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Designing of Efficient Multilevel Inverter by using Cascaded H Bridges (CHB) for Minimizing Harmonic Distortion

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Abstract ***–With the increasing uses of high voltage (HV) applications in industries,. It is required to evaluate the performance of inverters for achieving minimum total harmonic distortion (THD) using HV switching. Therefore this paper proposed to design and test Cascade H bridge (CHB) based multilevel inverters. It is expected to achieve closest sinusoidal approximation of step sine wave. Thus it is proposed to minimize the THD performance by using multilevel inverter (MLI). Using the CHB inverter is best choice for fulfilling the HV requirement. Paper initially reviewed various MLI design and the existing THD analysis works. Paper compares the performance of seven and eleven levels of the CHB inverters. Simulink model is validated and modified for designing the HV inverter. The basic four switch based single cell H Bridge units are cascaded to design the multi level inverters. The voltage rating of the inverter is raised to four times by increase supply of each H bridges to 400 V In the paper THD is taken into account as an evaluation criterion. The FFT assessment is carried out for analyzing the performance of designed multi-level inverters. Inverter-based equipment's voltage performance may improve and harmonic distortions may be reduced as a result of raising levels of inverter design.***

Key Words: **Multilevel inverter, Cascade H Bridge, FFT, GTO, sine wave inverter, Total Harmonic Distortion (THD).**

I. INTRODUCTION

For designing the inverters at higher voltage ratings the H bridge inverters are considered as best option. High voltage (HV) applications are being used in more and more industrial workplaces, Therefore, when using HV switching inverters it is expected to achieve minimum THD performance.

Power scaling is simple in case of the CHB inverter design. The only components in the circuit are switches, which could be IGBTs or GTOs. Paper has utilized this topology to investigate multi level inverters and simulate to design 11 levels inverter. The GTOs is preferred in this paper for designing the CHB inverters at high voltage uses. It is because GTO's offers faster switching and are less bulky. The CHB inverter offers lower THD values and higher output voltage power quality. With design of these CHB inverters less screening is needed, which reduces costs. This inverter is used in equipment that needs high power AC to operate.

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Therefore it is required to analyze the performance of existing inverter architectures.

Inverters: These days, a variety of inverter kind is available and is broadly classified as shown in the Figure 1. These inverters includes modified sine wave [1], Square wave inverter [3], pure sine wave [4] and the multilevel inverters [5 and 6], etc. are some of the inverter kinds that are most frequently utilized.

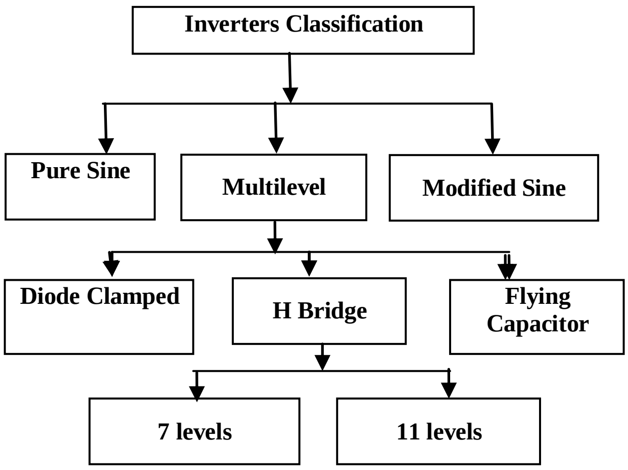

Fig.1. Classification of inverters design

The sine wave inverters are mostly being used for the domestic appliances. The key distinction among sine wave and square wave inverters is that pure sine inverters produce a pure sine wave output and offers the least amount of THD, but they are more expensive. Conversely, square wave inverters have a higher THD value, which reduces safety and shortens the lifespan of appliances, but are less expensive than sine wave inverters. The fusible solution is to adopt the modified sine inviter as shown in Figure 2. The multilevel inverter can produce god quality modified sine wave.

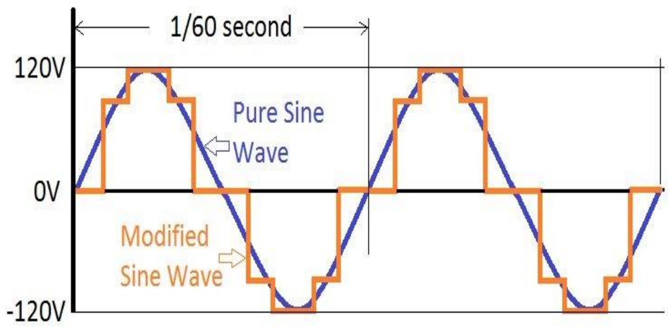

Fig.2. A Comparison of sine and step waves of inverter.

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In this paper our prime concern will be to compare the performance of each of the inverter based on the THD and FFT analysis. It is highly desired to minimize the THD in inverter designs. These multi level modes depend on the operating sequences and of the switches and the input of the switches. The three phase inverter is required to produce the three phase waveform as shown in the Figure 2.

This paper have validated and designed the High voltage (HV) MLI and compare the effectiveness of the increasing the number of levels for inverter designs. The quantitative evaluation of the 11 level CHB inverter design is presented.

II. H BRIDGE INVERTERS

The single cell architecture of the Cascade H Bridge (CHB) inverter is designed by using the four GTO switches. The main advantage is the reduction in capacitor and design-related component usage. The single cell construction used in the H Bridge is shown in Figure 3.

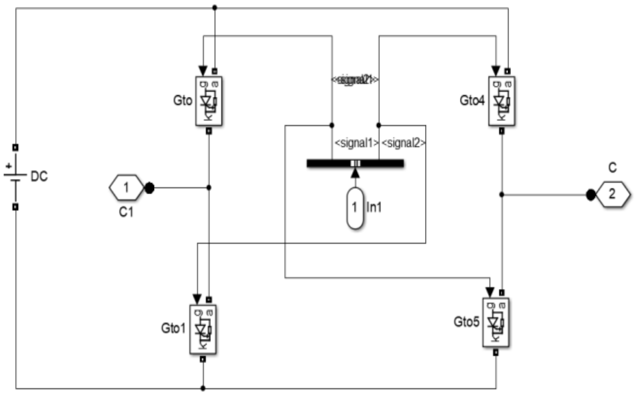

Fig. 3. Single cell H bridge model using switches

The multilayer inverter architecture for GTO has typically been chosen for high voltage appliances. For the GTO, it has a number of possible HV advantages and uses. Some of them are listed below:

1) It is extremely capable of blocking voltage.

2) It turns off more quickly and allows for increased switching frequency.

3) Due to its smaller size and less weight, it can operate at higher frequencies without a network connection.

4) When activated, it provides favorable evaluations.

Figure 4 illustrates the GTO's fundamental design. The acronym GTO is used to refer to the Gate Turn-Off Switch. This gadget uses a semiconductor to allow unilateral switching. The terms "Gate," "Anode," as well as "Cathode" refers to the terminals. It offers complete control for switching amongst techniques. A switch can be turned on and off using a single gate terminal. High working currents and voltages ratings equal to 1600 V and about 250 A are the key benefits of employing GTO for switching. Figure 4 depicts the basic architecture or structure of the GTO and its corresponding circuit. High power motor applications can benefit by utilizing the high power operational sources in the majority of industrial loads. However, it could also harm additional loads in the system. In these circumstances, using a H bridge inverter might be a good solution.

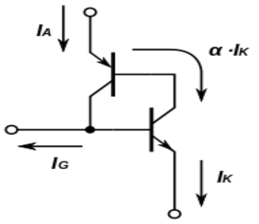

Fig. 4. GTO construction structure and circuit

III. REVIEW OF MULTILEVEL INVERTERS

The performance of the switches utilised for design determines the inverting operation's efficiency. Cascaded H bridge (CHB) inverters have a variety of architectural designs to enhance performance. Sotoodeh et al [1] have designed 11 levels inverter for the energy distribution system. They have evaluated the THD using the LC filter and obtained minimal THD performance. To enhance CHB inverting performance, E. Lee, et al [2] chose the modified PWM8 method with phase shifting. The performance of a cascaded H bridge inverter is controlled by PWM. THD performance of 3 and 5 levels CHB inverters has been compared by B. Rajesh et al. [3]. For level inverters, they observed THD of 26.3 percent, and for five level inverters operating at stator voltage, THD of 15.04 percent. Pulse width modulation (PWM) has been employed by A. Ali et al. [4] to enhance the functionality of multi-level CHB inverters. B. Widyo et al [7] have designed the 11 level diode clamped inverter and reported the THD of 8.68 % for transformer under lode applied. C. M. Van et al [8] have proposed to design SV-PWN for the MLLI design.

