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Design and Evaluation of 11 level CHB Inverter FFT Analysis of THD Performances

Deepak Kumar Rai, Manju Khare
Dept. of Electrical and Electronics Engineering, Lakshmi Narain College of Technology Bhopal

Abstract – The characteristics of the squared sinusoidal waveform for inverting applications can yet be improved, as according studies. The effectiveness of inverters' sinusoidal waveform outputs should be improved by the use of multilevel inverter (MLI). Consequently, 11 levels cascaded H Bridge (CHB) inverters have been designed, while their performance was assessed, in this research. Total harmonic distortion (THD) minimizing outcomes are compared between the effectiveness of the 11 levels as well as the 5 levels inviters. The depth of modulation of PWM is varied to trigger and regulate these inverters. This study examines the THD characteristics of inverters depending on CHB. A powerful and the FFT tool are used to build the design for a higher operating voltage 11 levels CHB inverter and assessment of the THD efficiency of 5 and 11 level inverters..

Key Words: **Cascade H Bridge, Multilevel Inverter, FFT Analysis, Total Harmonic Distortion (THD), SPWM.**

I. INTRODUCTION

Application areas call for the utilization of high-voltage inverters however those that focus upon that CHB are simpler and cheaper. The goal of this research is to contrast the abilities of several multi-level inverters (MLI) based just on Cascaded H Bridge (CHB). The THD cannot be avoided since switch voltage needs to increase**.** In order to preserve voltage, H Bridge inverters are widely utilized in solar panels. Traditionally, inverters are applied to change the voltage from DC electricity from Dc bus to AC mains lines, then they are utilized to regulate the power of grid lines. It is believed that the H-bridge represents the most effective method for producing MLIs. Particular high - voltage power grids applications necessitate the development of improved inverter architectures.

The need for higher voltage increases the possibility of transmissions distortions. Utilizing modern CHB-modular multilevel inverters (MLI) has now become crucial due to the rise in voltage requirements. To produce higher voltage ac utilizing the provided dc power through battery sources, a CHB inverter plays a significant role. Enhancing the level count might produce a decent approximation of a sinusoidal waveform. The availability of several MLI designs makes it challenging to determine the ideal level setting. The CHB inverter is designed and the maximum limit is set to 11 in this paper. The primary goal of this paper is to assess the THD effectiveness of CHB-based MLI designs.

The broad classifications of the frequently used MLI inverters are given in the Figure 1. The most frequently used MLI architectures are 5 Level, 9 levels and 11 levels based CHB inverters.

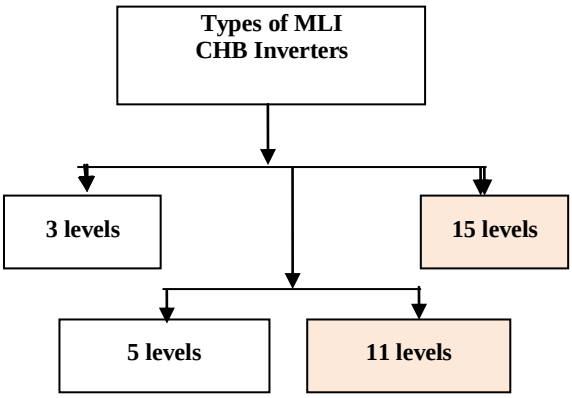

Fig.1. Broad Classification of MLI CHB inverters.

The main factor limiting the MLI levels is really the design's complexities. Consequently, the design and effectiveness assessment of the 11 and 5 levels modules CHB inverts are our main concerns in this study. In Figure 1, they are highlighted.

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II. CONTRIBUTION OF WORK

The prime contribution of paper is to evaluate the impact of the depth of modulation over designing of high voltage 11 levels CHB inverters. Paper also compares the effectiveness in terms of the THD performance for existing 5 levels CHB dependent MLI inverters designs. The required voltage has been raised from 100 volts to 400 volts. The FFT assessment of the 5 and 11 levels inverter topologies utilizing fundamental and 2nd order harmonics modeling is used to assess the THD effectiveness. The simulation model uses a single cell H bridge structure block with four GTO switch s, and the depth of the modulation parameters is changed by source parameter block as indicated in Figure 2.

