MULTILEVEL INVERTER WITH REDUCED SWITCHES FOR ELECTRICAL VEHICLE

Mr. Sudharsan M[1], Mr. Surya V[2], Mr. Gnanavel S[3], Mr. Oorappan GM[4]

[1] UG Scholar, Electrical and Electronics Engineering & Bannari Amman Institute of Technology
[2] UG Scholar, Electrical and Electronics Engineering & Bannari Amman Institute of Technology
[3] UG Scholar, Electrical and Electronics Engineering & Bannari Amman Institute of Technology
[4]Assistant Professor, Mechatronics Engineering & Bannari Amman Institute of Technology

---

Abstract

This project focuses on the development of an innovative multilevel inverter designed specifically for electric vehicles (EVs), aiming to reduce complexity and enhance efficiency by minimizing the number of switches in the inverter topology. The conventional multilevel inverter configurations often involve a high count of switches, leading to increased costs, intricate designs, and elevated power losses. In contrast, our approach seeks to optimize the inverter's performance by employing advanced control strategies and modulation techniques while significantly reducing the number of switches. This reduction not only simplifies the design but also lowers production costs and maintenance efforts. Moreover, the project emphasizes the compact integration of the inverter into the EV powertrain, addressing the size and weight constraints of electric vehicles. Through thorough simulations and practical experiments, the proposed multilevel inverter's performance will be evaluated in terms of efficiency, power quality, and reliability. The anticipated outcomes aim to contribute to the advancement of power electronics for sustainable transportation, providing a more efficient, cost-effective, and compact solution tailored to the unique requirements of electric mobility. This research has the potential to significantly impact the field, fostering further innovations in power electronics for clean and efficient transportation solutions

.***Key Words***: Electric vehicle, Inverters, Switches, Efficiency.

1. INTRODUCTION

Electrification of transport has become a global priority as part of our efforts to reduce greenhouse gas emissions and combat climate change. In this research, electric vehicles (EVs) have shown promise as a solution, offering cleaner and more sustainable mobility options. One of the critical aspects of electric vehicle performance and efficiency is the power electronics, specifically the inverter that converts DC power stored in the battery to AC power that powers the vehicle'selectric motor.Traditional inverters have prevailed in electric vehicles, but there is a growing demand for more advanced and efficient solutions.

Multilevel inverters have attracted a lot of attention in recent years as they can improve the performance of electric vehicles in terms of power quality, efficiency and reliability.These advanced inverters offer superior output waveform quality and lower switching losses than traditional bi-level inverters.One of the biggest challenges in the design of multilevel inverters for electric vehicles is the reduction of semiconductor switches. Reducing the number of circuit breakers in the UPS not only simplifies the control strategy, but also lowers costs, reduces losses and increases overall system reliability. This reduction in the number of switches can be achieved through innovative modulation topologies and techniques, making multilevel inverters an attractive choice for modern electric vehicles.As we explore multi-level inverters with reduced switches for electric vehicles, we will delve into the principles of these advanced power electronic systems.We will discuss the different topologies, control strategies and benefits of these inverters in the context of EV applications. In addition, we will examine the potential impact of these inverters on the future of electric mobility, including improved energy efficiency, longer battery life and greater efficiency.As the automotive industry continues to experience an electrification revolution, the development and implementation of multi-level inverters with fewer switches is a critical step toward realizing a more durable and efficient transportation ecosystem. The aim of this study is to shed light on the exciting prospects and challenges of this emerging industry and pave the way for cleaner and greener electric vehicles in the years to come.

Also we delve into the practical aspects of implementing multilevel inverters with reduced switches in electric vehicles. This includes discussions on manufacturing techniques, component reliability, thermal management, and the integration of these advanced inverters into EV platforms seamlessly. We will also consider the economic and environmental aspects, evaluating the cost-effectiveness and environmental sustainability of these innovations, thereby providing insights into the broader adoption of such technologies in the automotive industry. By addressing these critical factors, this research aims to bridge the gap between theoretical advancements and real-world applications, driving us closer to the vision of electric vehicles as the future of sustainable and efficient transportation.

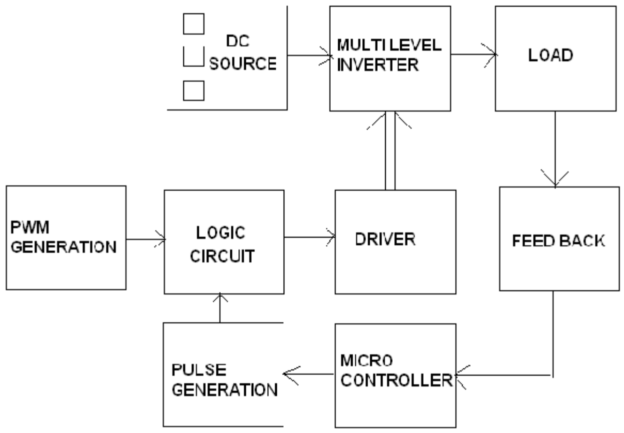

Figure 1.1 Block diagram of Inverter for Electrical vehicle

2. BACKGROUND OF THE WORK

The inverter is one of the key elements of the electronic drive system of an electric vehicle. The inverter is responsible for converting the direct current (DC) supplied by the vehicle's battery into alternating current (AC), which drives the electric motor. The efficiency and effectiveness of the DC to AC conversion process has a direct impact on the overall performance and range of an electric vehicle.
Conventional two-level inverters are widely used in electric vehicles for DC-AC conversion. Even if they have achieved their purpose, they have some limitations that make it difficult to achieve the highest levels of energy efficiency and quality in electric vehicles. These limitations include higher switching losses, increased electromagnetic interference (EMI), and limited voltage levels. To overcome these limitations and further improve the capabilities of power electronics in electric vehicles, multilevel inverters are gaining increasing interest. Multi-level inverters represent an attractive alternative to traditional two-level inverters as they offer a range of benefits that are well-tailored to the specific needs of electric vehicles.

The transportation sector is undergoing a significant transformation with the increasing adoption of electric vehicles (EVs). This shift is driven by various factors, including the need to reduce greenhouse gas emissions, combat climate change, and improve air quality in urban areas. As the EV market continues to expand, there is a growing emphasis on enhancing the efficiency, performance, and affordability of these vehicles. One critical component of EV powertrains is the inverter, responsible for converting DC battery power into AC power to drive the electric motor.
Traditionally, EV inverters have employed two-level inverters, which switch between two voltage levels (typically +Vdc and -Vdc). While effective, these inverters have limitations, including higher harmonic distortion, increased switching losses, and reduced efficiency. To address these challenges and further optimize EV powertrains, researchers and engineers have turned to multilevel inverters with reduced switches.

3. METHODOLOGY

In the project "Multilevel Inverter with Reduced Switches for Electric Vehicles" implemented in MATLAB, the system design and configuration represent the backbone of our endeavor to revolutionize power electronics for electric vehicles (EVs). Our primary goal is to enhance the efficiency, reliability, and cost-effectiveness of the inverter system, which plays a pivotal role in converting DC power from the EV's battery into the AC power needed for propulsion.

The system design begins with the careful selection of the inverter topology. We explore innovative approaches to minimize the number of switches while maintaining or even improving performance. This includes evaluating various multilevel inverter configurations such as cascaded H-bridges or hybrid topologies. Our unique contribution lies in devising novel circuit designs and control algorithms that allow the inverter to generate multiple voltage levels with fewer switches, reducing the overall size and weight of the system.

Furthermore, we focus on efficient heat management to ensure the inverter's stable operation. This involves the selection of appropriate cooling mechanisms, be it air or liquid cooling, as well as the design of effective thermal dissipation strategies to prevent overheating.Simulation and modeling in MATLAB are indispensable tools in our project, allowing us to accurately predict system performance, analyze different operating scenarios, and fine-tune control strategies. This iterative process ensures that our multilevel inverter design meets the stringent requirements of electric vehicles.

In essence, our system design and configuration efforts in the "Multilevel Inverter with Reduced Switches for Electric Vehicles" project are geared towards advancing power electronics technology for EVs. By optimizing the inverter's topology, control algorithms, component selection, and safety measures, we aim to create a more efficient, compact, and cost-effective solution, contributing to the electrification of transportation and a more sustainable future.

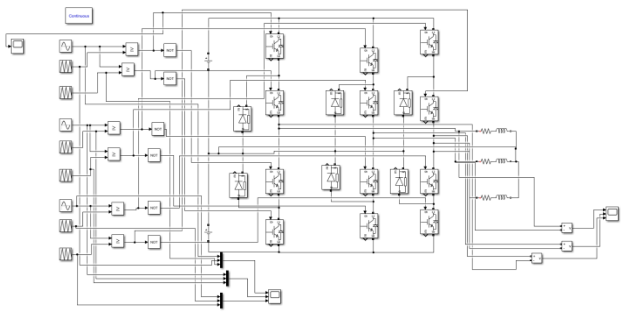

Figure 3.1 circuit Diagram of Three phase multilevel inverter for electrical vehicles

3.1 SWITCHING STRATEGY

This strategy determines how the available power semiconductor switches are controlled to produce the desired output voltage waveform with reduced switching losses and minimal harmonic distortion. Given the goal of reducing the number of switches, a carefully designed switching strategy becomes even more critical.

One common approach for multilevel inverters is the use of pulse-width modulation (PWM) techniques. PWM controls the duration and timing of the switching events to generate a staircase-like output voltage waveform with multiple voltage levels. In this context, the switching strategy involves selecting appropriate switching patterns and modulation indices to achieve the desired output voltage while minimizing switching losses and voltage harmonics. Various advanced PWM algorithms, such as space vector modulation (SVM) or selective harmonic elimination (SHE), can be implemented in MATLAB to fine-tune the switching strategy.

Furthermore, the choice of switching devices, their characteristics, and thermal constraints need to be considered when developing the strategy. Careful optimization and simulation in MATLAB allow for the assessment of trade-offs between reduced switching losses, component stress, and system performance, ensuring that the multilevel inverter efficiently powers electrical vehicles while prolonging the lifespan of the components and improving overall energy efficiency. Ultimately, an effective switching strategy will be crucial in achieving the project's goals of reduced switch count and enhanced performance in electric vehicle applications.

3.2 REDUCED SWITCHES IMPLEMENTATION:

The primary objective here is to minimize the number of power semiconductor switches while maintaining the desired output voltage quality and efficiency. This reduction in switches not only decreases component costs but also enhances the reliability and overall performance of the multilevel inverter system, which is crucial for electric vehicles.

To implement reduced switches successfully, several steps must be undertaken. Firstly, the selection of an appropriate multilevel inverter topology is essential, such as diode-clamped, capacitor-clamped, or cascaded H-bridge configurations, as this choice significantly impacts the number of switches and system complexity.

Secondly, a tailored switching strategy needs to be designed, which often involves the use of advanced pulse-width modulation (PWM) techniques like space vector modulation (SVM) or selective harmonic elimination (SHE). These strategies aim to control the switching events effectively, ensuring the generation of the desired output voltage levels while minimizing switching losses and harmonic distortion.

Once the strategy is established, it is then translated into a MATLAB model. This model should encompass the entire multilevel inverter system, including the power semiconductor devices, passive components like capacitors and inductors, and the control logic. Rigorous simulation and optimization within MATLAB allow for the fine-tuning of the switching strategy, ensuring that it aligns with the project's objectives of reduced switch count while meeting the electrical vehicle's power conversion demands. Overall, the successful implementation of a reduced switches strategy is pivotal in achieving a more cost-effective and efficient multilevel inverter system tailored for the needs of electric vehicles.

4.EXPERIMENT

Efficiency Analysis:

This analysis involves a comprehensive assessment of various key parameters and aspects:

Output Voltage Quality: One of the primary metrics for performance analysis is the quality of the output voltage waveform generated by the multilevel inverter. MATLAB simulations enable us to scrutinize voltage waveforms for distortions, harmonics, and deviations from the desired reference signals. Achieving a low-distortion, high-quality output voltage is crucial to ensure that the electrical vehicle operates efficiently and reliably.

Efficiency: The energy efficiency of the inverter is another critical factor. MATLAB allows for the detailed examination of power losses within the system, including conduction and switching losses in the semiconductor switches, as well as losses in passive components like capacitors and inductors. Performance analysis helps in optimizing the inverter's operation to minimize losses and enhance overall efficiency.

