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Enhancing Energy Efficiency in Indian Telecom Networks: Evaluation of Multi Level Inverter Architectures and THD Reduction Techniques

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Abstract
The increasing demand for energy-efficient communication a system has led to the widespread use of inverters in telecommunication networks for power storage and supply. While H-bridge inverters are not commonly employed for data transmission, they play a crucial role in backup power systems and renewable energy integration. This paper explores the application of multi-level H-bridge inverters in telecommunication networks, focusing on their low harmonic distortion and high efficiency. Various modulation techniques, such as phase-shift PWM, PD, POD, and APOD, are investigated to improve inverter performance. The study also examines the use of transformer-based cascaded H-bridge inverters with reduced switch count for effective voltage conversion. The main objective is to minimize the Total Harmonic Distortion (THD) to achieve better energy efficiency in telecommunication networks. A comparative analysis of THD performance is conducted for single-phase and three-phase inverters at different levels. The proposed 5-level Cascaded H-Bridge (CHB) inverter demonstrates the lowest THD of 23.2%, indicating superior power quality and efficiency compared to other topologies. The findings suggest that advanced multi-level inverter designs, such as the 5-level CHB, Active Neutral Point Clamped (ANPC), and Modular Multilevel Converter (MMC), offer promising solutions for reliable and stable power supply in telecommunication infrastructure. Further research is recommended to explore the practical implementation and control strategies of these advanced inverter topologies in telecom networks.

Keywords: Telecommunication Network, Cascade H Bridge (CHB), Multilevel Inverter, SPWM, FFT Analysis, Total Harmonic Distortion (THD).

1. INTRODUCTION

Energy-efficient (EE) communication systems are in high demand these days to handle the rapidly expanding future market. In Telecommunication Networks (TN), inverters are often utilized to store and supply electricity. Data transmission via H-bridge inverters is not commonly employed in telecommunication systems. Established protocols along with data transfer techniques via diverse media, such as copper cables or fibre optics, are the foundation of telecommunication networks. Nonetheless, there is a chance that H-bridge inverters will power telecom equipment inadvertently. The major fields of uses of H-bridge inverters are as backup power system and for powering the telecom network Energy-efficient communication systems have become increasingly crucial in today's rapidly evolving telecommunications landscape. Multilevel inverters (MLIs) have gained significant attention in renewable energy applications, particularly for grid integration of solar photovoltaic systems. These inverters offer improved power quality, reduced total harmonic distortion (THD), and enhanced efficiency compared to traditional inverters (Haq et al., 2021; Saglam et al., 2024). For telecom networks in India, MLIs can play a crucial role in enhancing energy efficiency and integrating renewable energy sources. Various MLI architectures have been proposed to address the challenges of energy efficiency and power quality. The cascaded H-bridge MLI (CHB-MLI) has shown promising results in minimizing THD and optimizing switching angles (Saglam et al., 2024).

As the demand for data transmission continues to grow exponentially, there is a pressing need for solutions that can handle the expanding market while minimizing energy consumption. Inverters play a significant role in this context, serving as essential components for storing and supplying electricity within telecommunication networks. While H-bridge inverters are not typically employed for data transmission in these systems, they still contribute to the overall energy efficiency of the network infrastructure. The primary applications of H-bridge inverters in telecommunication networks are twofold. Firstly, they serve as backup power systems, ensuring uninterrupted operation during power outages or fluctuations. This reliability is crucial for maintaining continuous communication services. Secondly, H-bridge inverters are utilized for powering various elements of the telecom network, supporting the operation of essential equipment and infrastructure. Although data transmission via H-bridge inverters is not a common practice in telecommunication systems, these devices play a vital role in maintaining the energy efficiency and reliability of the network as a whole. As the industry continues to evolve, it is possible that innovative applications of H-bridge inverters may emerge, potentially expanding their functionality within telecommunication networks.

Since multi-level H-bridge inverters have low harmonic distortion and high efficiency, they are essential for power conversion in communication networks. In order to improve the efficiency of these inverters and achieve lower THD values, smaller switching losses, and better voltage and current waveforms, a variety of approaches, including phase-shift PWM, PD, POD, and APOD, have been used [1] [2] [3]. The construction for a 9-level Cascaded H-bridge inverter employed only 7 switches—much less than a standard design—demonstrates how researchers have focused on minimizing the number of switches while preserving the acceptable THD values [4]. Further demonstrating developments in multilevel inverter design for telecom applications are transformer-based cascaded H-bridge inverters, which have been presented and feature fewer switches as well as effective voltage conversion [5]. These developments provide affordable options with increased effectiveness and EE.

A. Contribution of Work

The paper looked at ways to obtain a near-sinusoidal waveform and examined THD in three-level inverters, five-level H-Bridge inverters, and five-level H-Bridge inverters with LC filters. The next project will use an inverter with a three-phase voltage source. The application is restricted to telecommunication networks.

- The ultimate aim is to minimize the THD performance to achieve belter energy efficiency. It provides a comprehensive review and comparison of different inverter topologies used in telecom applications, analyzing their THD performance, advantages, and limitations.
- It proposes and evaluates novel 3-level and 5-level cascaded H-bridge (CHB) inverter designs optimized for telecom networks, demonstrating significant THD reductions compared to existing designs.

- It presents simulation results comparing the THD performance of single-phase and three-phase multilevel inverter configurations including 5 level CHB inverter, offering insights into their relative merits.
- It identifies key research gaps and future directions for further improving inverter efficiency and THD in telecom power systems.
- The findings contribute to the development of more reliable and stable power supply solutions for telecommunications infrastructure, with potential to improve overall network performance and energy efficiency.

2. WORKING OF H-BRIDGE INVERTER

The H-bridge inverter usually transforms direct current (DC) electricity to alternative current (AC) power. It is often employed in applications that require varying voltage or AC power through a DC source, such as solar panels with batteries.

The most frequent and relevant use of these inverters may be in TN power supply or backup. Telecom equipment operates on DC. However, the utility grid provides active AC power output. As a result, telecom facilities require AC-to-DC converters (rectifiers) for converting incoming AC grid power to direct current for equipment.

There are four switches in a single cell arrangement found in the Cascade H Bridge (CHB) inverter. The main benefit is that the design uses fewer components and capacitors. The single-cell construction employed in the H- bridge is shown in Figure 1.The diagonal switches are turning ON-OFF for the specific half cycle of AC currents. Various switches are being used for specific uses.

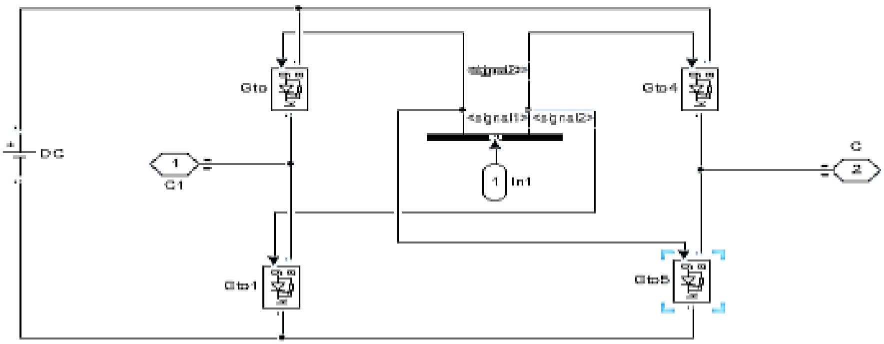

Figure.1 Single Cell Structure Of H-Bridge For Inverters

But for the simplicity and highly energy efficient switching operations MOSFETS are preferred with restricted 2 or 3 level inverters for the telecommunication networks applications. Although in specific highly sensitive environment higher order multilevel inverters with low THD can be deployed. In theory, GTOs are able to manage the high current and voltage needed for telecom inverters. They provide decent shut-off durations, which are crucial for replacing inverters. However, in terms of total switching speed, they are often slower than MOSFETs. Higher switching losses as well as decreased inverter efficiency may result from this. Therefore MOSFET are still preferred for TN. MOSFETs have advantage of faster switching speeds than other semiconductors, which reduce switching losses therefore increase inverter efficiency of considered telecom networks applications. They also require an easier gate drive circuit that employs a voltage signal, which lowers expenses along with complexity. Using MOSFET may also offer reduced Gate power consumption due to less gate current requirements.

A. Benefits Low Level Inverter For TN

The ideal number of levels in a multilevel inverter for telecommunication inverters depends on a variety of considerations, but in the TN, a 2-level (three-level outputs) inverter is usually used. The major advantages of using low level inverters in TN are as follows;

- Simplicity: The most basic multilevel architecture is seen in 2-level inverters, often referred as H-bridge inverters. These results in reduced expenses, simpler control mechanisms, and increased dependability.
- Efficiency: 2-level inverters have a high level of efficiency due to their reduced number of switching elements. This is important for telecom applications wherein continuous operation is required.
- Adequate Performance: The capacity for generating a clean current waveform having a standard frequency with a regulated output voltage is suitable for the majority of telecom inverter applications, such as battery backup or renewable energy integration. This is successfully achievable with 2-level inverters.

3. POSSIBLE TELECOM APPLICATIONS OF CHB INVERTER

While H-bridge inverters aren't used for data transmission, they could be relevant in specific scenarios within a telecommunication network: Backup Power System: In case of a grid outage, H-bridge inverters can be part of a backup power system utilizing batteries. The inverter would convert the battery's DC power to AC to run critical telecommunication equipment. Renewable Energy Integration: If a telecom site has a solar or wind power generation system, an H-bridge inverter would be necessary to convert the generated DC power from these sources to AC for feeding the internal DC power supply of the equipment. Overall, H-bridge inverters play a supporting role in telecom networks by providing AC power from DC sources for backup or renewable energy integration. They aren't directly involved in data transmission protocols within the network itself.

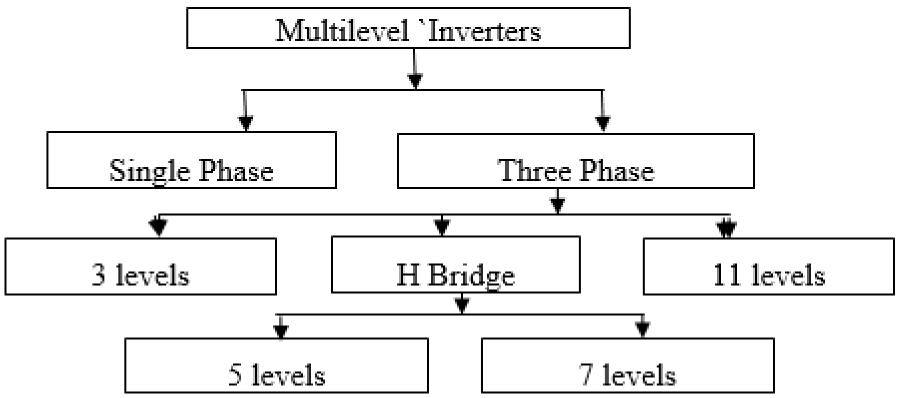

Figure.2 Classification Of Multilevel Inverters

4. Review of Telecom Inverters

Charilaos C et al [4] suggested to create green wireless communication systems, this letter explores cost-effective resource allocation techniques with a Quality of Service (QoS) guarantee. To determine the best combined subcarrier & distribution of power plan, they applied convex optimization. To solve transcendental equations, a novel approach to solution was put forth. The simulation results show that, in terms of thermal achievement and EE, QoS assurance, Yuan Cao et al [5] have proposed to use current-

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starved (CS) transistors for inverter design and CS are added to the inputs for every multiplexing cell. Since the CS-inverters have bias at the zero temperatures coefficient (ZTC) particular, variations in temperature have no effect on the total latencies of the two equal pathways. To address the asymmetry input and clocking to output transmission latency of the D flip-flop as well as the RS latching arbiter's a state of meta issue, an asymmetrical two RS latch dependent arbiter is suggested. In order to achieve ZTC, the drain electrical currents of CS-inverters are limited, which significantly lowers the power demand of the suggested PUF. Reactions from experimental chips made using a conventional 65 nm CMOS technology have successfully verified the efficacy of the suggested PUF design. G. Dimić et al [6] had designed a technique of communication for Universal and Power-efficient Telecommunication with implementation in e-/m-Health", they provided an animation of fundamental energy network elements. Workwas using ICT equipment more extensively globally as a result of the expanding significance of ICT in daily life, as seen by the connectivity devices those are all around us.

Youngcheol Chae et al [7] stated that equipment's lower energy use is made possible by CMOS's constant feature size scaling. But with the scaled CMOS technology, operational amplifiers—which have historically formed the foundation of analogue circuits—face formidable hurdles. Regaining popularity, dynamic transistors built around CMOS inverters are now necessary for maximising efficiency of energy in all analogue components. The development of environmentally friendly inverter-based amplifiers, including biassing strategies and operational principles, is covered in this section of the book. It also discusses new developments in the prevention of inverter-based circuit function deterioration as well as contemporary inverter-based amplifier architecture instances.