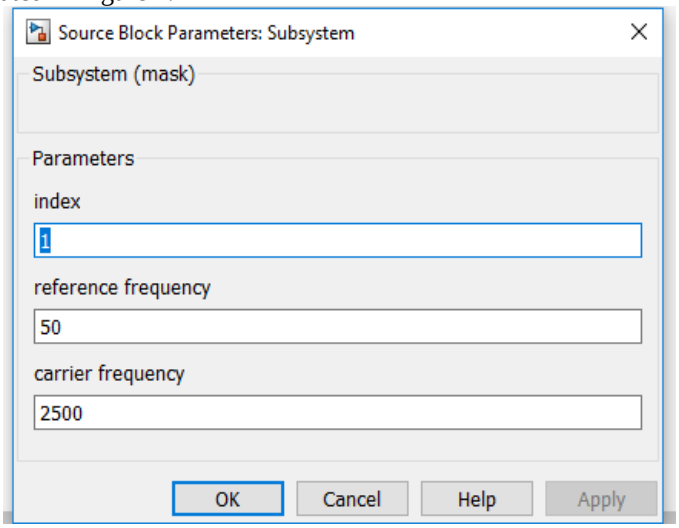
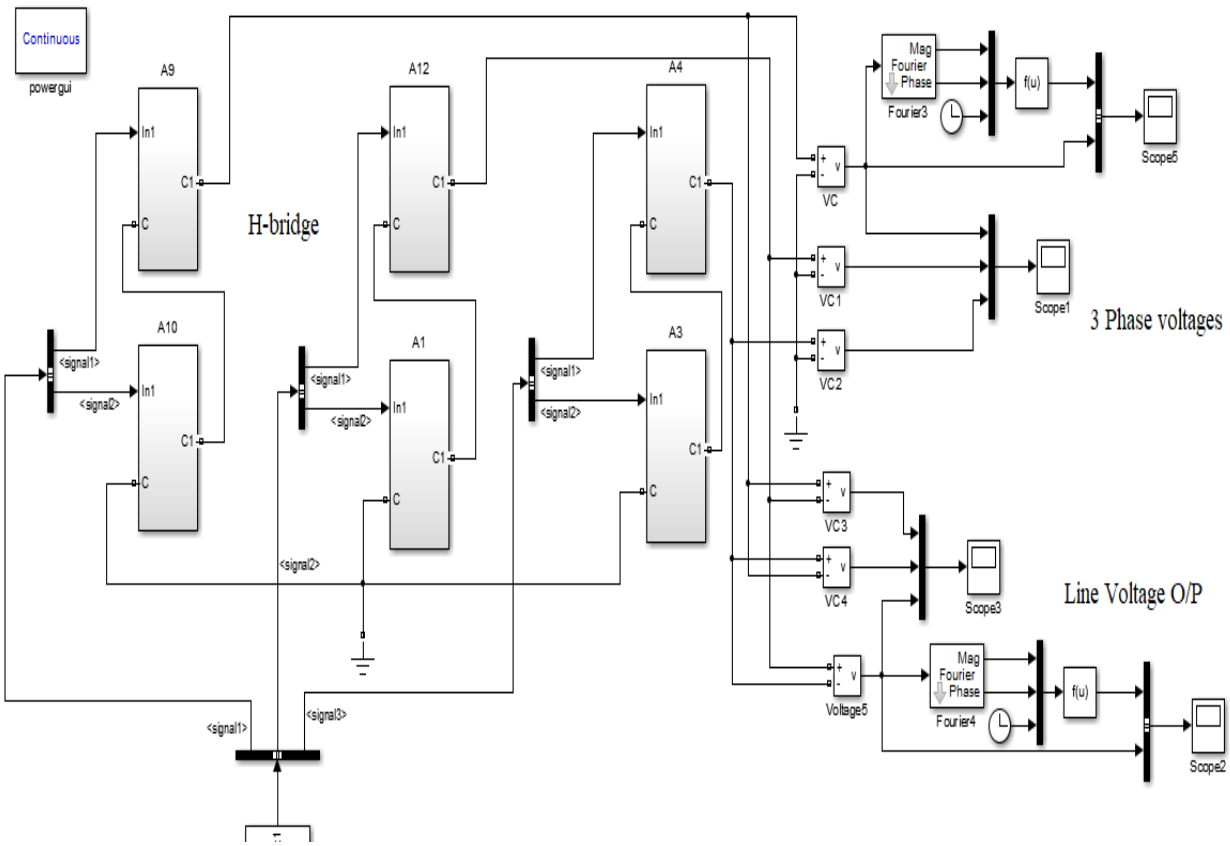


