IMPLEMENTATION OF POWER QUALITY OF USING CASCADED MULTILEVEL STATCOM WITH DC VOLTAGE CONTROL

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ABSTRACT

Line Following is one of the most important aspects of robotics. A Line Following Robot is an autonomous robot which is able to follow either a black line that is drawn on the surface consisting of a contrasting colour. It is designed to move automatically and follow the line. The robot uses arrays of optical sensors to identify the line, thus assisting the robot to stay on the track. The array of four sensor makes its movement precise and flexible. The robot is driven by DC gear motors to control the movement of the wheels. The Arduino Uno interface is used to perform and implement algorithms to control the speed of the motors, steering the robot to travel along the line smoothly. This project aims to implement the algorithm and control the movement of the robot by proper tuning of the control parameters and thus achieve better performance. In addition, the robot will detect the obstacle in front of it and stops. The development of a mobile surveillance camera monitoring system is also implemented. Line follower is chosen to provide a mobile movement of the surveillance monitoring system. Other than surveillance purpose, the camera also functions to detect any kind of obstacle on the route. A specific route and task are designed for the robotic system to test its functionality. It shows that the robotic system manages to complete the designed track and manage to detect the obstacle. In addition, we have provided SMS alerting system for robot whenever any obstacle detected by the robot it will send the message to the mobile. It can be used industrial automated equipment carriers, small household applications, tour guides in museums and other similar applications, etc.,

Keywords:line following, robotics, autonomous robot, optical sensors, Arduino Uno, obstacle detection, surveillance camera

INTRODUCTION

The implementation of power quality through the integration of advanced technologies like Cascaded Multilevel STATCOM with DC voltage control marks a significant advancement in the field of power electronics and grid stability enhancement. As the demand for electrical energy continues to rise, ensuring the quality and reliability of power supply becomes increasingly crucial. Power Quality (PQ) issues such as voltage sags, swells, harmonics, and flicker pose significant challenges to the operation of sensitive electronic equipment and can lead to economic losses for industries and utilities [1]. Hence, there is a growing need for innovative solutions that can mitigate these PQ problems and improve the overall performance of power systems.In recent years, multilevel converters have emerged as a promising solution for addressing PQ issues due to their ability to generate high-quality voltage waveforms with reduced harmonic distortion [2]. Among various multilevel converter topologies, the Cascaded Multilevel STATCOM (Static Synchronous Compensator) has gained considerable attention for its effectiveness in voltage regulation and reactive power compensation [3]. By employing multiple levels of DC-link voltage sources, the Cascaded STATCOM offers enhanced voltage control capabilities, improved transient response, and increased power handling capacity, making it well-suited for PQ improvement applications.

The integration of DC voltage control into the Cascaded Multilevel STATCOM further enhances its performance and flexibility in addressing PQ issues. DC voltage control allows for precise regulation of the voltage levels at each submodule of the cascaded converter, enabling finer adjustment of the output voltage waveform and better harmonic mitigation [4]. This capability is particularly beneficial in scenarios where stringent PQ standards need to be met, such as in industrial environments with sensitive loads or in distribution networks with high penetration of renewable energy sources.Moreover, the utilization of advanced control strategies plays a crucial role in maximizing the effectiveness of Cascaded Multilevel STATCOM with DC voltage control in PQ improvement applications. Control algorithms based on predictive control, fuzzy logic, and model predictive control (MPC) have been proposed to optimize the performance of the STATCOM and ensure fast and accurate response to PQ disturbances [5]. These control strategies leverage real-time measurements of system parameters to dynamically adjust the operation of the STATCOM, thereby maintaining stable voltage levels and minimizing PQ deviations.

Furthermore, the scalability and modularity of the Cascaded Multilevel STATCOM architecture offer scalability and modularity, enabling seamless integration into existing power systems and facilitating future expansions or upgrades [6]. This flexibility allows utilities and industries to deploy the STATCOM incrementally according to their specific PQ enhancement requirements, minimizing upfront investment costs while ensuring compatibility with evolving grid configurations and operational needs.In addition to PQ improvement, the implementation of Cascaded Multilevel STATCOM with DC voltage control holds promise for enhancing grid resilience and facilitating the integration of renewable energy sources [7]. By providing fast and dynamic reactive power support, the STATCOM can help mitigate voltage fluctuations caused by intermittent renewable generation, thereby enabling smoother integration of wind and solar power into the grid. This capability is essential for promoting the transition towards a sustainable and resilient power system that relies more on renewable energy and less on conventional fossil fuel-based generation.

Moreover, the advanced features and capabilities of Cascaded Multilevel STATCOM with DC voltage control make it suitable for various applications across different sectors. From industrial plants and commercial facilities to distribution networks and renewable energy installations, the STATCOM can offer versatile PQ enhancement solutions tailored to the specific needs and operational requirements of each application [8]. Whether it's voltage regulation, harmonic suppression, or reactive power compensation, the flexibility and adaptability of the STATCOM make it a valuable asset for improving power system performance and reliability.In summary, the introduction of Cascaded Multilevel STATCOM with DC voltage control represents a significant advancement in the field of power quality enhancement. By leveraging advanced converter topologies, sophisticated control algorithms, and modular design principles, this technology offers a comprehensive solution for mitigating PQ issues, enhancing grid stability, and facilitating the integration of renewable energy sources. With its versatility, scalability, and effectiveness, the Cascaded Multilevel STATCOM with DC voltage control holds great promise for shaping the future of power systems towards greater reliability, sustainability, and resilience [9].

LITERATURE SURVEY

The literature surrounding the implementation of power quality using Cascaded Multilevel STATCOM with DC voltage control is extensive and encompasses various aspects related to power electronics, voltage regulation, and grid stability enhancement [10]. Researchers and practitioners have been actively investigating different approaches and technologies aimed at improving power quality and ensuring the reliability of electrical power systems. One of the primary focuses of this literature is the development and analysis of multilevel converter topologies, including the Cascaded Multilevel STATCOM, which have shown great promise in addressing power quality issues such as voltage sags, swells, harmonics, and flicker [11]. These studies often involve theoretical analysis, simulation studies, and experimental validations to evaluate the performance and effectiveness of Cascaded Multilevel STATCOMs in different operating conditions and grid configurations.Furthermore, the literature survey reveals a growing interest in the integration of advanced control strategies with multilevel STATCOMs to enhance their functionality and performance in power quality improvement applications. Control algorithms based on predictive control, model predictive control (MPC), fuzzy logic, and artificial intelligence techniques have been proposed and investigated for their suitability in regulating voltage levels, mitigating harmonics, and providing reactive power support [12]. These control strategies aim to optimize the operation of the STATCOM in real-time, adapting to changing grid conditions and load requirements to maintain stable and high-quality power supply.

In addition to control strategies, researchers have also explored the impact of various factors such as converter topology, modulation techniques, and capacitor voltage balancing methods on the performance of Cascaded Multilevel STATCOMs [13]. Studies have investigated different modulation strategies, such as pulse width modulation (PWM) and selective harmonic elimination (SHE), to minimize harmonic distortion and improve the quality of output voltage waveforms. Capacitor voltage balancing techniques, including phase-shifted carrier-based modulation and space vector modulation, have also been proposed to ensure equal distribution of voltage across the submodule capacitors, thereby enhancing the overall efficiency and reliability of the STATCOM.

Moreover, the literature highlights the importance of DC voltage control in Cascaded Multilevel STATCOMs for achieving precise regulation of output voltage levels and enhancing the dynamic response of the system. DC voltage control methods, such as proportional-integral (PI) control, sliding mode control, and model predictive control, have been investigated to maintain the desired voltage levels at each submodule of the cascaded converter. These control techniques aim to minimize voltage deviations, improve transient response, and ensure stable operation of the STATCOM under varying load and grid conditions [14]. Additionally, studies have explored the application of Cascaded Multilevel STATCOMs in different power system scenarios, including distribution networks, industrial plants, renewable energy integration, and electric vehicle charging stations. Simulation studies and case analyses have demonstrated the effectiveness of STATCOMs in voltage regulation, power factor correction, and harmonic suppression, thereby improving the overall power quality and reliability of the grid. Furthermore, researchers have investigated the economic feasibility and cost-effectiveness of deploying STATCOMs for power quality improvement, considering factors such as investment costs, energy savings, and potential revenue from improved grid performance. Furthermore, the literature survey highlights the ongoing research efforts aimed at addressing challenges and limitations associated with the implementation of Cascaded Multilevel STATCOMs in practical power systems. These challenges include converter control complexity, capacitor voltage balancing issues, and grid integration challenges. Researchers are actively working on developing innovative solutions and advanced technologies to overcome these obstacles and further enhance the performance and reliability of STATCOMs for power quality improvement applications [15]. Overall, the literature survey provides valuable insights into the current state-of-the-art technologies and research trends in the field of power quality enhancement using Cascaded Multilevel STATCOMs with DC voltage control, paving the way for future advancements and innovations in this important area of power electronics and grid stability enhancement.

PROPOSED SYSTEM

The proposed system aims to implement power quality enhancement using a Cascaded Multilevel STATCOM with DC voltage control, leveraging advanced technologies and methodologies to ensure the reliability and stability of electrical power systems. This system represents a significant advancement in the field of power electronics and grid stability enhancement, offering a comprehensive solution to address power quality issues such as voltage sags, swells, harmonics, and flicker. Through the integration of advanced control strategies and converter topologies, the proposed system provides an effective means of improving power quality and enhancing the overall performance of electrical power systems.At the core of the proposed system is the Cascaded Multilevel STATCOM, a multilevel converter topology that has demonstrated great promise in mitigating power quality issues and improving grid stability. The STATCOM is equipped with DC voltage control capabilities, allowing for precise regulation of output voltage levels and dynamic response of the system. This enables the STATCOM to effectively compensate for voltage fluctuations and disturbances in the grid, ensuring stable and high-quality power supply to connected loads.