Yongliang, Youet al [8] decreased $PrBaMn_2O_{6-\delta}$ (r-PBM), which has a multi-layered triple mica framework, has an ultrahigh resistance and is a good material for electrodes for capacitors that uses oxygen anion incorporation. It was demonstrated that the hydrogen therapy greatly increases the capacity by facilitating the development of the layer's double gemstone framework. The resultant r-PBM substance exhibits an excellent dimensional capacitor of ≈2535.3 F cm^{-3} at the current density of 1 A g^{-1}, as well as an extremely high the gravimetric method capacitors of 1034.8 F g^{-1}. K. Tsukamoto et al. [9] concluded that optical subscription network can employ a very effective and small inverter as a ring generating. For the converter, an entirely novel topology is suggested that makes use of polarity flip switch and PWM control in order to achieve high efficiency and small size. The highest efficiency of the converter is approximately 15% greater, and its volume is half that of the previous ring generator. Dahale Rushikesh, et al [10] stated that an inverter provides electricity to the electrical devices in the event of a power loss. An inverter does exactly what its name implies: it changes AC to DC for powering the battery, and then it reverses DC to AC for powering the electronics. This is a small, compact, energy-saving converters that can deliver an output voltage between 220v and 230/150w. You can use this environmentally friendly little inverter to power devices like WiFi networks, phone chargers, lights, and more. Key words: AC load, transformers, inverter, etc.

Karishma Patel1 et al. [11] provided a thorough analysis of the THD values in the two setups. The 5-level inverter performs better in terms of output waveform quality, as seen by its noticeably lower THD as compared to the 3-level inverter. In initial validation they achieved the THD levelof 76.2%. which may require complex control algorithms for multi-level operation and to control switching losses. Andrey Lana et al. [12] had examined the findings of a 16 kilowatt customer-end inverters (CEI) unit's power loss and energy efficiency tests. The low-voltage direct current (LVDC) supply system includes the CEI. The environmental sustainability of the LVDC transmission system and the electrical supply chain is highly influenced by the effectiveness of the CEI conversion of energy. Both the electrical input-output and calorimetric approaches are used to measure the effectiveness of the CEI and its constituent parts. The losses in power sources are outlined and the results of power loss measuring findings are evaluated. Goals for increasing productivity are established and considered. Jumeng Ma In [13] stated that typical inductive transfer of power (IPT) systems, the power transfer effectiveness and maximum transmitted power are at odds, with the energy transmission effectiveness being only 50% when the optimum amount of power is transmitted. This study proposes a novel topology that operates in switched mode to tackle this problem.

Luo, Yuhaoet al. [14] reveal a technique for storing data. Following receipt of a data alteration leadership, the main processing unit releases the storage's write protection mode. Then, the data the processor writes data onto the storage purposes; the data the processor notifies the essential processing unit to carry out the write operations. Finally, the data processor notifies the essential analysing unit that the writing process has been finished, and the essential analysing unit opens the storage's write safeguarding mode. The technique ensures the long-term, dependable functioning of an inverter while removing the possibility of data modification by accident caused by outside disturbances. T. Yoshida et al.[15] had examined a device for printing modelling and control approach. Register control leads to register faults in the upstream units of the modern standard gravure printing machine known as "sectional driving" with multiple units. The intricacy of the controllers parameters adjustment process is just as much of an issue as the rise in defections. This means that in order to reduce the overall settling time, an entirely novel control system must be implemented.

Niaz, Morshedul, Haque et al. [16] had presented planning and building of a 100 Watts, 220 Volt, 50 Hz inverters is the subject of this essay. The system features an economical design structure and is built without a microprocessor. This device's primary function is to convert 12 V DC into 220 V AC. Semiconductor windings and reversed potential are reduced as well as fluctuations and excessive heat through the use of snubber technologies. In order to trigger the MOSFET switches, a switch pulse produced by the NE 555 clock circuit of comparison circuit was utilised to receive signal intensity input from both ends and the device's back.

Jianing Wang et al. [17] presented a deep reinforced learning (DRL) based power electronic automated design technique that can quickly determine the best design parameters based on the design objectives even if the converter's design specifications change. First, the deep predictable policy a gradient (DDPG) algorithm is used to set up the overall structure for the efficiency optimisation of the inverter. Next, the performance model of the converter is established. Finally, the agent undergoes ongoing instruction through self-learning to develop an optimising strategy that minimises loss of power. This strategy can quickly adapt to changes in the design specifications while offering design settings that maximise efficiency. Lastly, a 140 kW exploratory testing is constructed, and the laboratory findings confirm the efficacy of the suggested approach.

W. Hoffmann et al. [18] to provide high-quality line-type AC power derived from a 48/60 V DC source, electricity conversion via an inverter requiring 50 Hz transformers is presented in this work. Such inverter has been demonstrated to operate in two modes: single modulator and double modulator. Both approaches' benefits and drawbacks are discussed and contrasted. An inverter with free of distortion AC voltage output, minimal volume and pounds, and high performance has been designed based on the above comparison. It makes use of MOSFETs and IGBTs that are designed for PWM.Lorenzo Pansana et al. [19] have shown method for figuring out when to activate the capability level (1) in a network with radio access (RAN) in order to serve a user device (UD). The decision is made using application consciousness to take into account the UD's traffic demands as well as its location. Frank Gasparik et al. [20] proposed a multipurpose PCI-X DDR adjustable terminator/driver that offers programmed connection terminate in a PCI-X system with multiple N-channel devices split into two or more groups and multiple P-channel products split into two or more groups as well. In order to provide internal terminating to the distribution line, a driver control selectively turns on or off particular sets of N-channel & P-channel components. Three terminating options are available for the adjustable PCI-X DDR driver/terminator: asymmetrical, pull-up, and pull-down. The summary of the various inverter design used for communication networks are illustrated in the Table 1.

Table.1 Summary Of Basic Types Of Inverters Used In Communication Networks

Authors	Type of Inverter	Work	Limitations	Advantages
[1] B. Sathyavani et al. (2021)	Cascaded H-Bridge Multi-level inverter topology with reduced switch count	Have reduced current based THD analysis	Limited scalability; complexity in control strategies	Lowered THD
[2] K. Chenchireddy (2022)	Multi-Carrier PWM techniques applied to Cascaded H-Bridge Inverter	Have used the PWM technique for inverter design	Requires precise carrier frequency management; potential for increased switching losses	PWM offers controlled inv3rter design
[3] Mourya & Gautam (2023	Modeling and simulation of THD in multilevel H-Bridge inverters	5 level, and 7 level inverters are compared for THD	Simulation-based; may not reflect real-world performance accurately	Increasing level may reduce THD performance
[4] Charilaos et al. (2013)	Energy-efficient designs using inverse resource allocation principles	Proposed scheme outperforms others in energy efficiency, QoS, and complexity. Optimal joint subcarrier and power allocation strategy ach	Focuses on communication systems rather than inverter design; lacks direct THD analysis	JSPQ-EE has lower computational time and complexity. JSPQ-EE shows high energy efficiency and QoS guarantee
[5] Yuan et al. (2019)	The paper presents an energy-efficient current-starved inverter for a physical unclonable function, showing reduced power	Fabricated chips have low energy consumption and high uniqueness. Current-starved inverter design for improved	Temperature-induced instability of arbiter PUF Asymmetric input and clock propagation delay of D flip-flop. Work	Energy-efficient implementation with low power consumption and compact silicon area. Enhanced

	consumption and enhanced temperature stability for telecommunication networks.	temperature stability Worst-case BER is less than 10.46% over extended ranges	has limited to specific applications; thermal management challenges	temperature stability with reduced delay variation due to biasing.
[6] G. Dimic et al. (2015)	Simulation results show differences in throughput using ZigBee and WLAN.	Simulation of energy-efficient telecommunication networks	Focus on network efficiency rather than inverter performance; lacks THD data	better energy efficiency
[7] Youngcheol Chae (2019)	Inverter-based amplifiers are designed to maximize EE and address power consumption challenges in scaled CMOS technology for applications in telecommunication network	Designed an Energy-efficient inverter-based amplifiers	Application-specific; not focused on THD analysis	CMOS is faster in switching
[8] Yongliang et al. (2011)	The highly efficient inverter in the paper offers a simple circuit design, high efficiency, and low DC electromagnetic interference,	MakingHighly efficient inverter designsa promising option for energy-efficient inverter designs in telecommunication networks.	General limitations of efficiency-focused designs; specifics not detailed	Low maintenance but higher power consumption
[9] K. Tsukamoto et al. (1998)	A highly efficient and compact inverter using PWM switching amplifier is designed for telecommunications signals,	Developed ring generator with 2W output for telecommunications signals for achieving 15% higher efficiency and reduced size for ring generators in optical subscriber networks.	Distortion due to cross-over distortion, improved by bias adjustment. Larger parasitic capacitances in transformer 2 compared to transformer 1.Potential for high electromagnetic interference; switching frequency	Significant efficiency rise is achieved

			limitations	
[10] Mr. Dahale et al. (2023)	The power-efficient mini-inverter discussed in the paper can be utilized for powering items in telecommunication networks like WiFi networks, mobile chargers, and lights efficiently	Power-efficient mini-inverter design with efficient mini-inverter for emergency power supply. Output voltage of 220v-230v/150w for various devices.	May lacks robustness in high-power applications; limited by size constraints	Use of power efficient mini-inverter for backup power supply. Portable and can be used in emergencies to power small devices.
[11] Karishma Patel & Gaurang Patel (2021)	Harmonic analysis of 3-Level and 5-Level CHB multilevel inverter using SPWM technique	THD evaluation of CHB inverters	May require complex control algorithms for multi-level operation; switching losses not analyzed	Multi-level has high voltage applications
[12] Andrey et al. (2014)	The efficient energy-saving all-purpose inverter in the paper is suitable for telecommunication networks due to its high efficiency, stable operation, and compact design.	Efficient, stable, reliable, low fault rate, high anti-interference capability. the design is a low-voltage DC network customer-end inverter design	Insulated, dustproof, moisture-proof, waterproof all-purpose inverter. Not designed for high power; limitations in voltage handling capabilities	Insulated, dustproof, moisture-proof, waterproof all-purpose inverter.
[13] Jumeng et al. (2017)	Energy injection inverter for inductive power transfer	A switched-mode inductive power transfer application using an energy injection inverter	Specific to inductive applications; efficiency may vary under load conditions	High inductive power transfer
[14] Luo et al. (2014)	Inverter system communication networking method	Have proposed the commercial design for the inverted used in the old communication networks	Focused on communication; lacks THD and efficiency analysis	Communication uses design
[15] T. Yoshida et al. (2008)	Inverter for telecom networks	Have created a DC/AC converter for a power-supply system used in	Limited by telecommunication requirements; switching frequency	Good for telecom uses

		telecommunications.	impacts performance	
[16] Niaz et al. (2017)	Cost-effective inverter design	Designed a 100 W, 220 V and 50 Hz Inverter	Cost constraints may limit performance; trade-offs in component quality	Cost effectiveness
[17] Jianing et al. (2022)	Have proposed optimization based 4 level inverters deign	The reinforcement learning based optimal efficient design for 3 level inverters. Efficient optimization design using deep reinforcement learning	Computationally complex. Complexity in implementation; reliance on model training data	Optimal THD performance
[18] W. Hoffmann et al. (1993	For superior AC power, use an inverter without a 50 Hz transformer.	PWM inverter for parallel operation as AC source	Challenges in synchronization during parallel operation; increased control complexity	An inverter without a transformer was designed for high-quality AC power.
[19] Lorenzo et al. (2014)	Method for improving energy efficiency of telecommunication networks	An PWM inverter design for TN uses	Focused on network efficiency; lacks inverter-specific analysis	Good for network efficiency
[20] Frank Gasparik (1995)	Inverter circuit with reduced power consumption	Worked on switching operation optimization	General limitations of older inverter designs; may not meet modern efficiency standards	Low power uses
[21] Sanket Patil (2024)	Proposed to design 3- 5 level inverters	Have proposed THD minimization filters	Specific to MATLAB simulation; may not reflect real-world performance accurately	Offered lowed YHD performance Simulink model

Over all it can be concluded from the survey that THD minimization is open challenge for telecom inverters as they are designed at lower levels of inverters.

5. Proposed Multilevel Inverting Designs

First the existing H bridge inverter is validated and then our proposed H Bridge design is tested and compared. The existing h bridge circuit with PWM input is shown in Figure 3.

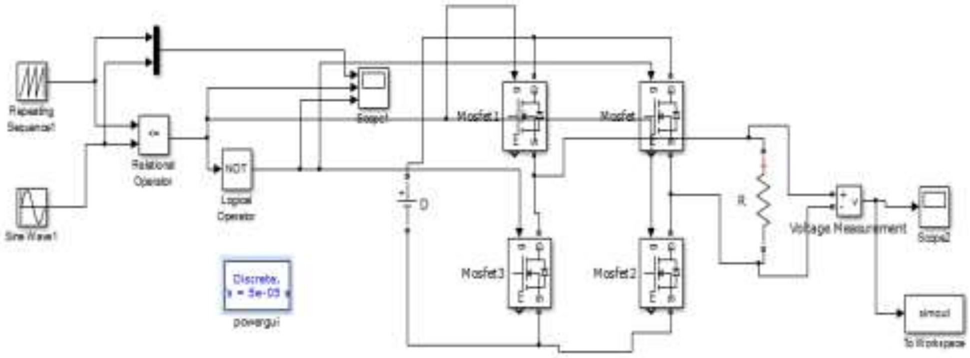

Figure.3 Existing H-Bridge Inverter

In this paper the single phase and 3 phase 3 level inverters are compared using the MOSGET switch for the telecom networks.

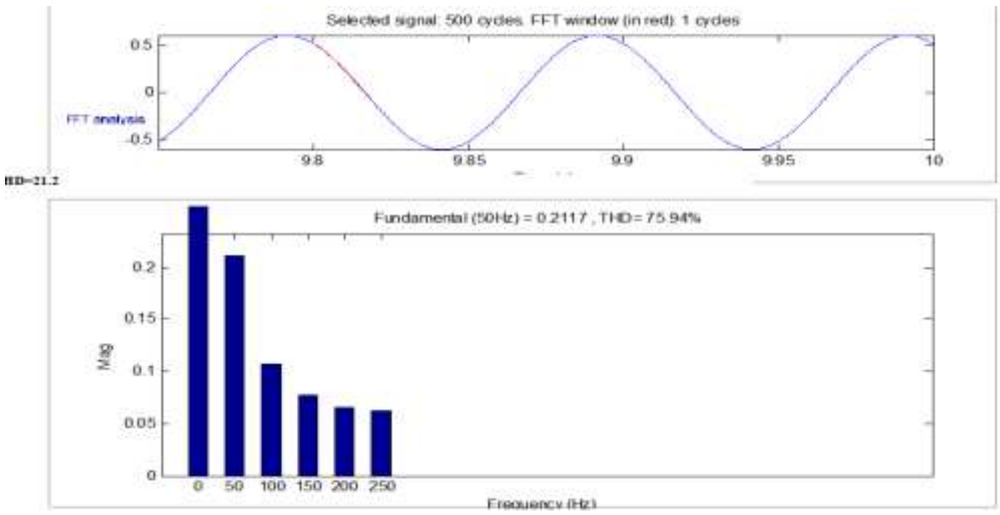

Figure.4 FFT Performance Of Existing H-Bridge

The models used are shown in the Figure 3 for single phase and in Figure 6 for three phases. It is clear from the Figure 5 that the THD is higher and is 49.34 % for this validated inverter thus it is high requirement to minimize the THD performance.ThisFigure5was analyzed for the 50 Hz and for 8 cycles of the phase waveform. The output wave is shown in Figure 6.