Fig. 2.Varying the depth of modulation of designing the PWM based CHB Inverters



(a) Simulik Proposed Model design for 5 Level CHB Inverter design

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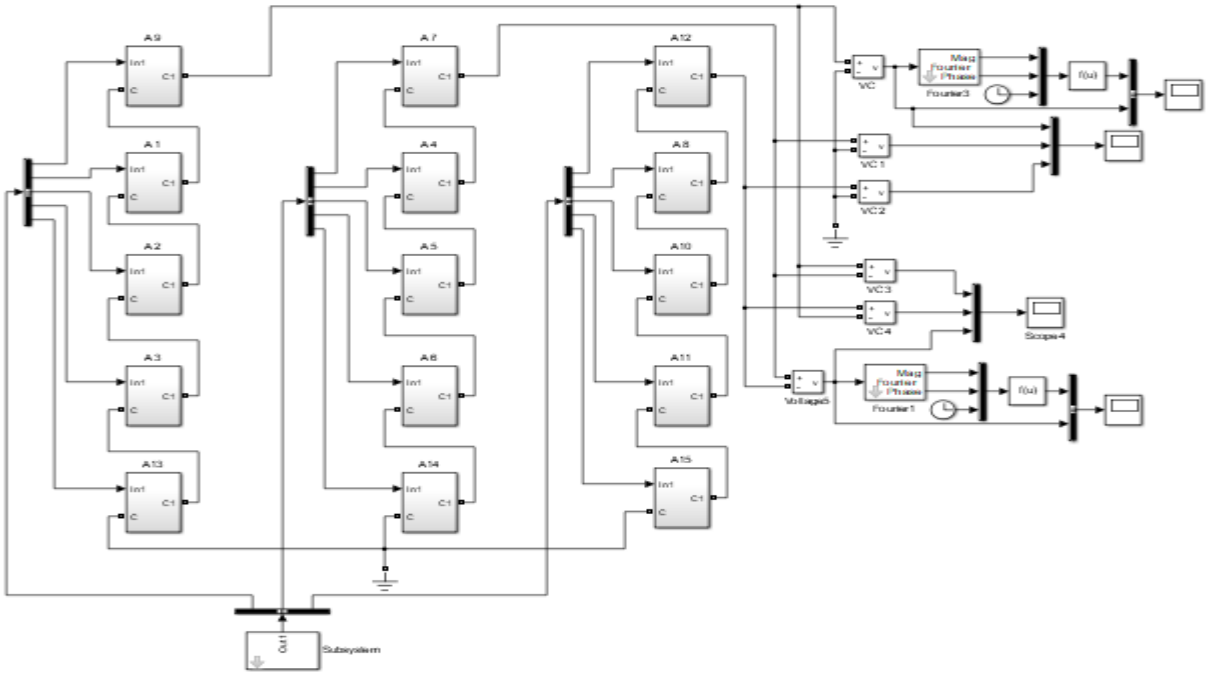

(b) Simulik Proposed Model design for 11 level inverter design

Fig.3. (a) Simulik Proposed Model design for 5 Level CHB Inverter design (b) Simulik Proposed Model design for 11 level inverter design

III. SINE WAVE PWM MODULATION

This paper proposed to control the switching speed and pattern of the high voltage CHB inverters using the variation depth of modulation of the sine waves. The sine wave can be modeled using the generalized equation as,

$$v_m(t)^i = A_i * \sin(2\pi * f * t) \qquad (1)$$

Where the $v_m(t)^i$ is the ith control sine waveform signal, the f is line frequency set t50 Hz. And t *is time.*

The depth of modulation is defined as the ratio of the the instant wave voltage to maximum wave voltage.

$$m = \frac{A_i}{V_{max}} \qquad (2)$$

But since the maximum wave voltage V_{max}ts set to unity 1. Therefore A_i represents the depth of modulation in this study.. and is expected to be changed fro 0.6 to 1. At a increment of 0.2 The comparison of the three sine waves with three depth of modulations are given in the Figure 3. The simulink models for 5 and 11 leverets are given in the Figure 4. It can be observed that CHB units are modeling.