. A. Singh et al simulation of a three-phase, five-level CHB inverter employing SPWM produced a 21.2 percent THD.

To enhance the performance of CHB inverting, E. Lee, et al. [2] chose a modified PWM8 method with phase shifting. PWM is used to regulate the output of cascaded H bridge inverters. The THD performances of CHB inverters with 3 and 5 levels were compared by B. Rajesh et al. in their study. At stator voltage, they reported THD of 26.3 percent for level and 15.04 percent for 5 level inverters. A. Singh et al. [4] used SPWM to model a five-level three-phase CHB inverter and found that the THD was 21.2 percent. Good analyses of THD for various multi-level CHB inverters were published by G. Singh et al. [5], who came to the conclusions that the THD for 9 level and 11 level CHB inverters was 23.54 percent and 10.84 percent, Mr. Mohd et al [9] have designed 11 level inverter and obtained the THD level of the 7.74 %.

According to S. Menaka et al. [13], MLI with evolutionary algorithm-based switching is a good substitute for medical electronic devices used in hospitals to obtain high-quality electricity with reduced THD. The

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versions of the DCDC coveters for diagnostic instruments were created by Miguez, Matas et al. [15] and George, L. et al.[16]. Table 1 presents summary of survey.

Table.1 Summary of MLI design Survey

S. No.	Authors	Type of Inverter	Work
1.	Sotoodeh et al [1]	11 level MLI inverter	Designed 11 levels inverter for the energy distribution system. and obtained 8.68.THD performance
2.	B. Rajeshet al [3]	3 and 5 levels MLI CHB	have assessed THD performances of 3 and 5 levels MLI CHB inverters
4.	G. Singh et al [5]	Single phase MLI inverter design	Analysed THD effectiveness of various MLI CHB inverters.
5.	Mr. Mohd et al [9]	11 level CHB	Offers 7.8 % THD performance
6.	S, Menaka et al [13]	Multi level Inverter	Inverter des6ign of electronic medical equipments harmonic analysis

IV. PROPOSED MULTILEVEL INVERTING MODELS

In this paper it is proposed to design the modified high voltage 11 level CHB inverter model. The carrier pulse width modulated PWM frequency is raised to 4000 Hz in order to achieve the lower THD and fast switching of the switches. Since there are certain applications required fast switching inverters. The GTO switches are proposed to design. The prime goal of research is to minimize the THD performance based on the FFT analysis is implemented using power GUI tool of Simulink. The systematic design methodology is presented in the Figure 5 below.