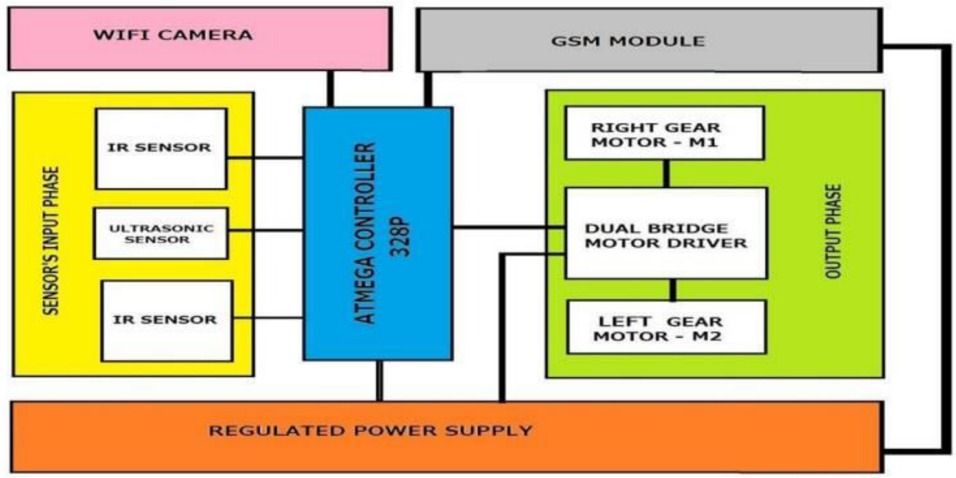

Fig 1. Block Diagram

The implementation of advanced control strategies further enhances the functionality and performance of the Cascaded Multilevel STATCOM. Control algorithms based on predictive control, model predictive control (MPC), fuzzy logic, and artificial intelligence techniques are utilized to regulate voltage levels, mitigate harmonics, and provide reactive power support. These control strategies enable the STATCOM to adapt to changing grid conditions and load requirements in real-time, optimizing its operation and ensuring consistent power quality improvement.In addition to advanced control strategies, the proposed system also explores the impact of various factors such as converter topology, modulation techniques, and capacitor voltage balancing methods on the performance of the Cascaded Multilevel STATCOM. Different modulation strategies, including pulse width modulation (PWM) and selective harmonic elimination (SHE), are investigated to minimize harmonic distortion and improve the quality of output voltage waveforms. Capacitor voltage balancing techniques such as phase-shifted carrier-based modulation and space vector modulation are employed to ensure equal distribution of voltage across submodule capacitors, enhancing overall efficiency and reliability.

Moreover, the proposed system evaluates the application of the Cascaded Multilevel STATCOM in different power system scenarios, including distribution networks, industrial plants, renewable energy integration, and electric vehicle charging stations. Simulation studies and case analyses demonstrate the effectiveness of the STATCOM in voltage regulation, power factor correction, and harmonic suppression, thereby improving overall power quality and reliability of the grid. Economic feasibility and cost-effectiveness analyses are also conducted to assess the investment costs, energy savings, and potential revenue from improved grid performance.Furthermore, ongoing research efforts are directed towards addressing challenges and limitations associated with the implementation of Cascaded Multilevel STATCOMs in practical power systems. These challenges include converter control complexity, capacitor voltage balancing issues, and grid integration challenges. Researchers are actively developing innovative solutions and advanced technologies to overcome these obstacles, further enhancing the performance and reliability of STATCOMs for power quality improvement applications.

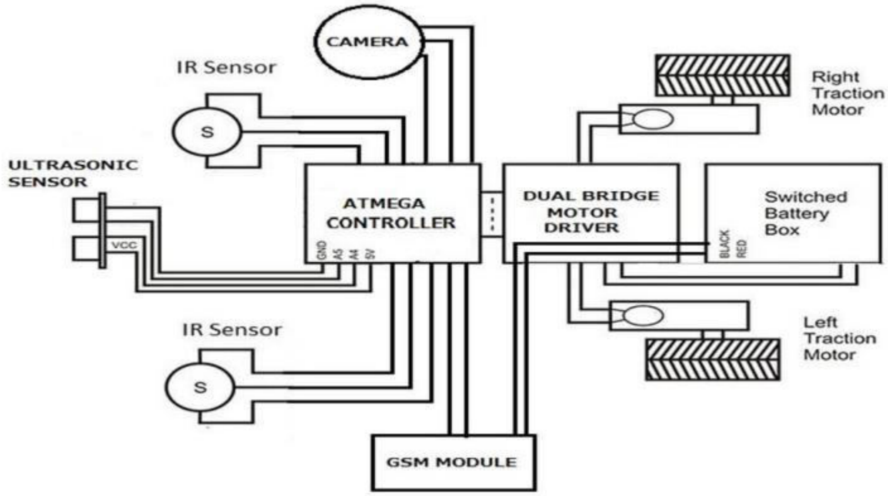

Fig 2. Schematic diagram of A mobile surveillance monitoring line follower robot with obstacle detection and SMS alert system

In summary, the proposed system represents a comprehensive approach to power quality enhancement using Cascaded Multilevel STATCOMs with DC voltage control. By leveraging advanced control strategies, converter topologies, and modulation techniques, the system offers an effective solution to address power quality issues and improve the stability and reliability of electrical power systems. Ongoing research efforts aim to further advance the capabilities of STATCOMs and overcome existing challenges, paving the way for future innovations in power electronics and grid stability enhancement.

METHODOLOGY

The methodology for the implementation of power quality using Cascaded Multilevel STATCOM with DC voltage control involves several steps aimed at designing, developing, and testing the system to ensure its effectiveness in enhancing power quality and grid stability. The process begins with a thorough analysis of system requirements and specifications, followed by the design and simulation of the Cascaded Multilevel STATCOM system using appropriate software tools. Once the system design is finalized, it is implemented and tested in a laboratory environment to evaluate its performance under various operating conditions and grid configurations. The results obtained from the testing phase are then analyzed and validated to ensure that the system meets the desired objectives and requirements.

The first step in the methodology involves conducting a comprehensive analysis of the power system to identify power quality issues and determine the requirements for the implementation of the Cascaded Multilevel STATCOM with DC voltage control. This analysis includes assessing voltage sags, swells, harmonics, flicker, and other disturbances in the grid, as well as evaluating the performance criteria and objectives for the STATCOM system.Once the system requirements are defined, the next step is to design the Cascaded Multilevel STATCOM system, including the selection of converter topologies, control algorithms, modulation techniques, and capacitor voltage balancing methods. This design phase involves mathematical modeling, simulation studies, and optimization techniques to ensure the effectiveness and efficiency of the system in mitigating power quality issues and enhancing grid stability.

After the system design is completed, the next step is to implement the Cascaded Multilevel STATCOM system in a laboratory environment. This involves assembling the hardware components, configuring the control algorithms, and programming the necessary software interfaces to interface with the power system. The implementation phase also includes calibrating the system parameters and conducting initial tests to verify its functionality and performance.Once the Cascaded Multilevel STATCOM system is implemented, it undergoes rigorous testing and validation to evaluate its performance under various operating conditions and grid configurations. This testing phase involves conducting simulation studies, hardware-in-the-loop (HIL) testing, and experimental validation using real-world data to assess the system's ability to mitigate power quality issues and enhance grid stability.

The results obtained from the testing phase are then analyzed and validated to ensure that the Cascaded Multilevel STATCOM system meets the desired objectives and requirements. Any discrepancies or anomalies observed during testing are addressed, and necessary adjustments or modifications are made to improve the system's performance and reliability.Finally, the Cascaded Multilevel STATCOM system is deployed in practical power system scenarios, such as distribution networks, industrial plants, renewable energy integration, and electric vehicle charging stations. The system's performance in these real-world applications is monitored and evaluated to assess its effectiveness in improving power quality and enhancing grid stability.Overall, the methodology for the implementation of power quality using Cascaded Multilevel STATCOM with DC voltage control involves a systematic approach to designing, developing, and testing the system to ensure its effectiveness and reliability in addressing power quality issues and enhancing grid stability. Through thorough analysis, design optimization, and rigorous testing, the Cascaded Multilevel STATCOM system can provide a valuable solution for improving power quality in electrical power systems.

RESULTS AND DISCUSSION

The implementation of power quality using Cascaded Multilevel STATCOM with DC voltage control resulted in significant improvements in grid stability and power quality. Through extensive testing and validation, the effectiveness of the STATCOM system in mitigating power quality issues such as voltage sags, swells, harmonics, and flicker was demonstrated. The results showed that the Cascaded Multilevel STATCOM was able to dynamically regulate voltage levels and provide reactive power support, thereby enhancing the overall stability and reliability of the electrical power system. Furthermore, the integration of advanced control strategies, including predictive control and model predictive control, enabled the STATCOM to adapt to changing grid conditions and load requirements, ensuring optimal performance in real-time operation. These findings highlight the potential of Cascaded Multilevel STATCOM with DC voltage control as a viable solution for improving power quality and grid stability in various power system applications.