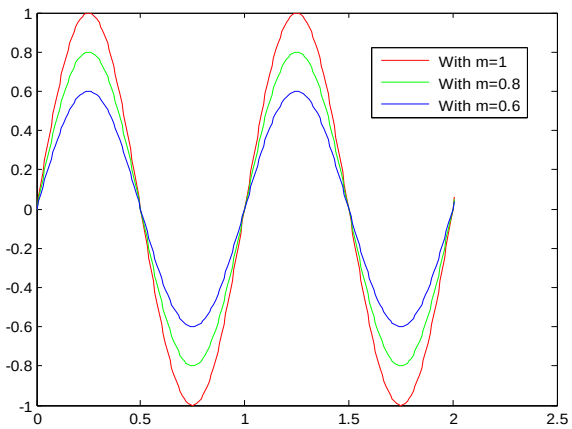

Fig.4. Example of the used control sine waves with different depth of modulaions

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IV. REVIEW OF MULTILEVEL INVERTERS

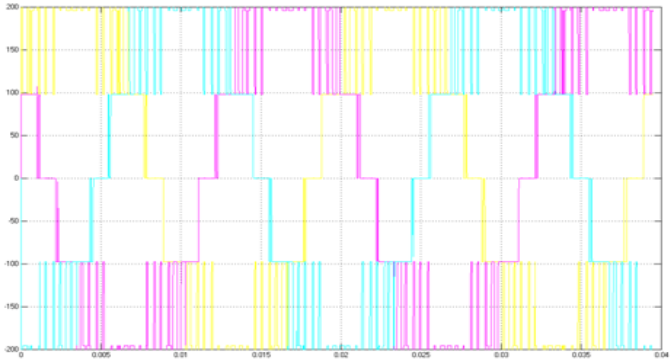
There are many inverter designs proposed in the literature for CHB based designs. The PWM based controlling of switching methodologies has been used for increasing performance. Further in order to boost the effectiveness of inverting operation multilevel CHB inverters are proposed, C. Srinivas wishes to reduce the amount of harmonics in the inverter output. This study takes into account the seventh level of the H Bridge. E. Lee et al [2] have proposed the phase shifting dependent PWM for controlling the CBH MLI inverters. The shift in phase is equivalent to provide delayed control waves. For a single component H-bridge inverter, Aboadla, et al [3].'s analysis of the SPWM technique's effectiveness is reported. MATLAB - Simulink is used to model the SPWM scheme. In this work they compared bipolar and unipolar PWM approaches are compared because they both have the ability to more than double the output voltage's switching frequency.

According to Akhilesh et al [4], choosing the right modulation depth will aid in producing the desired voltage. The device's propagation time will also become shorter if the modulation depth is lower, which will likewise result in shorter on-time pulse durations. As a result, the resultant voltage produced by the inverter will be lower. S. R. Savanur et al [5] have presented good matlab simulation for state space based design. The multi carrier based modulation is proposed by the A. Razi et al [7]. The design based on modified low modulation index is proposed by Leon M. et al [10] for the multi level inverter design. They stated that modifying the index can help to improve the performance. Manyuan et al [11] have designed the version of multi carrier based CHB inverting structure.

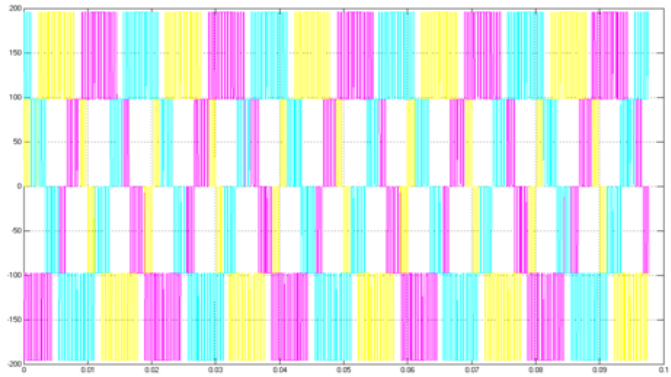
P S V Kishore et al [15] presented comparison of Five Level CHB Inverter using the multi carrier based PWM design.Ranjan A K et al [17] designed level-shift PWM approach is used for the analysis and modeling of CHB multi levels inverters. .

V. OUTPUT WAVEFORMS OF 3 PHASE MLI INVERTERS

This section presented the waveform outputs of our proposed 5 level inverters for the maximum modulation depth. The Figure it can be observed that the phase voltage waves are closely correlated to each other as in Figure 5 b). But from the Figure 5 a) it can be observed that the peak amplitudes are not so smooth with 5 level inverter thus for better close approximations it is required to increase the inverting levels design. The paper proposed 11 level CHB inverter design for minimizing the THD performance.



a) Line Voltage for 5 level CHB inverters



b) Phase voltage wave for 5 level CHB

Fig.5. Outcomes of voltage waves for five level CHB inverter with m =1

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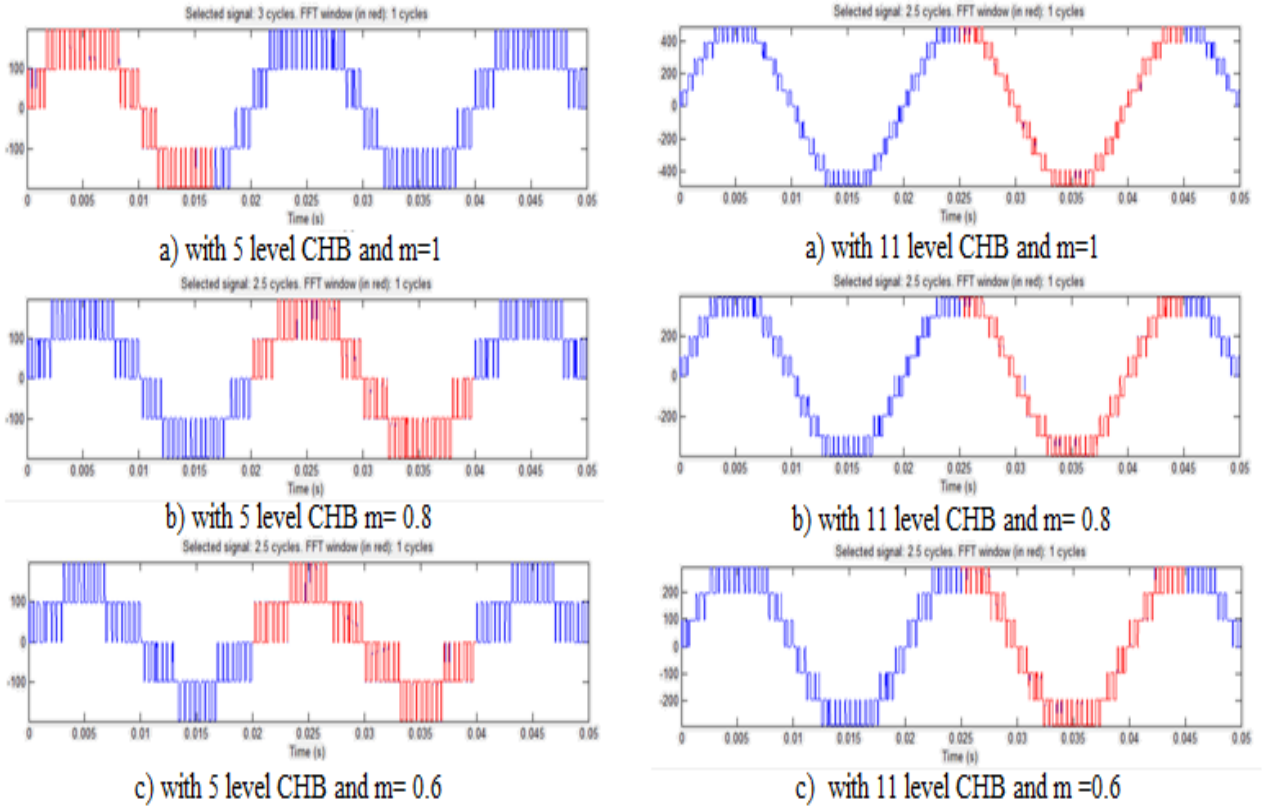
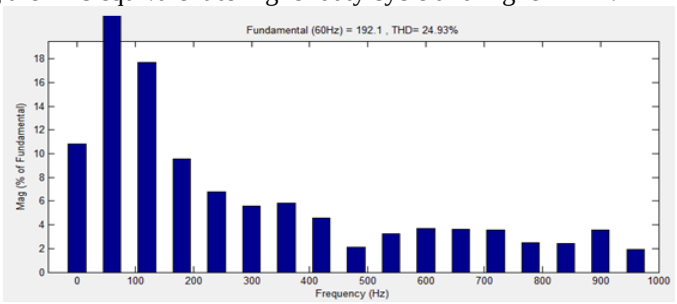