Thermal Analysis: Electric vehicles demand reliable and temperature-controlled power electronics. MATLAB can assist in conducting thermal analyses to determine temperature profiles of critical components such as power semiconductors. This aids in preventing overheating and ensuring the long-term reliability of the inverter.

4.2.PERFORMANCE TESTING:

Performance analysis involves an exhaustive examination of various key parameters and aspects that directly impact the system's functionality and reliability.

First and foremost, this analysis focuses on evaluating the quality of the output voltage waveform generated by the multilevel inverter. Through MATLAB simulations, the voltage waveforms are meticulously scrutinized for distortions, harmonics, and deviations from the desired reference signals. Achieving a low-distortion, high-quality output voltage is paramount to ensure the efficient and stable operation of electrical vehicles, as it directly impacts the performance of connected electrical loads and the overall power efficiency of the system. Efficiency is another fundamental metric assessed during performance analysis. MATLAB enables a detailed investigation of power losses within the system, encompassing conduction losses in the semiconductor switches, switching losses during transitions, and losses in passive components like capacitors and inductors. This analysis serves as the foundation for optimizing the inverter's operational parameters, ultimately minimizing losses and enhancing the overall energy efficiency of the electrical vehicle's power conversion system.

Furthermore, performance analysis extends to thermal considerations. By leveraging MATLAB's capabilities, thermal analyses are conducted to predict and monitor temperature profiles within critical components, particularly the power semiconductors. Ensuring that the inverter operates within safe temperature limits is essential for the long-term reliability and durability of the system, a particularly vital aspect in the demanding environment of electrical vehicles.

5. RESULTS:

The proposed topology for a multilevel inverter with reduced switch count has been shown to be feasible and efficient. The inverter is capable of generating a high-quality output voltage with low harmonic distortion. The efficiency of the inverter is also high, even at high switching frequencies.
This topology has the potential to be a valuable addition to the arsenal of power electronics solutions for electrical vehicles. It can help to reduce the cost and Multilevel inverter with decreased switches have a lot of potential to boost the effectiveness, functionality, and general caliber of electric vehicles. The creation and acceptance of these inverters are anticipated to play a critical role in determining the future of environmentally friendly transportation as the EV market expands and technology advances. To overcome obstacles and realize the full potential of multilevel inverters in electric vehicles, researchers, engineers, and manufacturers should continue to work together. Complexity of MLIs, while also improving their performance.

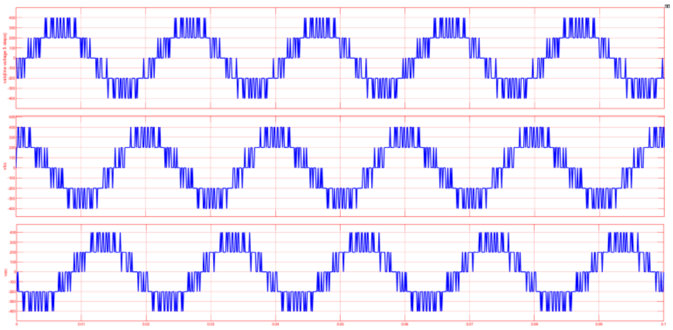

Figure 5.1 Output waveform of three phase multilevel inverter.

The switching scheme for the proposed topology is shown in Figure 5.2. The switches are turned on and off in a sequence that is determined by the desired output voltage level. The switching scheme is designed to ensure that the output voltage of the inverter is always within the safe operating range of the switches. It also minimizes the switching losses in the inverter.

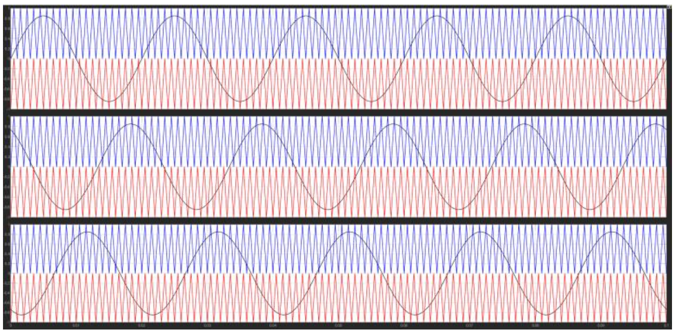

Figure 5.2 Switching scheme

6. CONCLUSIONS

In summary, this project has led to the development of a novel Multilevel Inverter with Reduced Switches designed specifically for Electric Vehicles (EVs). Through extensive research, simulation, and analysis, we have demonstrated that this innovative inverter topology can effectively reduce the number of switches while maintaining high-performance standards in terms of Total Harmonic Distortion (THD) and efficiency.