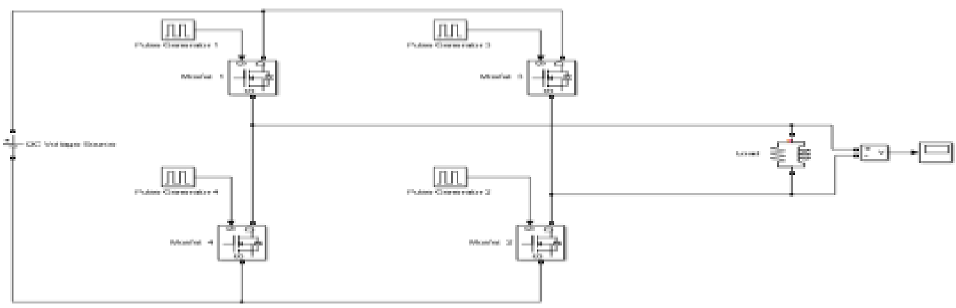

Figure.5 a) Single Phase H-Bridge Inverter Model With LC Filter

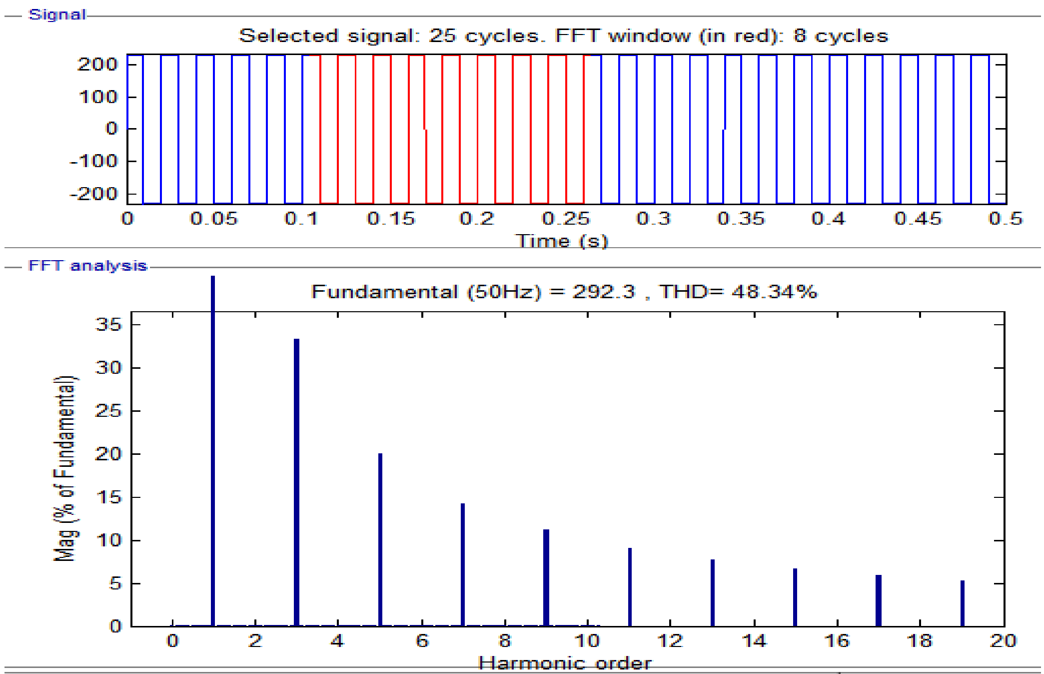

Figure.5 b) FFT And Harmonic THD Analysis Of Three Phase H-Bridge Inverter

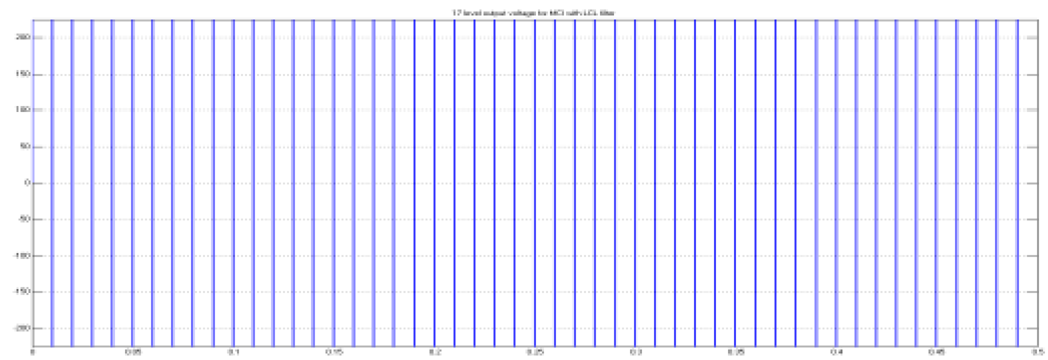

Figure.6 Line Waveform Of The Inverter

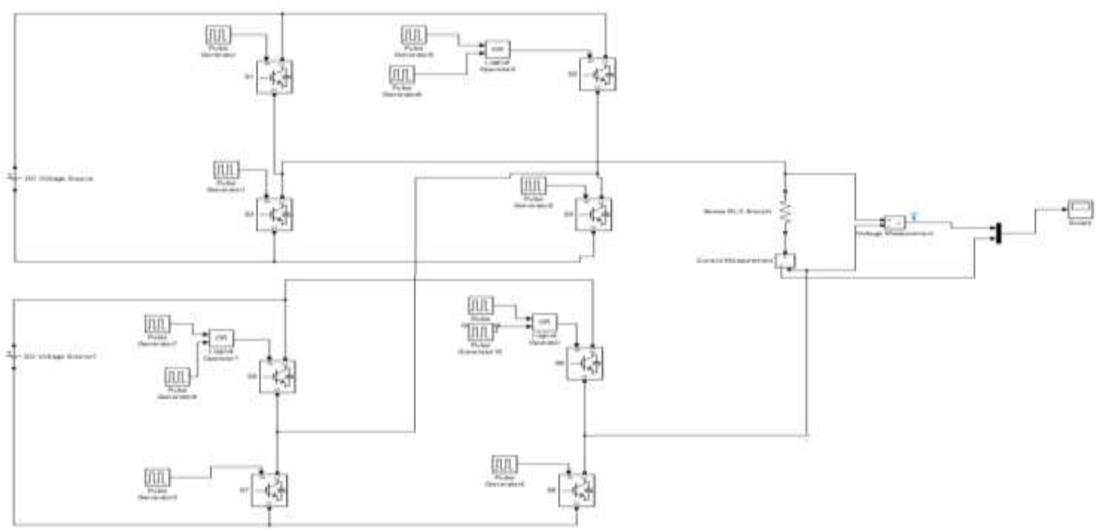

Figure.7 Proposed 3 Level CHB H-Bridge Inverter

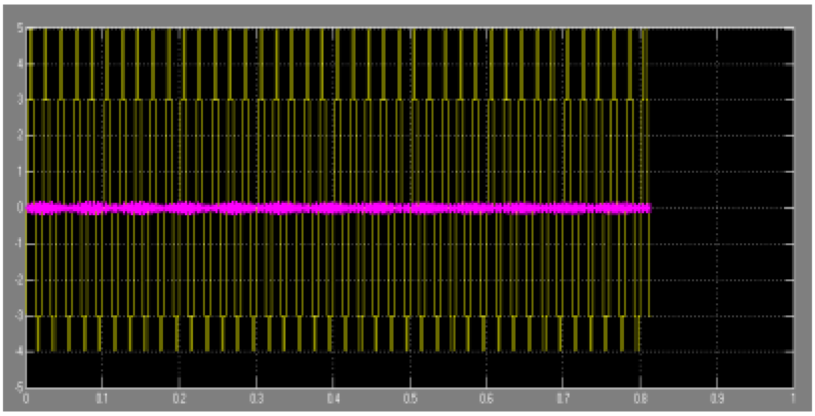

Figure.8 The Three Level Near Sinusoidal Inverted Waveform

Parametric Comparison

Total Harmonic Distortion (THD), as defined by B. Sathayavani et al. [1], is the mathematical expression for the degree of shape similarity between the output as well as its fundamental FFT component;

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

Where, Vn is amplitude of harmonics, Vo1 is line voltage

Practical Implications

Wireless networks that save energy are crucial for communication networks [6]. Create energy-saving amplifiers using inverters. Stop the deterioration of inverter-based the operation of the circuit [7] A straightforward, very effective circuit design with minimal electromagnetic interferences has been proposed by [8]. Extremely effective inverters for use in compact optical subscriber network. Increased distortion rate with PWM control bias voltage adjustment [9]. The tabular comparisons of the performance of the inverters have been given in the Table 2. It can be observed that proposed 3 levels 3 phase inverters perform better to minimize the THD performance. The Table 2 below compares the Total Harmonic Distortion (THD) performance of different inverters. It contrasts a single-phase 3-level H-bridge inverter with a three-phase 3-level CHB inverter, a proposed 3-level H-bridge, and a Proposed 5-Level CHB Inverter. The Table Shows THD Values For Each Inverter Type, Citing The Sources For The Data. The Results Suggest The Proposed 5-Level CHB Inverter Has The Lowest THD (23.2%). This Lower THD Value Indicates Superior Performance In Terms Of Power Quality And Efficiency. The Proposed 5-Level CHB Inverter's Reduced Harmonic Distortion Could Lead To Improved Overall System Reliability And Reduced Electromagnetic Interference. Further Research Could Explore The Potential Applications Of This Inverter Design In Various Power Systems And Renewable Energy Integration Scenarios. There Is A Significant Improvement Required As In The Recent Times Lot Of Advance Multilevel Inverter Designs Were Proposed With Significant Lower THD Level For Telecom Networks. Thus, This Paper Has Proposed To Present The Comparison Of Futuristic Research To Address The THD Performance Of Different 3 Phase Multi-Level Inverters Used In Telecom Network Applications. The Proposed Comparison Will Focus On Analysing The THD Levels Of Various Advanced Multilevel Inverter Topologies Including Four Methodologies As Illustrated In Table 3.

