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Simulation and Comparison of Three and Nine level Cascaded H-bridge Multilevel Inverter

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Abstract

The multilevel inverter was developed as a solution to increase the converter operating voltage above the voltage limits of classical semiconductors. The function of the multilevel inverter is to synthesize a high voltage waveform from several lower levels of dc voltages. If the switching angle arrangement technique is not selected properly then the total harmonic distortion of voltage output waveform may become unacceptable. In this paper the sinusoidal pulse width modulation (SPWM) control strategy is used to control output voltage. In this paper simulation of single phase three and nine level cascaded H-bridge multilevel inverter is performed in Simulink environment. The comparison of THD values of these inverters is done.

Keywords—*component; Multilevel inverter(MLI), Cascaded H-bridge inverter(CHB), Total harmonic distortion THD, pulse width modulation, Fast Fourier Transform (FFT), IGBT*

INTRODUCTION

An inverter is essential in the power conversion interface to convert the dc power to ac power. Inverters can be generally classified into two types, voltage source and current source inverters. A voltage-fed inverter (VFI) or more commonly a voltage-source inverter (VSI) is one in which the dc source has little or insignificant impedance. The voltage at the input terminals is stable. A current-source inverter (CSI) is connected with adjustable current from the dc source of high impedance that is from a constant dc source. A VSI uses thyristors as switches; some type of forced commutation is required, while the VSIs made of Gate turn-off (GTOs), power transistors, power Metal oxide semiconductor field effect transistor (MOSFETs) or Insulated gate bipolar transistors (IGBTs), self commutation with base or gate drive signals for their controlled turn-on and turn-off. A typical single-phase voltage or current source inverter can be in the half-bridge or full-bridge configuration. The single-units can be attached to have 3-phase or multiphase topologies. a few commercial programs of inverters are for adjustable-velocity ac drives, induction heating, standby aircraft strength materials, uninterruptible electricity supply (UPS) for computer systems and HVDC transmission traces.

The inverter is used to control the essential voltage value and the frequency of the ac output voltage. AC hundreds may additionally need regular or adjustable voltage at their enter terminals; while such loads are related to inverters, it is necessary that the output voltage of the inverters is so regulated as to accomplish the requirement of the masses. If the inverter components strength to a magnetic circuit, such as an induction motor, the voltage to frequency ratio at the inverter output terminals must be reserved consistent. This avoids saturation within the magnetic circuit of the device fed through the inverter [4].

the global electric energy fed on is rising and there may be a regular boom of the call for at the energy capacity, green production, distribution and utilization of power. The conventional energy structures are changing globally, a huge number of dispersed generation (DG) units, inclusive of each renewable and nonrenewable strength resources together with wind mills, photovoltaic (PV) mills, fuel cells, small hydro, wave generators and gas/steam powered mixed warmth and electricity stations, are being incorporated into energy systems at distribution stage. Energy electronics, the era of effectively processing electric powered electricity, performs a vital part in the integration of the dispersed era units for correct performance and high performance of the energy systems. The ac output voltage obtained from the inverters can be fed to a load at once or interconnected to the ac grid without voltage balancing problems [3].

Development in industrial revolution has been increased rapidly in all over the world. And suitable voltage, current and frequency are minimal requirement of any industrial utility for better power quality [7].

The recent development in solid-state electronics is widely used in industries to control motor drives, computers and communications, power systems, switching mode power supplies, automotives, etc. The inverter is one of the most full-size assemblies in energy electronics. the principle components for the improvement of multilevel inverters are multilevel voltage waveform, low general harmonic distortion and department of voltage to the switching gadgets. using multilevel inverters for excessive-voltage programs including static var compensators, active power filters and adjustable pace drives for medium voltage induction motors are accelerated in industries [5].

Multilevel inverters have attracted much research interest, particularly in high power applications. The advantages of the usage of multilevel inverters are twofold. firstly the voltage pressure throughout every converter will get reduced because of its collection connection of energy semiconductor modules, making the inverters suitable for excessive voltage applications. Secondly the first-class of the generated voltage increases with the range of voltage stages. Therefore the resolution of the waveform gets extended and the filtering efforts can be reduced due to the advanced resolution in the voltage harmonic content [6].

Structure of the multilevel voltage source inverters allow them to reach high voltages with low harmonics without the use of transformers or series-connected synchronized switching devices. Multilevel inverters also have several advantages with respect to hard switched two level pulse width-modulations (PWM) variable-speed drives. Motor damage failure have been reported by industry as a result of some variable-speed drives operated by the inverters by the having high rate of change of voltage, which produced a common-mode voltage across the motor windings.

High frequency switching creates many problems because common-mode voltage is impressed numerous times upon the motor at each cycle. The main problems of high frequency switching are failure of motor bearing and insulation breakdown in motor winding because of dielectric stresses, circulating currents, voltage surge and corona discharge. Multilevel inverters will be able to overcome these problems because their individual devices have a much lower stress per switching action [5].

The multilevel inverter system is a very promising device in ac power drives when both reduced harmonic content and high power are required. High magnitude sinusoidal voltage with extremely low distortion at fundamental frequency can be produced at the output with the help of multilevel inverters by connecting sufficient number of dc levels at input side [3].

To produce multilevel output ac voltage using different levels of dc inputs, the semiconductor devices must be switched ON and OFF in such a way that the fundamental voltage is obtained a desired along with the elimination of certain harmonics in order to have least harmonic distortion in the ac output voltage. For switching the semiconductors, proper selection of switching angles is must [3].

Multi-level power conversion is allowed for more than two voltage stages to reap smoothened and minimal distorted dc to ac energy conversion and it is able to generate aa couple of-step voltage waveform with less distortion, much less switching frequency and better performance. The stepped waveforms are fabricated by way of multiple voltage levels produced through the appropriate connection of the burden. This connection is finished via the appropriate switching in the energy semiconductors. To obtain a high-quality output voltage waveform they require excessive switching frequency along with special pulse-width modulation strategies. The multilevel cascaded H-bridge inverter is one of the famous inverter topologies for high electricity programs due to its excessive voltage operating functionality low dv/dt with reduced total harmonic distortion and modular structure for reduced manufacturing cost. The level-shifted modulation schemes have a good total harmonic distortion profile, but suffer from unbalanced power distribution, whereas the phase shifted schemes are simpler but produce higher total harmonic distortion [2].

The developments in power electronics and semiconductor era have caused the improvements in strength digital structures. So, unique circuit configurations namely multilevel inverters have come to be popular and sizeable hobby by means of researchers are given on them. The output voltage waveforms in multilevel inverters can be generated at low switching frequencies with low distortion and high frequency. For a medium voltage grid, it's far difficult to connect best one power semiconductor switches at once. As a end result, a multilevel electricity converter shape has been introduced as an alternative in excessive strength and medium voltage conditions along with laminators, generators, conveyors, pumps, fanatics, blowers, compressors and so on. The cascaded multilevel inverter turned into first delivered in 1975. Separate DC-sourced complete-bridge cells were placed in series to synthesize a staircase AC output voltage. The time period multilevel started out with the 3-degree converter. sooner or later, numerous multilevel converter topologies had been developed. In 1981, diode-clamped multilevel inverter additionally known as the neutral-factor Clamped (NPC) inverter schemes had been proposed. In 1992, capacitor-clamped (or flying capacitor) multilevel inverters, and in 1996, cascaded multilevel inverters had

been proposed. The improvements inside the subject of strength electronics and microelectronics made it possible to lessen the importance of harmonics with multilevel inverters, wherein the variety of levels of the inverters are improved instead of growing the scale of the filters. The overall performance of multilevel inverters complements because the quantity of degrees of the inverter increases [1].