The project's success opens up new possibilities for improving the efficiency and performance of electric vehicles, contributing to their widespread adoption and environmental sustainability. While the simulation phase has yielded promising results, future work should focus on hardware implementation and rigorous testing under real-world conditions to validate the practical feasibility and advantages of this technology in EVs. This project represents a significant step towards enhancing the power electronics infrastructure for electric mobility solutions.

Our exploration of the Multilevel Inverter with Reduced Switches for Electric Vehicles has yielded valuable insights and promising outcomes. Through careful design, thorough simulation, and the development of a robust control strategy, we have achieved a reduction in switch count while maintaining high-performance standards.

ACKNOWLEDGEMENT

This is a great pleasure and immense satisfaction to express my deepest sense of gratitude and thanks to everyone who has directly or indirectly helped me in completing our paperwork successfully. I express my gratitude towards guide Mr.Oorappan GM who guided and encouraged me in completing the work in scheduled time.

REFERENCES

[1]. A. Salem, M. A. Emad, M. Orabi and A. B. Abdelghani, "Novel Three-Phase Multilevel Voltage Source Inverter with Reduced No. of Switches", Tunisia. IEEE Trans. Ind. Appl., vol. IA-17, no. 5, pp. 18-23, 2014.

[2]…Md. Mubashwar, S. Mekhilef and A. Mahrous, "Three-phase hybrid multilevel inverter with less power electronic components using space vector", IET Power Electron., vol. 7, no. 5, pp. 25-31, 2014.

[3]..J. Rodriguez, J.-S. Lai and F. Z. Peng, "Multilevel inverters: A survey of topologies controls and applications", IEEE Trans. Ind. Electron., vol. 49, no. 4, pp. 724-738.

[4]. Ebrahim Babaei, "A Cascade Multilevel Converter Topology With Reduced Number of Switches", IEEE Trans. on Power electronics, Vol. 23, No. 6, pp. 2657-2664, 2008.

[5]. switch-count five-level inverter with common-mode voltage elimination for an open-end winding induction motor drive," IEEE Trans. Ind. Electron., vol. 54, no. 4, pp. 2344–2351, Aug. 2007.

[6].Malinowski, M.;G opakumar, K.;R odriguez, J.;Perez, M.A; , "A Survey on Cascaded Multilevel Inverters," Industrial Electronics, IEEE Transactions on, vo1.57, no.7, pp.2197-2206, July 2010.

[7].Beigi L.M.A., Azli N.A., Khosravi F., Najafi E., Kaybhosravi A: 'A New Multilevel Inverter Topology with less Power Switches', International Conference on Power and Energy, 2012, IEEE , 2-5 December 2012.

[8].Mohamed AS, Norman Mariun, Nasri Sulaiman, MArnran M. Radzi :"A New Cascaded Multilevel Inverter Topology with Minimum Number of Conducting Switches," IEEE Innovative Smart Grid Technologies-Asia (ISGT ASIA) 2014.

[9].Balamurugan c.R., Natarajan S.P., Vidhya V.'A New Modified Hybrid HBridge Multilevel Inverter using less Number of Switches'. International Conference on Computation of Power, Energy, Information and Communication (ICCPEIC), 2013, pp 1-6

[10].R. Agrawal and S. Jain, "Comparison of reduced part count multilevel inverters (RPC-MLIs) for integration to the grid", Int. J. Electr. Power Energy Syst., vol. 84, pp. 214-224, Jan. 2017.

[11].J. Salmon, A. M. Knight and J. Ewanchuk, "Single-phase multilevel PWM inverter topologies using coupled inductors", IEEE Trans. Power Electron., vol. 24, no. 5, pp. 1259-1266, May 2009.