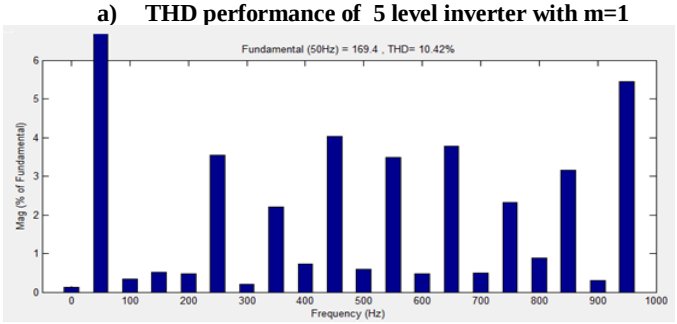
Fig.6. Waveform comparisons for the CHB 5 and 11 level inverters with different depth of modulation

VI. EVALUATION OF MULTILEVEL INVERTER

The section presents the proposed outcomes of this research. For better sine approximations the MLI inverters with 11 levels are designed. The performance evaluation of the THD values achieved by 5 levels and 11 level CHB inverters are compared. The waveform of the line voltage for the 5 level and 11 level inverters are presented in the Figure 6 for the three different depth of modulation. The depth m is varied from 0.6 to 1.0. it is clearly observed that best possible wave approximation is achieved with m=1 and 11 level inverter. Also it is observed that decreasing the m is equivalent to higher duty cycle and higher THD.



a) THD performance of 5 level inverter with m=1



b) THD performance of 5 level inverter with m=0.8

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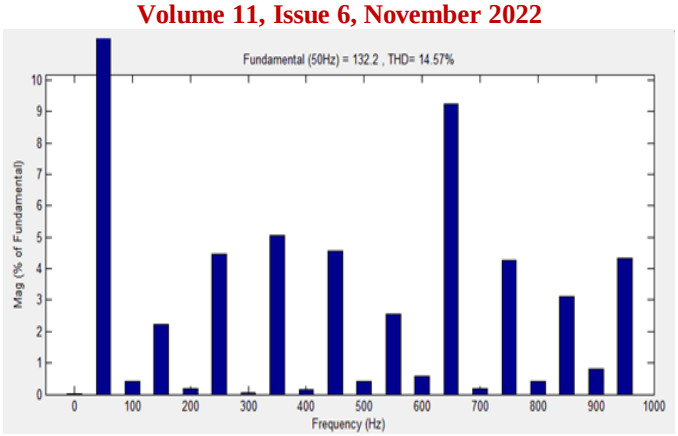
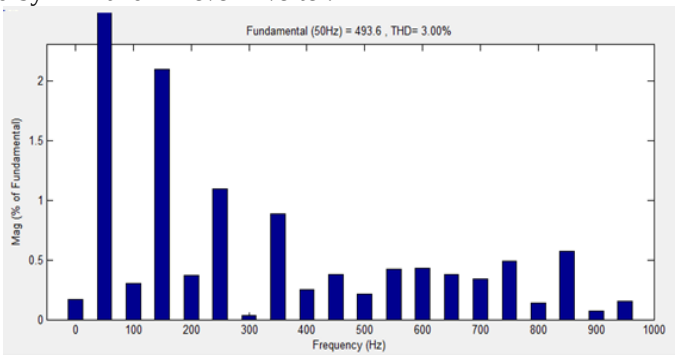


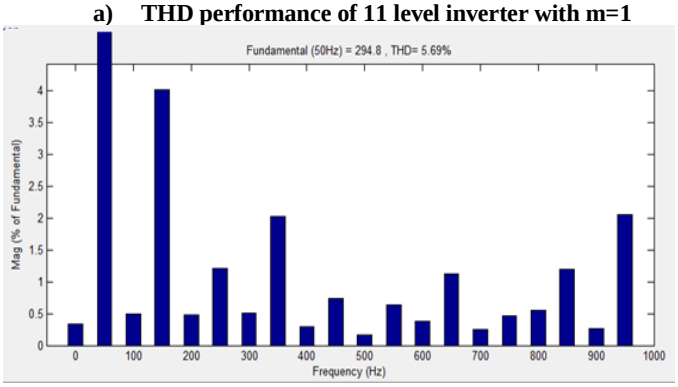
c) THD performance of 5 level inverter with m=0.6