MULTILEVEL INVERTERS

The unique structure of voltage supply inverters permits them to reach high voltages with low harmonics without the usage of collection-connected synchronized switching gadgets or transformers. The fundamental idea of a multilevel converter to attain high power is to use a sequence of energy semiconductor switches with several decrease voltage dc resources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries and renewable energy voltage assets can be used as the more than one dc voltage sources. The commutation of the strength switches aggregate these a couple of dc resources so that it will achieve excessive voltage on the output; however, the rated voltage of the electricity semiconductor switches relies upon only upon the score of the dc voltage sources to which they're linked A multilevel converter can be implemented in different ways. The simplest techniques involve the parallel or series connection of conventional converters to form the multilevel waveforms. greater complicated systems successfully insert converter within converters. The voltage or current rating of the multilevel converter will become a more than one of the man or woman switches, and so the power score of the converter can exceed the restriction imposed by way of the individual switching gadgets. numerous multilevel inverter topologies had been developed; i) diode clamped, ii) flying capacitors and iii) cascaded or H-bridge [1]. as compared to flying capacitor multilevel inverter and diode-clamped multilevel inverter, the cascaded multilevel inverter desires less wide variety of additives and simple control methods. In excessive voltage fields, the cascaded multilevel inverters are widely used. In multilevel inverters, cascaded H-bridge multilevel inverter with unequal dc voltage resources is wise as it isn't always laid low with capacitor voltage unbalancing. However switching devices are subjected to unequal voltage pressure [5]. Classification of multilevel Inverters
Classification of multilevel inverters is done in fig 1.

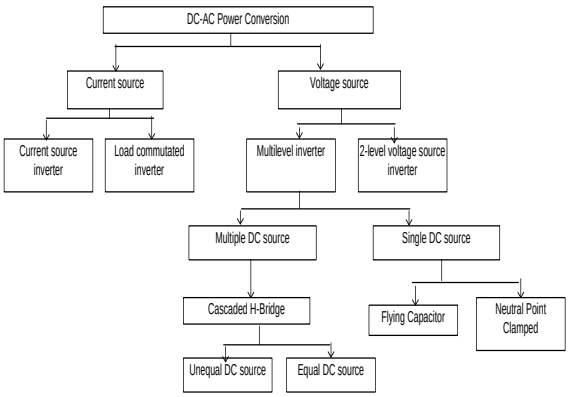

Fig.1 *Classification of multilevel inverter*

COMPARISON OF DIFFERENT MULTILEVEL INVERTERS

Tables 1, 2 and 3 show the comparison of the various topologies of multilevel inverter.

Table I. *Applications Of Different Inverteers*

Diode-clamped multilevel inverter	**Flying capacitor multilevel inverters**	**Cascaded H-bridge multilevel inverter**
Static var compensation	Induction motor control using DTC (Direct Torque Control)circuit	Motor drives
Variable speed motor drives	Static var generation	Active filters

High voltage system interconnections	Both AC-DC and DC-AC conversion applications	Electric vehicle drives
High voltage DC and AC transmission lines	Converters with Harmonic distortion capability	DC power source utilization
	Sinusoidal current rectifiers	Power factor compensators
		Interfacing with renewable energy sources.

TABLE II. *COMPARISON OF POWER COMPONENT REQUIREMENTS PER PHASE LEG AMONG THREE MULTILEVEL INVERTERS*

Inverter configuration	**Diode clamped**	**Flying capacitors**	**Cascaded inverter**
Main switching devices	2(m-1)	2(m-1)	2(m-1)
Main diodes	2(m-1)	2(m-1)	2(m-1)
Clamping diodes	(m-1)(m-2)	0	0
DC bus capacitors	(m-1)	(m-1)	(m-1)/2
Balancing capacitors	0	(m-1)(m-2)/2	0

TABLE III. *ADVANTAGES AND DISADVANTAGES OF DIFFERENT INVERTERS*

	Cascaded H-bridge multilevel inverters	**Diode clamped inverters**	**Capacitor clamped inverters**
Advantages	We get same switching frequencies for all the switches. Modular structure is easier to analyze.	Low cost and less components due to less number of capacitors. Can be operated on separate DC source.	Each branch can be analyzed independently.
Disadvantages	Separate DC sources are required	For more than three levels, the charge balance gets disturbed. Output voltage gets limited.	Pre-charging capacitor is difficult.