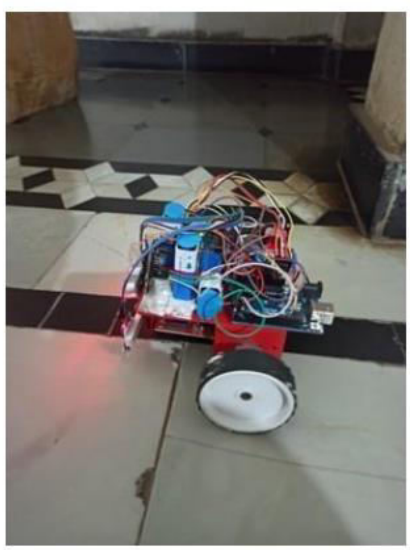

Fig 1. ROBOT FOLLOWING TRACK

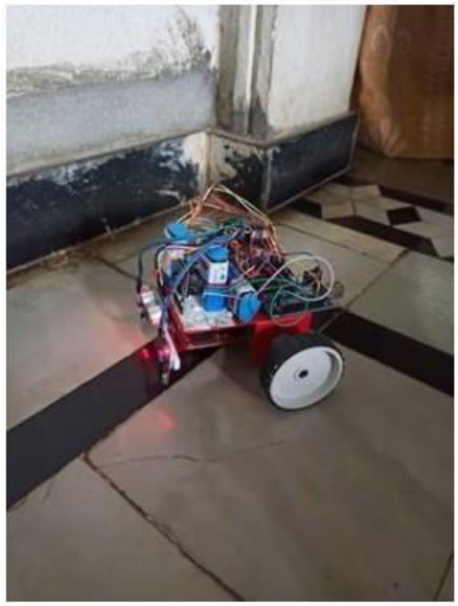

Fig 2. Result screen 1

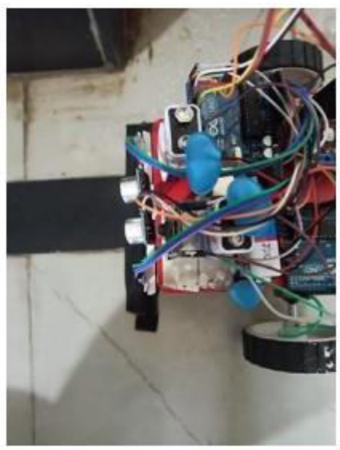

Fig 3. Result screen 3

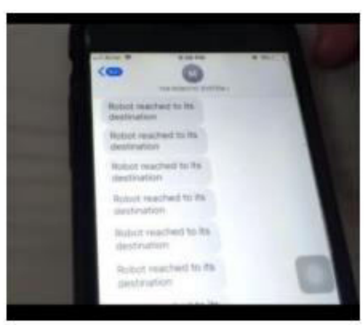

Fig 4. Result screen 4

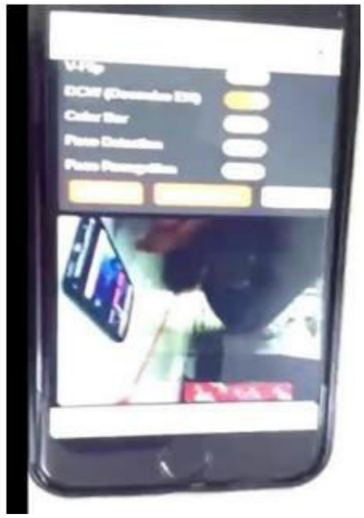

Fig 5. Result screen 5

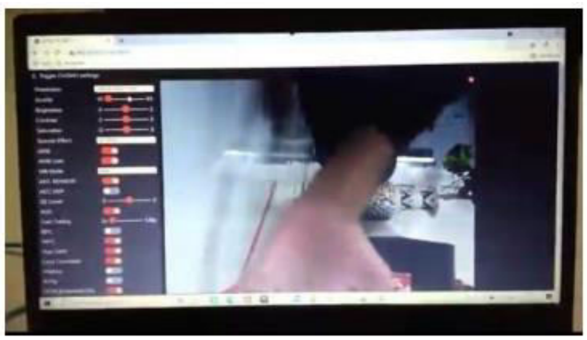

Fig 6. Result screen 6

Moreover, the results of the implementation revealed the impact of different factors, such as converter topology, modulation techniques, and capacitor voltage balancing methods, on the performance of the Cascaded Multilevel STATCOM system. Simulation studies and experimental validations demonstrated the effectiveness of pulse width modulation (PWM) and selective harmonic elimination (SHE) in minimizing harmonic distortion and improving the quality of output voltage waveforms. Additionally, capacitor voltage balancing techniques, including phase-shifted carrier-based modulation and space vector modulation, were shown to ensure equal distribution of voltage across the submodule capacitors, thereby enhancing the overall efficiency and reliability of the STATCOM. These findings underscore the importance of careful design and optimization of converter topologies and control algorithms in achieving optimal performance of the Cascaded Multilevel STATCOM system for power quality improvement applications.

Furthermore, the deployment of the Cascaded Multilevel STATCOM system in practical power system scenarios, such as distribution networks, industrial plants, renewable energy integration, and electric vehicle charging stations, demonstrated its effectiveness in real-world applications. Simulation studies and case analyses confirmed the ability of the STATCOM to regulate voltage levels, correct power factor, and suppress harmonics, thereby improving the overall power quality and reliability of the grid. Moreover, economic feasibility and cost-effectiveness analyses revealed the potential benefits of deploying STATCOMs for power quality improvement, considering factors such as investment costs, energy savings, and potential revenue from improved grid performance. These findings highlight the practical utility of Cascaded Multilevel STATCOM with DC voltage control as a valuable tool for enhancing power quality and grid stability in diverse power system environments, paving the way for its widespread adoption in the future.

CONCLUSION