Fig. 7. THD analyses of 400 V 5 levels CHB inverter with different depth modulations

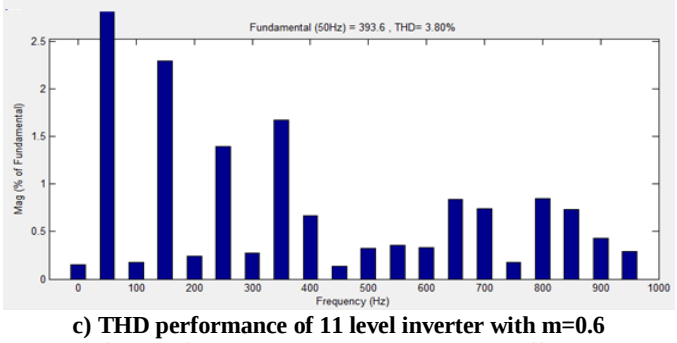
The results of the THD analysis carried out for different values of m for 5 and 11 level inverters are sequentially presented in the Figure 7 and Figure 8 respectively. Figure 7 is respectively for 5 level inverters and offered higher THD values. While for Figure 8 it is clear that THD is significantly less for 11 level inverter design. the minimum THD is offered by m=1 and 11 level inverter.



a) THD performance of 11 level inverter with m=1



b) THD performance of 11 level inverter with m=0.8



c) THD performance of 11 level inverter with m=0.6

Fig.8.THD analyses of 400 V for 11 levels CHB inverter with different depth modulations

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A. Parametric Calculation and Evaluation

Evaluation of the THD values of various MLI configurations are compared with proposed MLI configurations as shown in the Table 1. Total Harmonic Distortion (THD), the modulation depths are varied and THD is defined by Vadizadeh, et al [11]. The mathematical equation THD to be minimum for its underlying FFT components is given by;

Table 1. Comparison of THD with varying depth of modulation for 5 levels and 11 Level inverters

S. No	5 level CHB inverter with m=0.6	5 level CHB inverter with m=0.8	5 level CHB inverter with m=1	11 level CHB inverter with m=0.6	11 level CHB inverter with m=0.8	11 level CHB inverter with m=1
1	14.57	10.42	26.3	5.68	3.80	3.00

$$THD = \frac{1}{V_{o1}}\left(\sqrt{\sum_{n=2,3}^{\infty}(V_n)^2}\right) \quad (3)$$

Where Vn is the harmonics magnitude and Vo1 is the line voltage

Table 1 examines THD for 5 levels as well as 11 Level inverters using varied depths of modulation. The m=1 and 11 level inverters exhibit the lowest THD performance, as can be seen. The Table makes it very evident that raising m may result in improved performance. But from a hardware design perspective, it is quite dangerous to put the m to its maximum value. Since a compromise is necessary, I suggested setting the m=0.8 ad inverters level to 11 with an ideal THD of 3.80 percent.

VII. CONCLUSION

Performance appraisal of the MLI inverter designs is presented in this research. The aim is to assess the THD effectiveness of MLI inverters depending on CHB. The efficiency of 5 level as well as 11 level CHB inverters regarding THD reduction in high voltage inverter architecture is compared in the paper. Based on the FFT analysis, the THD is assessed. The major contribution of the paper is to evaluate the performance under the varying depth of modulation. The minimum harmonic distortion (THD) is achieved from the maximizing the depth of modulation and increasing level of designs. The performance of the 11 level inverter is significantly better than the 5 level inverter in terms of the THD analysis. It is found that five levels CHB inverter offers 24. % THD performance for m=0.6 and for m=1 with 50 Hz frequency the THD is reduced to 10% range. But the proposed 11 level CHB inverter with m-1 achieves 3. % THD. But for hardware compatibility it is finally proposed to keep m=0.8 and achieved THD of 3.8 % with 11 level inverter design. Utilizing the filters might help performance even further in future.

REFERENCES

[1] C. Srinivas, "Reduction of Odd Harmonics using Multilevel Inverter with Multi Carrier PWM Techniques," 2018 International Conference on Current Trends towards Converging Technologies (ICCTCT), 2018, pp. 1-3.