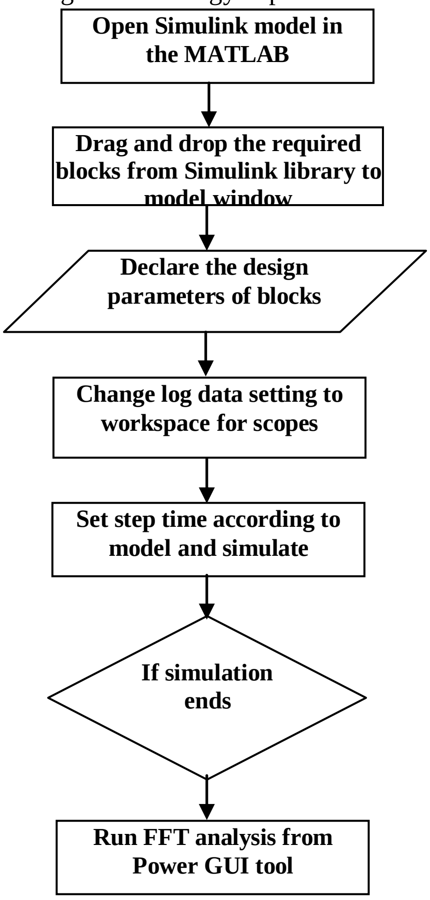


Fig. 5. Proposed design methodologies for THD analysis

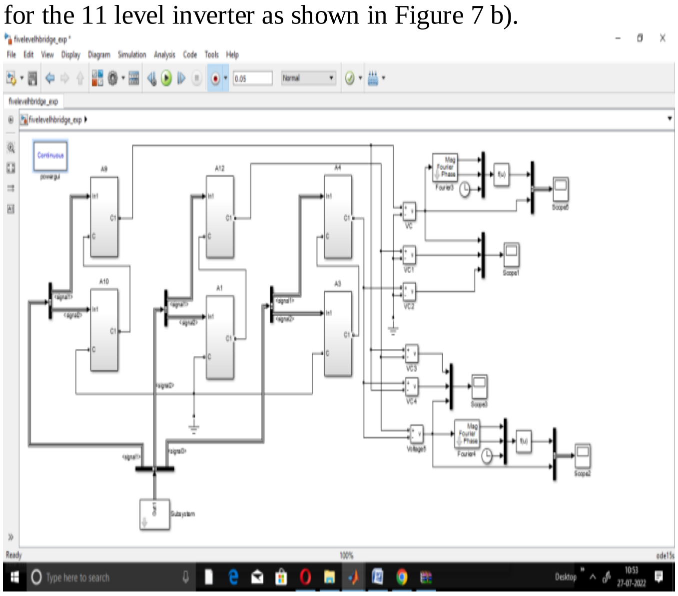
The main point to notice is the setting of the step time. Since, it is responsible for fast simulation of the designed model. in addition it also affect the THD analysis cycles. The performance evaluation is based on the degree of closeness to sine nature and the THD analysis.

V. EVALUATIONS OF MULTILEVEL INVERTER

The THD effectiveness of CHB inverters must be reduced. As a result, this article compares the results of THD performance through the FFT analysis for assessing the effectiveness of the 5 and 11 multi-levels cascaded H bridge inverters.

Validation of the basic model and THD analysis of the five level's MLI inviting CHB architecture is presented in the Figure 6 a) and Figure 6 b) respectively. The 5 level MLI uses 6 CHB cells and the respective THD performance is higher and is required to improve using higher level of inverter designs. Improved sine wave obtained by MLI in Figure 7 a).

The design of 11 level MLI model inverter proposed is shown in Figure 7 respectively and minimizes the THD by nearly 3 times. The THD level of 5.8 % .is achieved for the 11 level inverter as shown in Figure 7 b).



a) 5 level CHB inverter model validated

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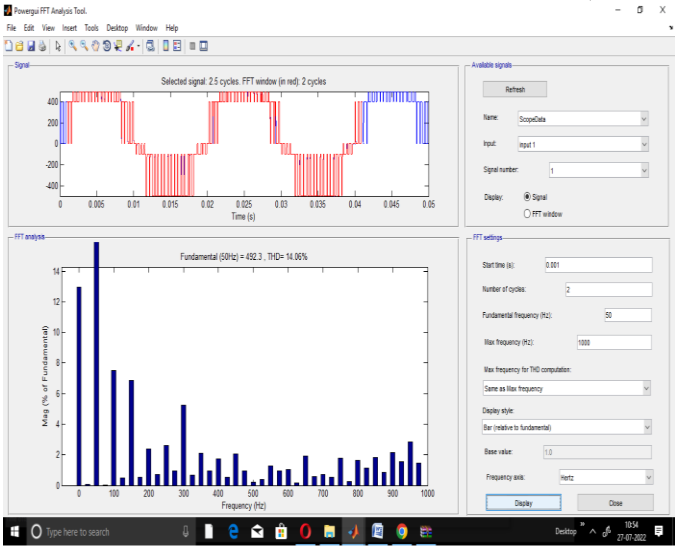
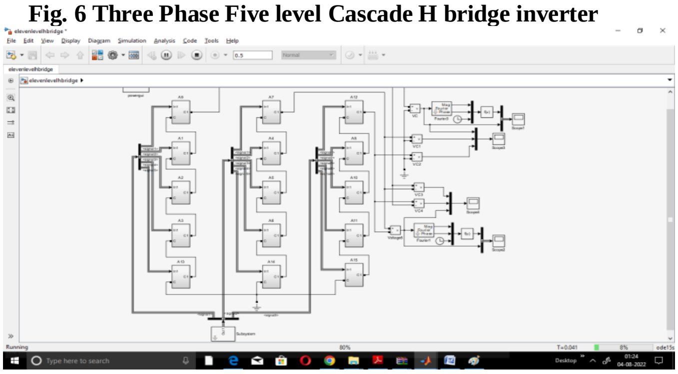
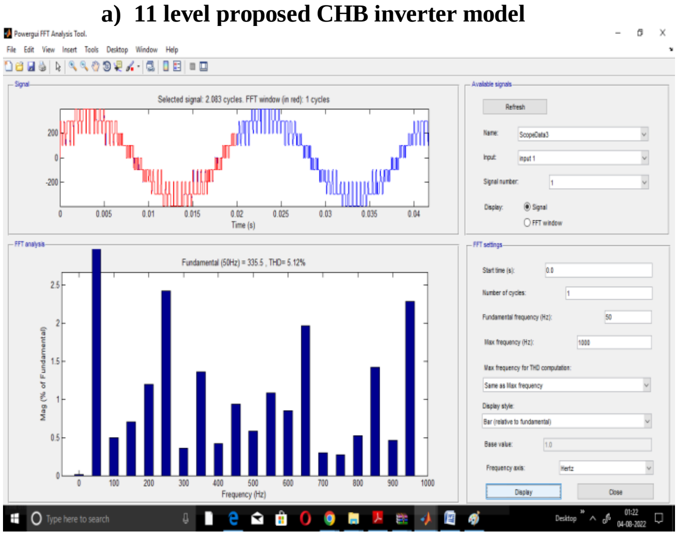