CASCADED H-BRIDGE MULTILEVEL INVERTER

Cascaded H-Bridge configuration has recently become very popular in high-strength AC resources and adjustable-speed power packages. A cascaded multilevel inverter includes a sequence of H-bridge (unmarried-phase full bridge) inverter gadgets. Each H-bridge unit has its personal dc supply. Every SDC (separate DC source) is related to a single segment full-bridge inverter. The ac terminal voltages of various stage inverters are connected in collection. Fig indicates a unmarried-section structure of a cascaded H-bridge inverter with separate dc assets. The AC outputs of various full-bridge converters are connected in series such that the synthesized voltage waveform is the sum of the individual converter outputs. In this topology, the number of output-phase voltage levels is defined by M=2N+1, where 'M' is the no. of levels and 'N' is the number of DC sources. So, for an example the output phase voltage of eleven level inverter is given by Van=Va1+Va2+Va3+Va4+Va5 [1].

Full H-bridge converter

Fig 2. Shows the Full H-Bridge Configuration. By using H-bridge we can get 2 and 3 voltage levels. The number of output voltage levels of cascaded Full H-Bridge are given by 2n+1 and voltage step of each level is given by Vdc/n, where n is number of H-bridges inverter connected in cascade. The switching table is shown in table 4 [4].

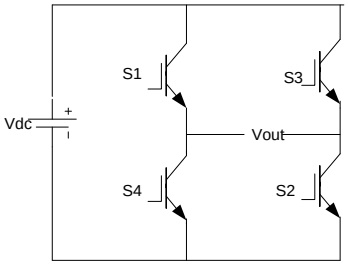

Fig2. *Full H-Bridge inverter*

TABLE IV. *SWITCHING TABLE FOR FULL H-BRIDGE INVERTER*

Switches Turn ON	Voltage level
S1, S2	Vdc/2
S3, S4	-Vdc/2
S2, S4	0

SIMULATION RESULTS

Single phase three level Cascaded H-Bridge multilevel inverter

Fig 3.shows the design of single phase three level H-bridge inverter with R-load.

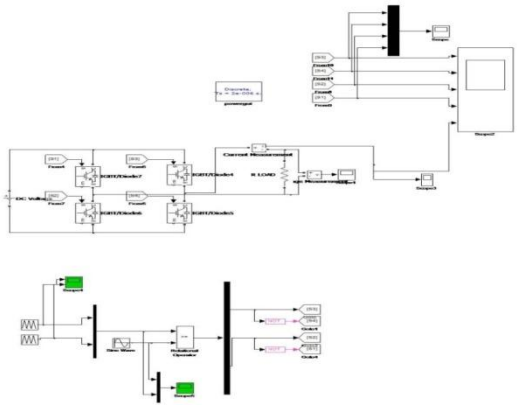

Fig 3. *Design of three level inverter*

Fig 4.shows the output voltage waveform for single phase three level multilevel inverter.

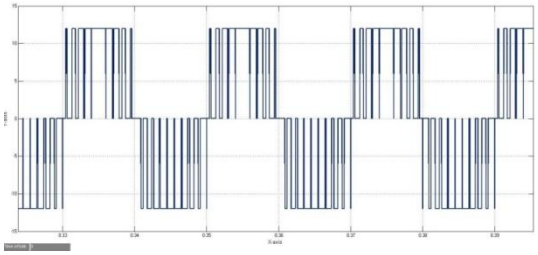

Fig 4. *Output voltage of three level inverter*

Fig 5 shows the FFT spectrum of the output voltage of three level inverter.

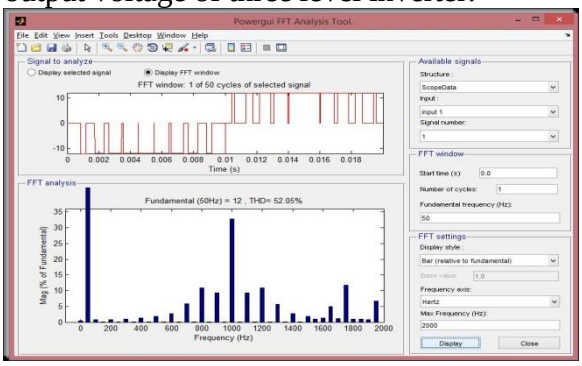

Fig 5. *THD Analysis of output voltage waveform of three level cascaded multilevel inverter (THD=52.05%)*

Single phase eleven level Cascaded H-Bridge multilevel inverter

Fig 6.shows the design of single phase nine level H-bridge inverter with R-load.

