diode transfers a limited amount of voltage, thereby reducing the stress on other electrical devices. The maximum output voltage is half of the input DC voltage. It is the main drawback of the diode clamped multilevel inverter. This problem can be solved by increasing the switches, diodes, capacitors. Due to the capacitor balancing issues, these are limited to the three levels. This type of inverters provides high efficiency because of the fundamental frequency used for all the switching devices and it is a simple method of the back to back power transfer systems [2].

B. Flying capacitors multilevel inverter

The main concept of this inverter is to use capacitors. It is of a series connection of capacitor clamped switching cells. The capacitors transfer the limited amount of voltage to electrical devices. In this inverter switching states are like in the diode clamped inverter. Clamping diodes are not required in this type of multilevel inverters. The output is half of the input DC voltage. It is a drawback of the flying capacitors multilevel inverter. It also has the switching redundancy within the phase to balance the flying capacitors. It can control both the active and reactive power flow. But due to the high-frequency switching, switching losses will take place [8]

C. Cascaded H- bridge multilevel inverter

The cascaded H-bride multilevel inverter consists of capacitors and switches and requires less number of components in each level. The combination of capacitors and switches pair is called an H-bridge and gives the separate input DC voltage for each H-bridge. It consists of H-bridge cells and each cell can provide the three different voltages like zero, positive DC, and negative DC voltages. One of the advantages of this type of multi-level inverter is that it needs less number of components compared with diode clamped and flying capacitor inverters. The price and weight of the inverter are less than those of the two inverters.

A multilevel inverter has four main advantages over the conventional inverter. First, the voltage stress on each switch decreased due to series connection of the switches. Therefore, the rated voltage and consequently the total power of the inverter could be safely increased. Second, the rate of change of voltage (dv/dt) decreased due to lower the lower voltage swing of each switching cycle. Third, harmonic distortion reduced due to more output levels. Fourth, lower acoustic noise and electromagnetic interference(EMI) obtained [2].

C.1. Cascaded H Bridge Three Level Inverter

The cascaded H-bridge three level inverter consists of one H-bridge, DC source, R load. The DC source may be batteries, solar cells, etc. The H-bridge may be having MOSFET, IGBT, Diode. The number of levels of output voltage wave depends on number of H-bridges. In cascaded H-bridge three level inverter, single H-bridge produces three levels of output voltage. The voltage levels are +V,0 and –V. The voltage output is in staircase form. The simulation diagram and THD result of cascaded H-bridge three level inverter is shown in figures below:

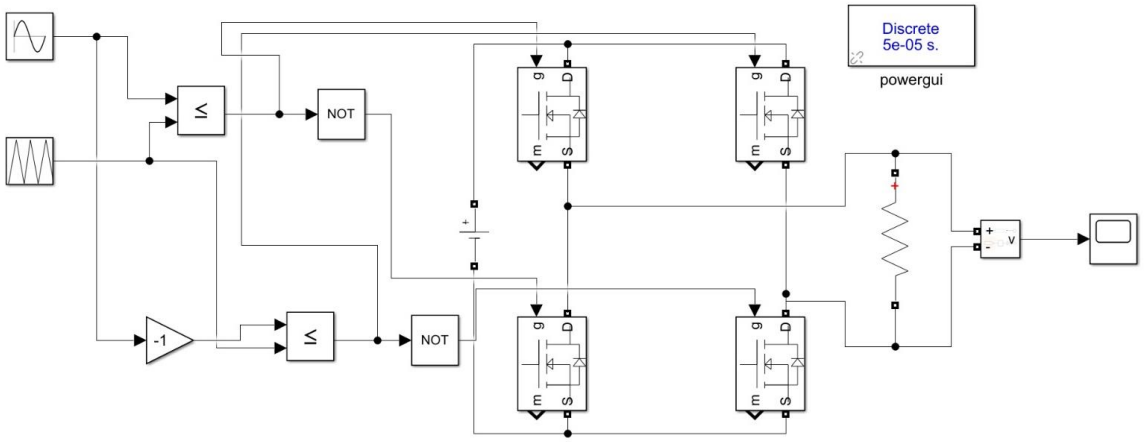

Fig C.1. (a) Simulation Model of 3 Level H Bridge Inverter

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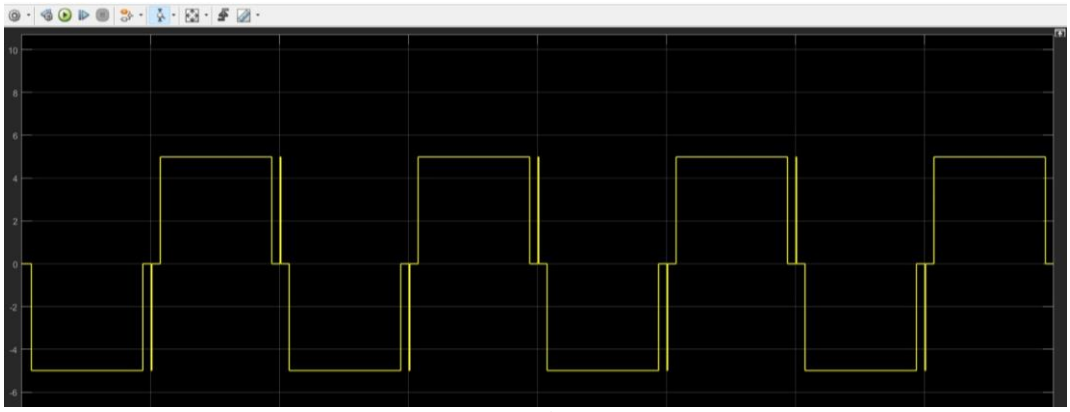

Fig C.1. (b) Output Voltage of 3 Level H Bridge Inverter

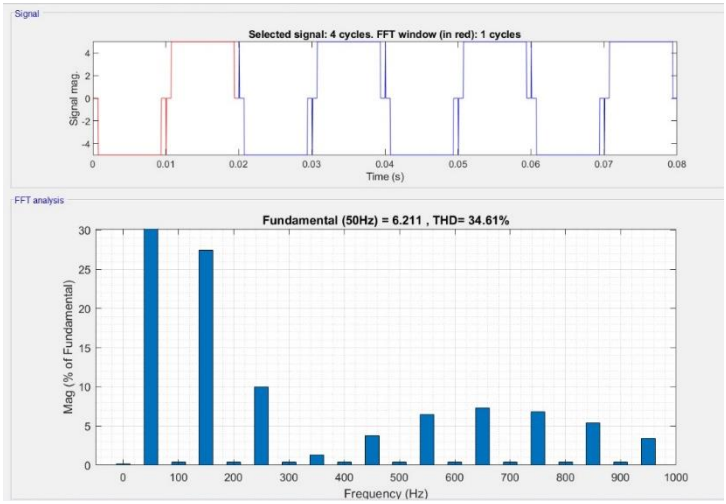

Fig C.1 (c) THD Level in Output voltage of 3 Level Inverter

The % of THD for three level inverter is 34.61%. The % of THD depends upon number of switches used in inverter circuit.

C.2. Cascaded H Bridge Five Level Inverter

The cascaded H-bridge five level inverter consists of two H-bridges, two equipotential DC sources and R load. The DC source may be batteries, solar cells, etc. The H-bridge may have MOSFET, IGBT, Diode. The number of levels of output voltage wave depends on number of H-bridges. In cascaded H-bridge five level inverter, two H-bridges produces five levels of output voltage. The voltage levels are +2V, +V, 0 and –V, -2V. The voltage output is in staircase form. The simulation diagram and THD result of cascaded H-bridge five level inverter is shown in below:

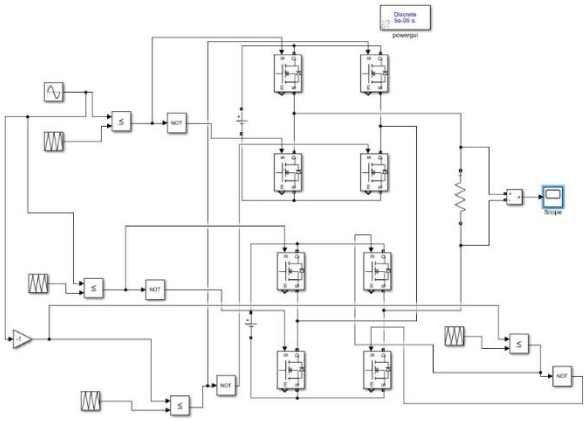

Fig C.2. (a) Simulation Model of 5 Level H Bridge Inverter

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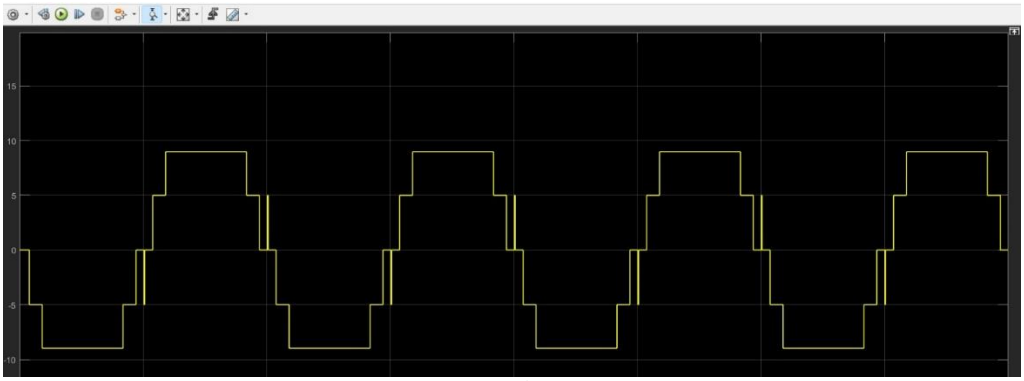

Fig C.2. (b) Output Voltage of 5 Level H Bridge Inverter

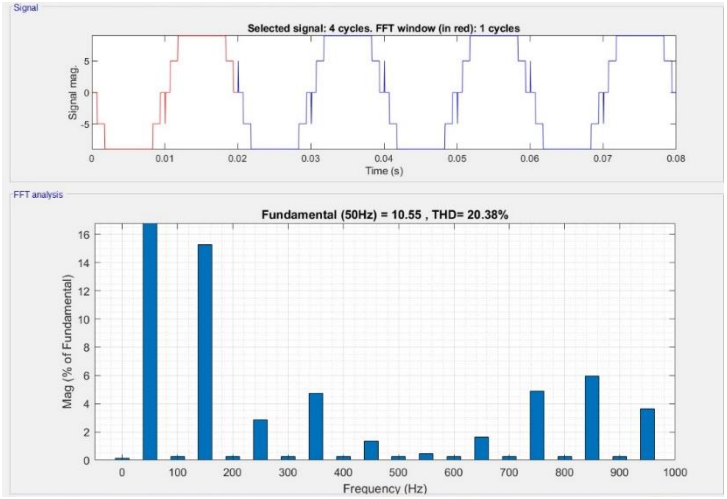

Fig C.2. (c) THD Level in Output voltage of 5 Level Inverter

The % of THD for five level inverter is 20.38%. The THD % decreased as the number of circuits increases for cascaded H Bridge Multilevel Inverter.

C.3. Cascaded H Bridge Seven Level Inverter

The cascaded H-bridge seven level inverter consists of three H-bridge, three equipotential DC sources, R load. The DC source may be batteries, solar cells, etc. The H-bridge may have MOSFET, IGBT, Diode. The number of levels of output voltage wave depends on number of H-bridges. In cascaded H-bridge seven level inverter, three H bridges produces seven levels of output voltage. The voltage levels are +2V, +V, 0 and –V, -2V. The voltage output is in staircase form. The simulation diagram and THD result of cascaded H-bridge seven level inverter is shown in figures below:

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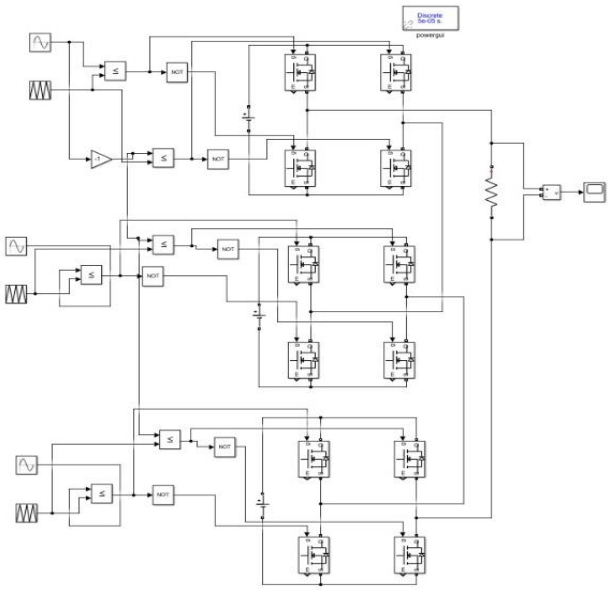