b) THD of the five level single phase Inverter.[5]
Fig. 6 Three Phase Five level Cascade H bridge inverter

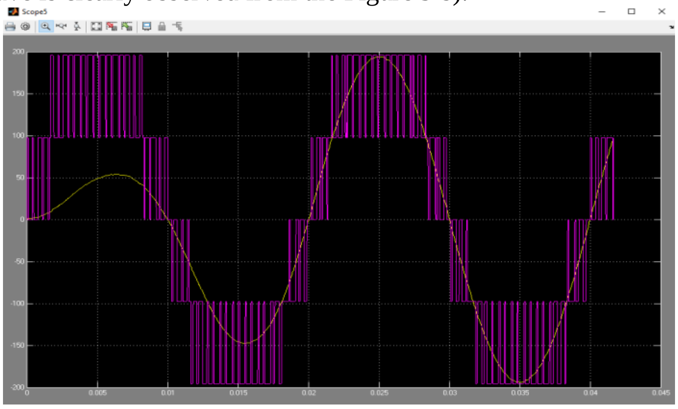


a) 11 level proposed CHB inverter model

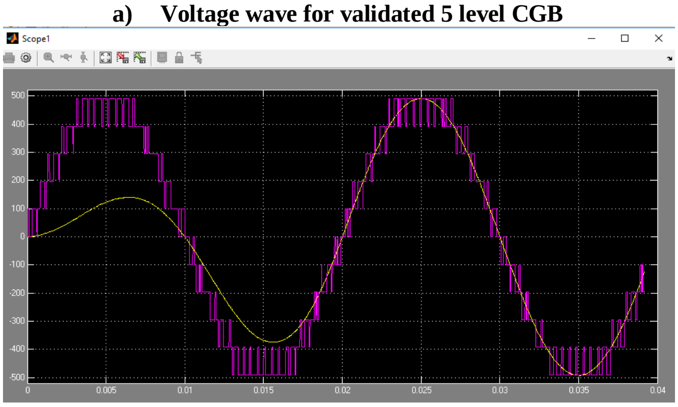


b) FFT analysis for THD of the 11 level 3 phase Inverter.
Fig. 7 Three Phase 11 level CNG inverter design and analysis

The section presents qualitative evaluation of the line waves offered by the MLI-CHB inverters. The waveform of the line voltage for the 5 and 11 level CHB invertres are shown in the Figure 8 a) and b) respectivly. The more precise qualitative comparison of the results for the proposed 11 level and 5 level MLI inverter architectures for phase voltage comparison are given in the Figure 9.The degree of the smoothness of 11 levels near sine wave is clearly observed from the Figure 9 b).



a) Voltage wave for validated 5 level CGB



b) Voltage wave for proposed 11 level CHB inverter
Fig. 8. Qualitative comparisons of the ML-CHB inverter waveforms

VI. PARAMETRIC COMPARISON

The degree of similarity between the output shape and its core FFT component is defined by the quantitative assessments of the Total Harmonic Distortion (THD) as referenced by R. B. Widyo et al [7], and is mathematically provided as;

$$V_{THD} = \frac{1}{V_{01}}\left(\sqrt{\sum_{n=2,3}^{\infty}(V_n)^2}\right) \qquad (1)$$

Where Vn is the harmonic amplitude and Vo1 is the line voltage

Table 2. Comparison of 3 phase effectiveness of the MLI THD for 5 and 11 level inverters

S. No	Single Phase 5 level CHB inverter	3 phase validate 5 level CHB Inverter	Three phase 11 level CHB Inverter	Proposed 3 phase 11 level CHB Inverter
1.	26.3 B Rajesha et al [3]	14.80	8.68 R. B. Widyo et al [7]	5,8 % Proposed

Quantitative evaluation of THD performance of MLI have been presenting in the Table 2. It is clear that proposed 11 levels 3 phase inverter out perform better to minimize the THD performance.

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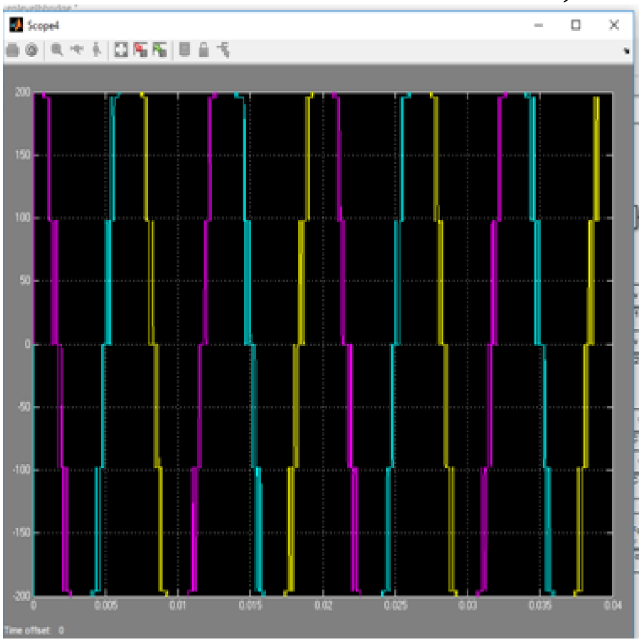
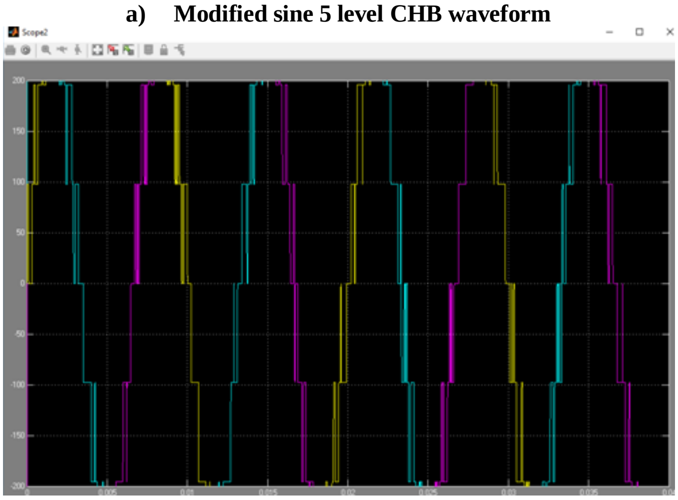


a) **Modified sine 5 level CHB waveform**



a) **Modified sine 11 level CHB waveform**

Fig. 9. Approximate sine wave comparison

VII. CONCLUSION

MLI designs models for HV applications were briefly examined in this work, along with their simulation. It is important to consider harmonic distortion while determining the effectiveness of inverters. The FFT analysis is used to assess efficiency. In the paper, simulation and modeling work for 11 and 5 levels three-phase inverters was evaluated.

Validation of the basic model and THD analysis of the five level's MLI inviting CHB architecture is presented. It is concluded that a quantitative assessment of MLI's THD performance has been provided. It is evident that the suggested 11-level 3-phase inverter outperforms existing ones in terms of reducing THD performancehe THD level of 5.8%.is achieved for the 11 level inverter. Overall paper contributed a good mprovement over existing MLI architectures.

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