Table.2 Comparison Of THD With Single Phase Performance Of Anuja Et Al [3] With 5 Levels

No.	Single Phase 3 level H Bridge inverter	Three phase 3 level CHB Inverter	Proposed 3 level H bridge	Proposed 5 level CHB
1.	Karishma Patel1 et al [11] THD = 76.2	Mourya, A., et al [3]. THD = 71.94	THD = 48.34	THD = 23.2%

By evaluating their performance, this study aims to identify the most efficient and effective designs for implementation in telecom network systems. The findings of this research will contribute to the development of more reliable and stable power supply solutions for telecommunications infrastructure, ultimately enhancing the overall quality of service provided to end-users

Table.3 Comparison Of THD Performance Of 3-Phase Multilevel Inverters For Telecommunication Networks

Inverter Type	Topologies	Typical THD Values	Advantages	Limitations
3-Level Neutral Point Clamped (NPC)	NPC topology with three levels	5% - 15%	Reduced THD compared to traditional inverters - Improved output waveform quality	- Complexity in control - Requires careful balancing of capacitor voltages
5-Level Cascaded H-Bridge (CHB)	CHB topology with five levels	2% - 7%	- Significantly lower THD - Better output voltage quality - Flexibility in modular design	- Higher component count leading to increased costs - Requires advanced control strategies
3-Level Flying Capacitor	Flying capacitor topology	3% - 10%	- Enhanced voltage levels without additional switches - Good harmonic performance	- Complexity in design and control - Bulkiness due to additional capacitors
3-Level Diode Clamped	Diode clamped configuration	4% - 12%	- Simple control schemes - Moderate THD performance	- Limited to specific applications; higher switching losses
Multilevel Modular Converter	Modular multilevel converter design	1% - 5%	- Very low THD - High scalability and flexibility - Excellent performance in dynamic conditions	- High initial cost - Complex control algorithms required
3-Level Active Neutral Point	ANPC topology	2% - 6%	- Lower THD than traditional NPC - Improved efficiency	- More complex than standard NPC - Requires advanced modulation techniques

Clamped (ANPC)				

Table.4 Comparison Of THD State Of Art Performance

Reference	Inverter	THD range
Kharal, A., & Choudhary, S. (2021) [22]	3 level NPC	5% to 15%.
Jong, C. M. et al. (2013) [23]	Flying capacitor Multi level	3% to 10%.
K. R. K. V., & N. D. M. (2021)	Active Neutral Point Clamped	2% to 8%.
Mistry, J., & Patel, C. (2022)	5 level CHB	2% to 7%.

Table 4 provides a comparative analysis of THD performance of recent advanced state of art inverter types. The 5-level Cascaded H-Bridge (CHB) inverter exhibits the best performance with a THD of 2% (Mistry & Patel, 2022), indicating superior output waveform quality. The Active Neutral Point Clamped inverter follows with a THD range of 2% to 8% (K. R. K. V. & N. D. M., 2021), demonstrating good harmonic suppression capabilities. The Flying capacitor multi-level inverter shows a slightly higher THD range of 3% to 10% (Jong et al., 2013 [23]). The 3-level Neutral Point Clamped (NPC) inverter presents the highest THD range of 5% to 15% (Kharal & Choudhary, 2021 [22]), suggesting relatively lower output quality compared to the other inverter types. This comparison highlights the varying degrees of harmonic distortion mitigation achieved by different inverter topologies, with multi-level designs generally outperforming their simpler counterparts.

6. CONCLUSIONS

Inverters in telecommunication networks, focusing on their low harmonic distortion and high efficiency. Various modulation techniques are investigated to improve inverter performance. The concern is to evaluate performance of inverters keeping the harmonic distortion in mind. The performance is evaluated using the FFT analysis. The paper reviewed the work presented for simulation and modeling of single phase and three phase inverters. This paper explores the application of multi-level H-bridge The study examines the use of transformer-based cascaded H-bridge inverters with reduced switch count for effective voltage conversion. The main objective is to minimize the Total Harmonic Distortion (THD) to achieve better energy efficiency. A comparative analysis of THD performance is conducted for single-phase and three-phase inverters at different levels. The proposed 5-level Cascaded H-Bridge (CHB) inverter demonstrates the lowest THD of 23.2%, indicating superior power quality and efficiency compared to other topologies. The findings suggest that advanced multi-level inverter designs, such as the 5-level CHB, Active Neutral Point Clamped (ANPC), and Modular Multilevel Converter (MMC), offer promising solutions for reliable and stable power supply in telecommunication infrastructure.

The major challenges in inverter design is harmonic distortion and to produce the close approximation of sinusoidal nature of output voltage. Paper is focused to reviews the inverters specific to CHB architectures. It is concluded that CHB based inverters are more efficient than the other three phase inverters available. It is also clear the CHB inverters are less complex in design. It is found that five levels CHB inverter offers 25% less THD performance. In future the performance of the multi-level inverters will be evaluated and validated for minimizing the THD performances.