Fig C.3. (a) Simulation Model of 7 Level H Bridge Inverter

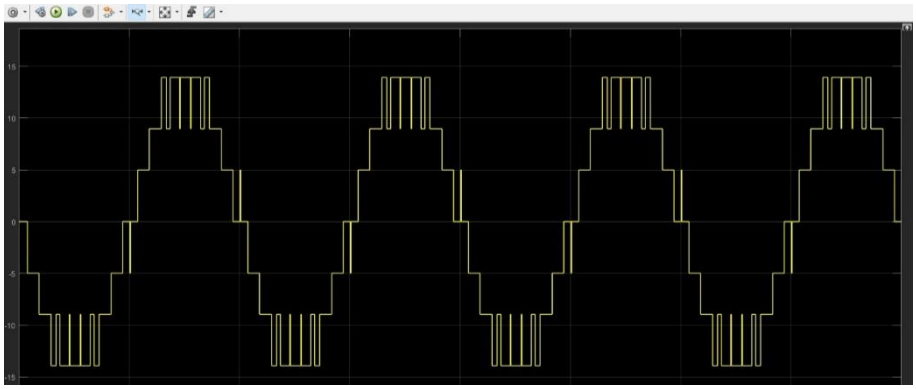

Fig C.3. (b) Output Voltage of 7 Level H Bridge Inverter

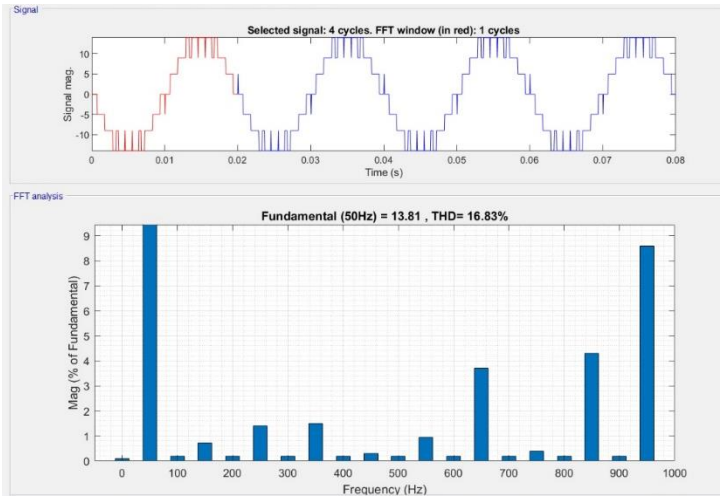

Fig C.3. (c) THD Level in Output voltage of 7 Level Inverter

The % of THD for seven level inverter is 16.83%. The THD level of seven level inverter is less as compared to the three level and five level inverter. This is major advantage of seven level cascaded H-bridge inverter over three level and five level inverter.

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4. COMPARISON OF CASCADED H BRIDGE MULTILEVEL INVERTERS

The table 1 illustrates the comparison of Cascaded H inverters with three level five level and seven level.

Sr. No.	Parameters	Three Level CHBI	Five Level CHBI	Seven Level CHBI
1.	No. of bridges	1 H Bridge	2 H Bridge	3 H Bridge
2.	No. of switches	4	8	12
3.	Output levels	3	5	7
4.	No. of DC sources	1	2	3
5.	%THD	34.16	20.38	16.83

Table No. 1

The performance of proposed cascaded multilevel inverter is evaluated by using MATLAB/SIMULINK software. From this simulation we can observe that as the number of levels are increased the %THD decreased. The above table shows the comparison between different level cascaded H-bridge inverters with the help of different parameters.

5. CONCLUSION

In this paper, three level, five level and seven level cascaded H-bridge inverters have been simulated by using MATLAB/SIMULINK. The results of simulated system of multilevel Cascaded H- Bridge inverter have been compared on the basis of different parameters such as number of switches, number of DC sources required for operation and THD levels. According to the comparison, the seven level inverter has less THD level as compared to the three level and seven level inverter. From this comparison, we can conclude that as the number of level increases the THD level decreases. As the H-bridges increases the harmonic content in the output of inverter decreases.

The controlled switching pulses are used to minimize the THD present in the multilevel inverter output voltage as the reduction of THD leads to eliminate the harmonics present in the inverter output voltage and improve the power quality with energy efficiency.

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