Multilevel Inverter Systems: Design, Control, and Utilization of Three-Level Cascaded H-Bridge Technology

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Abstract: This research paper offers a thorough analysis of the 3-level CHB-MLI topology used in applications with high power. The paper discusses a number of CHB-MLI-related topics, such as voltage level, total harmonic distortion (THD), H-bridge structure, loss estimation, and driver circuit. The impact of various modulation methods on the voltage level and THD as used in the CHB-MLI is compared in this paper. The study emphasizes the value of the CHB-MLI in high power applications as well as its potential for further study and development.

Keywords: CHB-MLI, ac/dc power, Voltage level, Thd, H bridge, loss calculation, driver circuit.

1. INTRODUCTION
Most recently, the demand for high-quality electrical power has increased significantly, and this has led to the development of more advanced power electronics solutions. The use of multilevel inverters, which are becoming more and more popular because they can generate an AC output voltage that is smoother and more effective than conventional single-level inverters, is one such solution. Among the various multilevel inverter topologies, due to its capacity to lower the total harmonic distortion of a voltage level, the 3L-CHB MLI has attracted a lot of interest. The 3L-CHB MLI is well-suited for numerous applications, including renewable energy systems and industrial motor drives. In renewable energy systems, the 3L-CHB MLI can improve the performance of the system by reducing the THD of the output voltage, making it suitable for adding renewable energies to the grid. In industrial motor drives, the 3L-CHB MLI can improve the efficiency and performance of the system by providing a smoother and more efficient AC output voltage.

The fundamental component of the 3L-CHB MLI is the H-bridge cell, which contains four switching devices arranged in a bridge configuration. The H-bridge cell can produce multiple levels of output voltage, which can then be combined in a cascaded configuration to create more levels of output voltage. The cascaded configuration allows for the reduction of the THD of an output voltage, enhancing the system's performance. Another advantage of the 3L-CHB MLI is its ability to handle high voltage levels, making it perfect for medium to high-voltage applications.

To construct a 3L-CHB MLI, three DC voltage sources of the same voltage level are required. An H-bridge circuit is made up of four switching devices, such as transistors or thyristors, arranged in an ‘H’ shape. Cascaded connections are made from the input of one H-bridge to the output of the following H-bridge. The switching of the transistors in every H-bridge circuit is controlled to produce the desired output voltage waveform, which can be done using a control circuit or a microcontroller. The load is then connected to the output of the third H-bridge, which could be an AC motor or another type of load.

Designing a 3L-CHB MLI requires careful consideration of various design criteria to ensure optimal performance, reliability, and safety of the system. This research paper aims to investigate the 3L-CHB MLI in detail, covering aspects such as AC/DC power conversion, voltage level, THD, H-bridge structure, loss calculation, and driver circuit. The paper will compare different modulation techniques used in the 3L-CHB MLI and their impact on the voltage level and THD. The research will highlight the importance of the 3L-CHB MLI in high power applications and its potential for future research and development.

A. Problem Definition
The problem addressed in this research paper is the need for high-quality electrical power and the limitations of traditional single-level inverters in achieving this goal. The paper focuses on the use of 3L-CHB MLI as a solution to reduce THD and improve the efficiency of power systems in various applications. The paper highlights the design
challenges and considerations in implementing a 3L-CHB MLI system.

B. Need
The need for a 3-level CHB MLI arises from the greater demand for high-quality electrical power in various applications. This inverter topology offers a higher output voltage level with lower harmonic distortion, making it suitable for high-power and medium to high-voltage applications requiring high voltage, like industrial motor drives and renewable energy sources and industrial motor drives. The H-bridge cell is the fundamental component of the inverter, and the cascaded configuration allows for the output voltage waveform's reduced THD.

II. LITERATURE SURVEY
This study compares SPWM and SVPWM techniques in a three-phase Cascaded H-bridge Multilevel Inverter (CHMLI) with three H-bridge inverters in series. SVPWM is shown to have advantages in terms of Total Harmonic Distortion (THD) and switching losses. The CHMLI offers simplicity in circuit design and the ability to produce 3-level voltages.

The conversion of dc power to ac is achieved using a Cascaded H-bridge Multilevel Inverter with high output voltage, reliability, power levels, and simplicity of control. Multilevel voltage source inverters are found to be more commonly used due to the high fault current observed in multilevel current source inverters.

This paper presents a Cascaded H-bridge Multilevel Inverter with Sinusoidal Pulse Width Modulation technique and compares the performance of 3-level, 5-level, and 7-level CHMLIs in terms of number of switches, THD, waveform pattern, harmonic spectrum, output voltage, voltage stress across the switch, and input DC voltage. Cascaded H-bridge Multilevel Inverter synthesizes high to medium voltage as its output using low voltage standard component configuration. This study investigates methods for lowering the amount of total harmonic distortion that sinusoidal pulse width modulation introduces into the output.