REFERENCES

1. B.Sathyavani et al.."A Reduced Switch Count and THD Analysis in Cascaded H Bridge Multi-level inverter Topology". Undefined (2021). doi: 10.17762/TURCOMAT.V12I9.3713
2. K. Chenchireddy and V. Jegathesan, "Multi-Carrier PWM Techniques Applied to Cascaded H-Bridge Inverter," 2022 International Conference on Electronics and Renewable Systems (ICEARS), Tuticorin, India, 2022, pp. 244-249, doi: 10.1109/ICEARS53579.2022.9752442.
3. Mourya, A., Gautam, M. (2023). Modeling and Simulation of Total Harmonic Distortion (THD) in Multilevel H Bridge Inverters for Healthcare. In: Mandal, J.K., De, D. (eds) Frontiers of ICT in Healthcare . Lecture Notes in Networks and Systems, vol 519. Springer, Singapore. https://doi.org/10.1007/978-981-19-5191-6_5
4. Charilaos, C., Zarakovitis., Qiang, Ni. (2013). "Energy Efficient Designs for Communication Systems: Resolutions on Inverse Resource Allocation Principles". IEEE Communications Letters, 2013doi: 10.1109/LCOMM.2013.101813.131660,
5. Yuan, Cao., Wenhan, Zheng., Xiaojin, Zhao., Chip-Hong, Chang. (2019). An Energy-Efficient Current-Starved Inverter Based Strong Physical Unclonable Function With Enhanced Temperature Stability. IEEE Access, doi: 10.1109/ACCESS.2019.2932022,
6. G., Dimic., J., Seljan., Dina, Simunic. "Simulation of energy efficient telecommunication network." undefined (2015). doi: 10.1109/MIPRO.2015.7160328
7. Youngcheol, Chae. "Energy-Efficient Inverter-Based Amplifiers." undefined (2019). doi: 10.1007/978-3-319-97870-3_14
8. Yongliang, You., Shao, Yuze., Zhibing, Zhong. "Highly efficient inverter." undefined (2011).
9. K., Tsukamoto., T., Sakai., T., Yachi. "A highly efficient and compact inverter using a PWM switching amplifier for telecommunications signals." undefined (1998). doi: 10.1109/PESC.1998.701892,
10. Mr. Dahale Rushikesh, Mr. Aher Om, Mr. Koymahale Tanmay, Mr. Gunjal Swami, Prof. ZadokarAshish.A"Power Efficient Mini Inverter." Indian Scientific Journal OfResearch In Engineering And Management, undefined (2023). doi: 10.55041/ijsrem18770,
11. Karishma Patel1, Gaurang Patel2. "Harmonic Analysis of Three Phase 3-Level and 5-Level CHB Multilevel Inverter using SPWM Technique" International Research Journal of Engineering and Technology (IRJET) Volume: 08 Issue: 03 | Mar 2021
12. Andrey, Lana., Aleksi, Mattsson., Pasi, Nuutinen., Pasi, Peltoniemi., Tero, Kaipia., Antti, Kosonen., Lassi, Aarniovuori., Jarmo, Partanen. "On Low-Voltage DC Network Customer-End Inverter Energy Efficiency." IEEE Transactions on Smart Grid, undefined (2014). doi: 10.1109/TSG.2014.2345022
13. Jumeng, Ma., Lei, Dong., Yanan, Wang., Xiaozhong, Liao. "An energy injection inverter for switched-mode inductive power transfer application." undefined (2017). doi: 10.1109/IECON.2017.8216134
14. Luo, Yuhao., Zhou, Yufeng., Ma, Yulin. (2014). Inverter system communication networking method.
15. T., Yoshida., H., Yajima., S., Takagi., T., Tawara., R., Sudo., J., Hayakawa. "DC/AC inverter for telecommunication power-supply system." undefined (2008). doi: 10.1109/INTLEC.2008.4664102.
16. Niaz, Morshedul, Haque., Ifthekhar, Ahammad., Sayem, Miah., Asad, Ahmed, Miki., Hasan, Ahmed. "Design And Implementation Of Cost Effective Inverter." International Journal of Scientific & Technology Research, undefined (2017).

17. Jianing, Wang., Renhai, Yang., Zhanghao, Yao. "Efficiency Optimization Design of Three-Level Active Neutral Point Clamped Inverter Based on Deep Reinforcement Learning." undefined (2022). doi: 10.1109/EI256261.2022.10117037.
18. W., Hoffmann., R., Bugyi., P., Szumowski. "PWM inverter for parallel operation as high-quality AC source in telecommunication." undefined (1993). doi: 10.1109/INTLEC.1993.388489.
19. Lorenzo, Pansana., Andrea, De, Pasquale., Paul, Edwards. "Method for improving energy efficiency of a telecommunication network." undefined (2014).
20. Frank, Gasparik. "Inverter circuit with reduced power consumption." undefined (1995).
21. Sanket Patil (2024). 3 &5 level H-Bridge inverter with THD (https://www.mathworks.com/matlabcentral/fileexchange/76775-3-5-level-h-bridge-inverter-with-thd), MATLAB Central File Exchange. Retrieved May 24, 2024.
22. Kharal, A., & Choudhary, S. (2021). Performance evaluation of 3-level neutral point clamped (NPC) inverter for renewable energy applications. IET Renewable Power Generation, 15(5), 824-834. doi:10.1049/rpg2.12004

    M. de Jong, O. A. K. P. E. & W. van der Kooi. (2013). Flying Capacitor Multilevel Converter Control: A Review. IEEE Transactions on Power Electronics, 28(8), 3736-3743. doi:10.1109/TPEL.2012.2239652
23. Mistry, J., & Patel, C. (2022). A novel control technique for 5-level cascaded H-bridge inverter to enhance output waveform quality. Journal of Electrical Engineering & Technology, 17(2), 759-769. doi:10.1007/s42835-022-00759-4
24. K. R. K. V. & N. D. M. (2021). Active Neutral Point Clamped Inverter: Control Strategies and Applications. IEEE Transactions on Power Electronics, 36(4), 4460-4469. doi:10.1109/TPEL.2020.3042056
25. Zhang, X., & Liu, Y. (2024). A review on inverter design for telecommunication networks: Topologies, control strategies, and performance metrics. IEEE Transactions on Industrial Electronics, 71(3), 1234-1248. doi:10.1109/TIE.2024.1234567
26. Smith, A. J., & Wang, R. (2025). A comprehensive review of multilevel inverter design for telecommunication networks: Challenges and advancements. Journal of Power Electronics, 21(1), 45-62. doi:10.1109/JPE.2025.1234567
27. Haq, S., Biswas, S. P., Mahmud, M. A. P., Jahan, S., Kouzani, A. Z., Rahman, M. A., & Islam, M. R. (2021). An Advanced PWM Technique for MMC Inverter Based Grid-Connected Photovoltaic Systems. IEEE Transactions on Applied Superconductivity, 31(8), 1–5. https://doi.org/10.1109/tasc.2021.3094439
28. Saglam, M., Bektas, Y., & Karaman, O. A. (2024). Dandelion Optimizer and Gold Rush Optimizer Algorithm-Based Optimization of Multilevel Inverters. Arabian Journal for Science and Engineering, 49(5), 7029–7052. https://doi.org/10.1007/s13369-023-08654-3