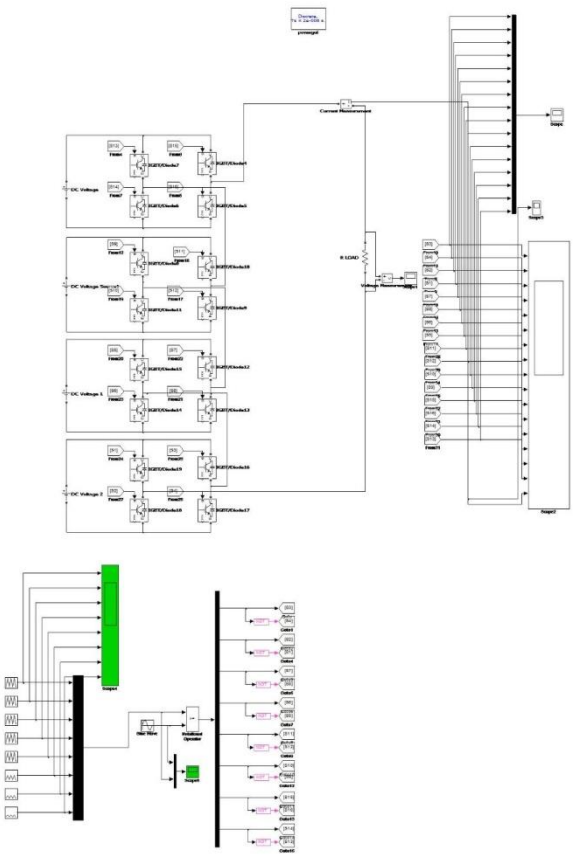

Fig 6. *Design of nine level inverter*

Fig 7.shows the output voltage waveform for single phase nine level multilevel inverter.

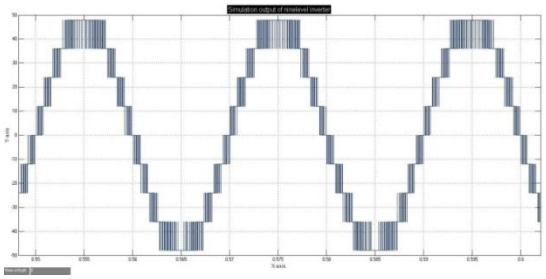

Fig 7. *Output voltage of nine level inverter*

Fig 8 shows the FFT spectrum of the output voltage of nine level inverter.

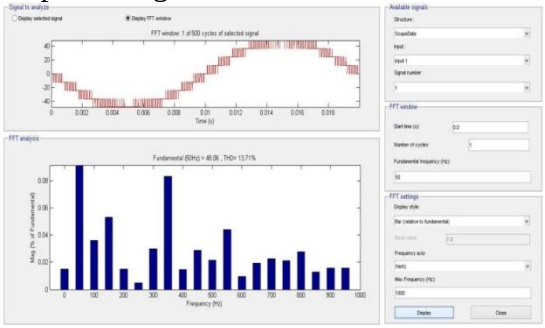

Fig 8. *THD Analysis of output voltage waveform of nine level cascaded multilevel inverter (THD=13.71%)*

Comparison of THD values

Table 5 shows the comparison of THD values of three and nine level cascaded h-bridge multilevel inverter.

TABLE V*. THD VALUES*

	Single phase three level cascaded H-bridge multilevel inverter with R-load	Single phase nine level cascaded H-bridge multilevel inverter with R-load
%THD	52.05	13.71

CONCLUSION

In this paper, the simulation results of three and nine level single phase cascaded multilevel inverters are compared. It is found that the total harmonic distortion reduces as we go on increasing the number of levels in a multilevel inverter and hence we get improved power quality. The %THD in three level cascaded multilevel inverter is 52.05 and that in nine level inverter is 13.71. Hence, the output voltage waveform of nine level inverter has lesser harmonic content that of three level multilevel inverter.

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