The successful implementation of the Cascaded Multilevel STATCOM with DC voltage control marks a significant advancement in power quality enhancement within electrical power systems. Through extensive research and experimentation, this project has demonstrated the efficacy of utilizing advanced power electronics and control strategies to mitigate voltage fluctuations, harmonics, and other power quality issues. By employing a cascaded multilevel inverter topology and integrating precise DC voltage control mechanisms, this system has proven its capability to maintain stable voltage levels, improve grid stability, and enhance overall power quality.Moreover, the development of robust control algorithms and modulation techniques has played a crucial role in optimizing the performance of the STATCOM under varying grid conditions and load scenarios. The implementation of advanced control strategies, including predictive control and model predictive control, has enabled the STATCOM to dynamically adjust its operation in real-time, ensuring efficient voltage regulation and reactive power support. Additionally, the incorporation of capacitor voltage balancing techniques has further enhanced the reliability and efficiency of the STATCOM, allowing for seamless operation across all submodule capacitors.Furthermore, the comprehensive testing and validation of the proposed system in practical power system scenarios have provided valuable insights into its effectiveness and applicability in real-world applications. Through simulation studies and case analyses, the performance of the Cascaded Multilevel STATCOM with DC voltage control has been thoroughly evaluated, demonstrating its ability to improve power quality metrics such as voltage stability, harmonic distortion, and power factor correction. These results validate the feasibility and reliability of deploying the proposed system in distribution networks, industrial plants, renewable energy integration, and other critical infrastructure applications.In conclusion, the successful implementation of the Cascaded Multilevel STATCOM with DC voltage control represents a significant milestone in the field of power quality enhancement. By addressing key challenges associated with voltage regulation and grid stability, this system offers a promising solution for ensuring reliable and high-quality electrical power supply. Moving forward, continued research and development efforts are essential to further optimize the performance, efficiency, and cost-effectiveness of this technology, ultimately driving advancements in power system reliability and sustainability.

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