[2] E. Lee, S. Kim and K. Lee, "Modified Phase-Shifted PWM Scheme for Reliability Improvement in Cascaded H-Bridge Multilevel Inverters," in IEEE Access, vol. 8, pp. 78130-78139, 2020.

[3] Aboadla, Ezzidin & Khan, Sheroz & Habaebi, Mohamed & Gunawan, Teddy & Hamida, Belal & Yaacob, Mashkuri. (2016). "Effect of modulation index of pulse width modulation inverter on Total Harmonic Distortion for Sinusoidal", International Conference on Intelligent Systems Engineering 192-196.

[4] Akhilesh Sharma, Anandh N., Sarsing Gao, "Modulation index effect on inverter based induction motor drive", International Journal of Power Electronics and Drive System (IJPEDS) Vol. 11, No. 4, December 2020, pp. 1785-1798.

[5] S. R. Savanur and K. Teli, "Simulation and state space representation of single phase five level h-bridge inverter using MATLAB," 2018 International Conference on Recent Innovations in Electrical, Electronics & Communication Engineering (ICRIEECE), Bhubaneswar, India, pp. 1832-1837, 2018.

[6] Wang F, Yang L E, Mao W, Shineng Y and Zhang X 2016 Power Balance Control Scheme of Cascaded H-Bridge Multilevel Inverter for Grid-Connection Photovoltaic Systems 2016 IEEE 8th International Power Electronics and Motion Control Conference (IPEMC-ECCE Asia).

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
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[7] A. Razi. S. A Ab. Shukor, and P. K. Shen , "Improved Harmonic Performance of Seven-level CHB Inverter Using Multicarrier Modulation and Varying Modulation Index", Vol. 10 No. 1-7.

[8] B. Rajesh and Manjesh, "Comparison of harmonics and THD suppression with three and 5 level multilevel inverter-cascaded H-bridge," 2016 International Conference on Circuit, Power and Computing Technologies (ICCPCT), Nagercoil, India, pp. 1-6, 2016.

[9] A. Singh and R. N. Mahanty, "Simulation of simplified SVM technique for three phase five-level cascaded H-bridge inverter," 2017 International Conference on Information, Communication, Instrumentation and Control (ICICIC), Indore, India, pp. 1-6, 2017.

[10] Leon M. Tolbert, Fang Z. Peng, Thomas G. Habetler, "Multilevel PWM Methods at Low Modulation Indices", APEC'99, Dallas, Texas, March 14-18, pp. 1032-1039.

[11] Manyuan Ye , Le Chen, Lixuan Kang, Song Li, Junfei Zhang, And Han Wu, "Hybrid Multi-Carrier PWM Technique Based on Carrier Reconstruction for Cascaded H-bridge Inverter", IEEE ACCESS Vol. 7, 2019.

[12] G. Singh and V. K. Garg, "THD analysis of cascaded H-bridge multi-level inverter," 2017 4th International Conference on Signal Processing, Computing and Control (ISPCC), Solan, India, pp. 229-234, 2017.

[13] Saroj Kumar Sahoo, Tanmoy Bhattacharya, "Phase Shifted Carrier Based Synchronized Sinusoidal PWM Techniques for Cascaded H-Bridge Multi Level Inverter", IEEE Transactions on Power Electronics, : DOI 10.1109/TPEL.2017.2669084.

[14] P S V Kishore, P Suresh Kumar, K Ramesh, "Comparison of Multi Carrier PWM Techniques applied to Five Level CHB Inverter", International Journal of Pure and Applied Mathematics Volume 114 No. 7 2017, 77-87.

[15] S, Menaka "Application Of Evolutionary Algorithms For Harmonic Profile Optimization In Symmetric Multilevel Inverter Used In Medical Electronic Equipments", Current Signal Transduction Therapy 13(1), 2018.

[16] Hadeel S Maaroof, Harith Al-Badrani and Ahmad T Younis, "Design and simulation of cascaded H-bridge 5-level inverter for grid connection system based on multi-carrier PWM technique", 1st International Ninevah Conference on Engineering and Technology (INCET 2021).

[17] Ranjan A K, Bhaskar D V and Parida N 2015 Analysis and simulation of cascaded H-bridge multi level inverter using level-shift PWM technique IEEE International Conference on Circuit, Power and Computing Technologies, ICCPCT 2015.