III. PROPOSED METHODOLOGY
Selection of suitable power devices and capacitors for H-bridge configuration.
Design and simulation of the H-bridge inverters using software such as MATLAB Simulink to determine their individual outputs.
selecting a suitable modulation method, including (SPWM) or (SVPWM) for the inverter and cascading the H-bridge inverters in series to create the 3-level cascaded H-bridge multilevel inverter.
Simulation of the inverter using software such as MATLAB Simulink to determine the harmonic distortion, voltage levels, and efficiency of the inverter.
Implementation of the inverter on hardware and testing to validate the simulation results.
Optimization of the inverter design to improve efficiency and reduce harmonic distortion

IV. SYSTEM ARCHITECTURE
The single-phase 3L CHB MLI consists of a DC source, four IGBT switches, load.

Fig7: 3L CHB MLI
Operation:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Switches On</th>
<th>Output Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1 and S2</td>
<td>No voltage</td>
</tr>
<tr>
<td>2</td>
<td>S1 and S4</td>
<td>+Vdc</td>
</tr>
<tr>
<td>3</td>
<td>S2 and S3</td>
<td>-Vdc</td>
</tr>
<tr>
<td>4</td>
<td>S3 and S4</td>
<td>No voltage</td>
</tr>
</tbody>
</table>

Table 1: Modes of operation

<table>
<thead>
<tr>
<th>Mode</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>S3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>S4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2: Modes of operation

Designing a 3L CHB MLI system requires consideration of various design criteria. These include the voltage level, power rating, pulse frequency, control strategy, harmonic distortion, dimensions and weight, reliability, cost, and safety. These factors can impact the system's performance, efficiency, power quality, ease of installation and maintenance, lifespan, feasibility, and safety. It is crucial to take into account the specific system details when evaluating its performance.

MATLAB Simulation Results:

Simulating a 3L-CHB MLI using MATLAB can be a useful way to analyze and understand the behavior of the inverter under different operating conditions. The simulation could be used to evaluate the inverter's performance, such as its output voltage waveform, harmonic distortion, and efficiency.

Here are the general steps to simulate a 3L-CHB MLI using MATLAB:

Model the circuit: Develop a mathematical model of the 3L-CHB MLI circuit using MATLAB. This includes modeling the switching devices (such as transistors or IGBTs), diodes, capacitors, inductors, and other passive components.

Implement the control algorithm: Implement the control algorithm for regulating the switching of the devices in the circuit. This can be a Pulse Width Modulation (PWM) algorithm or any other suitable algorithm.

Simulate the circuit: Use the model and control algorithm to simulate the circuit in MATLAB. This involves specifying the input voltage, switching sequence, and other operating conditions.

Analyze the results: Analyze the output of the simulation, such as the output voltage waveform, harmonic distortion, and efficiency.

Iterate the design: Iterate the design by making changes to the circuit or control algorithm and re-simulating the circuit to evaluate the impact of the changes.

It's crucial to keep in mind that the simulation will be influenced by the specifics of the system, including the level of voltage, power rating, and control scheme. Additionally, a good understanding of the cascaded H-Bridge topology, control algorithm, and MATLAB programming is crucial for successful simulation.[2]
The presented circuit consists of a driver circuit and a rectifier circuit. The driver circuit is responsible for providing the gate pulses required for the MOSFET switches. The rectifier circuit converts the AC input to DC and supplies it to the driver circuit. The objective of the circuit is to generate a three-level staircase output waveform with the lowest possible harmonic distortion.

IV. RESULT
The presented circuit consists of a driver circuit and a rectifier circuit. The driver circuit is responsible for providing the gate pulses required for the MOSFET switches. The rectifier circuit converts the AC input to DC and supplies it to the driver circuit. The objective of the circuit is to generate a three-level staircase output waveform with the lowest possible harmonic distortion.
V. CONCLUSION

The 3L CHB MLI is a high-quality inverter that generates low harmonic distortion output voltage using cascaded H-bridge inverters. It is appropriate for high-power uses like industrial drives and solar power systems. The low-rating components used in the design make it economically feasible. The project provides a practical understanding of power electronics concepts and their application in real-world circuits using MATLAB Simulink.

VII. FUTURE SCOPE

The future of 3-level multilevel inverters is promising, with potential advancements in advanced control strategies, increased power density, fault diagnosis and fault-tolerant operation, integration of emerging technologies, and application-specific optimization. Continued research and development in these areas can lead to further improvements in the performance and applicability of 3-level multilevel inverters in various applications.

REFERENCES: