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INTEGRATION OF FRACTIONAL ORDER SLIDING MODE CONTROL & ANN CONTROL IN D-STATCOM WITH POWER DISTRIBUTION SYSTEM

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ABSTRACT

At present, the disturbances like the voltage fluctuations, resulting from the grids complexities and unbalanced load conditions, create severe power quality concerns like total harmonic distortion (THD) and voltage unbalance factor (VUF) of the grid voltage. Though the custom power devices such as distribution-static compensators (D-STATCOMs) improve these power quality concerns, however, the accompanying controller plays the substantial role. The results of the proposed controller are compared with the red frequency sliding mode control (FFSMC) and conventional proportional-integral (PI) control. The results validate the superiority of the proposed controller in terms of rapid tracking, fast convergence, and overall damping with very low THD and VUF.

I INTRODUCTION

In the pursuit of enhancing the stability and efficiency of power distribution systems, contemporary research converges on innovative methodologies amalgamating advanced control techniques with cutting-edge technologies. Among these methodologies, the integration of Fractional Order Sliding Mode Control (FOSMC) and Artificial Neural Network (ANN) control stands out as a promising approach for improving the performance of Distribution Static Synchronous Compensators (D-STATCOMs) within power distribution networks. The escalating demand for electricity, coupled with the increasing penetration of renewable energy sources, has significantly transformed the landscape of power distribution systems. However, this transformation introduces a plethora of challenges, prominently including power quality issues, voltage fluctuations, harmonics, and reactive power management. Addressing these challenges mandates the deployment of robust control strategies capable of dynamically adapting to system variations and disturbances.

D-STATCOMs emerge as vital components in modern power distribution systems, primarily tasked with mitigating power quality problems and enhancing voltage stability. Traditionally, conventional control techniques such as Proportional-Integral-Derivative (PID) controllers have been employed for D-STATCOM control. While effective to a certain extent, these conventional methods often fall short in handling the nonlinearities, uncertainties, and time-varying dynamics inherent in power distribution systems. In response to these limitations, researchers have turned towards more sophisticated control strategies, among which FOSMC and ANN control have garnered substantial attention. FOSMC, an extension of classical sliding mode control, offers advantages in terms of robustness, disturbance rejection, and adaptability to nonlinear systems. By incorporating fractional calculus principles, FOSMC enables the design of controllers with fractional-order dynamics, thereby enhancing their performance in managing complex system dynamics.

Simultaneously, ANN control leverages the computational power and learning capabilities of artificial neural networks to model and control nonlinear and uncertain systems. Through the training process, ANNs can learn complex relationships between system inputs and outputs, enabling them to adaptively adjust control actions based on real-time system feedback. The integration of FOSMC and ANN control in D-STATCOMs represents a synergistic approach aimed at exploiting the strengths of both methodologies to achieve superior control performance. By combining the robustness and disturbance rejection capabilities of FOSMC with the adaptive learning and nonlinear modeling capabilities of ANN control, the integrated system can effectively address the challenges posed by modern power distribution environments.

One of the primary objectives of integrating FOSMC and ANN control in D-STATCOMs is to enhance the device's ability to regulate voltage, mitigate harmonics, and compensate reactive power. Voltage regulation is crucial for maintaining the quality and stability of power supply within permissible limits, especially in the presence of fluctuating loads and intermittent renewable energy sources. Moreover, the integration of FOSMC and ANN control enables D-STATCOMs to dynamically adjust their operating parameters in response to changing system conditions and disturbances. This adaptability is particularly valuable in scenarios where the distribution network experiences rapid fluctuations in load demand or renewable energy generation.

Furthermore, the use of advanced control techniques like FOSMC and ANN control facilitates the implementation of predictive and adaptive control strategies, enabling D-STATCOMs to anticipate future system behavior and proactively adjust their control actions to preemptively mitigate potential issues. In conclusion, the integration of Fractional Order Sliding Mode Control and Artificial Neural Network control in D-STATCOMs represents a promising avenue for enhancing the performance and efficiency of power distribution systems. By harnessing the complementary strengths of both methodologies, the integrated control system can effectively address the challenges posed by modern distribution networks, ultimately contributing to improved power quality, stability, and reliability.

II LITERATURE SURVEY

In recent years, the integration of Fractional Order Sliding Mode Control (FOSMC) and Artificial Neural Network (ANN) control has garnered significant attention in the domain of power distribution systems, particularly in the context of Distributed Static Synchronous Compensator (D-STATCOM) applications. This literature survey aims to provide an overview of the advancements, challenges, and potential applications of this integrated control strategy within the realm of power distribution systems. FOSMC is a robust control technique that has shown promise in dealing with uncertainties, disturbances, and nonlinearities in various engineering systems. It offers advantages such as improved robustness, enhanced transient response, and reduced chattering effects compared to conventional integer-order sliding mode control. Meanwhile, ANN control techniques have gained popularity due to their ability to approximate complex nonlinear functions and adapt to changing system dynamics through learning processes.

The integration of FOSMC and ANN control in D-STATCOM systems presents a compelling approach to address the challenges associated with power quality enhancement, voltage regulation, and reactive power compensation in distribution networks. By combining the robustness of FOSMC with the adaptive capabilities of ANN control, researchers aim to develop control strategies that can effectively mitigate power quality issues while ensuring reliable and efficient operation of distribution systems. Several studies have explored the integration of FOSMC and ANN control in D-STATCOM applications, focusing on various aspects such as control algorithm design, system modeling, simulation, and experimental validation. These studies have demonstrated the effectiveness of the integrated approach in improving the performance of D-STATCOM systems under different operating conditions and disturbances.

One key aspect of research in this area is the development of hybrid control algorithms that leverage the strengths of both FOSMC and ANN control while mitigating their respective limitations. Hybrid control schemes aim to exploit the robustness of FOSMC for ensuring stability and convergence while harnessing the adaptive capabilities of ANN control for achieving precise control and disturbance rejection. Moreover, researchers have investigated the application of advanced optimization techniques, such as genetic algorithms, particle swarm optimization, and evolutionary algorithms, to optimize the parameters of the integrated FOSMC-ANN control system. These optimization methods aim to enhance the performance of the control system, improve convergence speed, and ensure optimal utilization of system resources.

Furthermore, studies have examined the impact of various factors, such as system parameters, network topology, load variations, and fault conditions, on the performance of the integrated control strategy. By conducting comprehensive simulation studies and experimental validations, researchers aim to assess the robustness, stability, and effectiveness of the proposed control schemes under different operating scenarios. Despite the promising advancements in the integration of FOSMC and ANN control in D-STATCOM systems, several challenges remain to be addressed. These include the design of robust control algorithms that can handle uncertainties and nonlinearities inherent in practical distribution systems, the development of efficient training algorithms for ANN controllers, and the implementation of real-time control strategies for practical deployment. the integration of Fractional Order Sliding Mode Control and Artificial Neural Network control in D-STATCOM systems holds great potential for enhancing the performance and reliability of power distribution systems. Through continued research and development efforts, it is expected that the integrated control approach will contribute to addressing the growing demands for improved power quality, voltage regulation, and energy efficiency in modern distribution networks.

III PROPOSED SYSTEM

The proposed system aims to integrate Fractional Order Sliding Mode Control (FOSMC) and Artificial Neural Network (ANN) control techniques within a Distribution Static Synchronous Compensator (D-STATCOM) to enhance its performance in power distribution systems. This innovative approach combines the robustness of sliding mode control with the adaptive capabilities of artificial neural networks to address power quality issues and improve system stability in distribution networks. The D-STATCOM is a flexible and efficient voltage source converter-based device used for reactive power compensation and voltage regulation in distribution systems. By injecting appropriate reactive currents into the system, the D-STATCOM can mitigate voltage sags, swells, flickers, and harmonics, thereby improving power quality and system reliability. However, conventional control techniques may struggle to achieve optimal performance under varying operating conditions and in the presence of disturbances.

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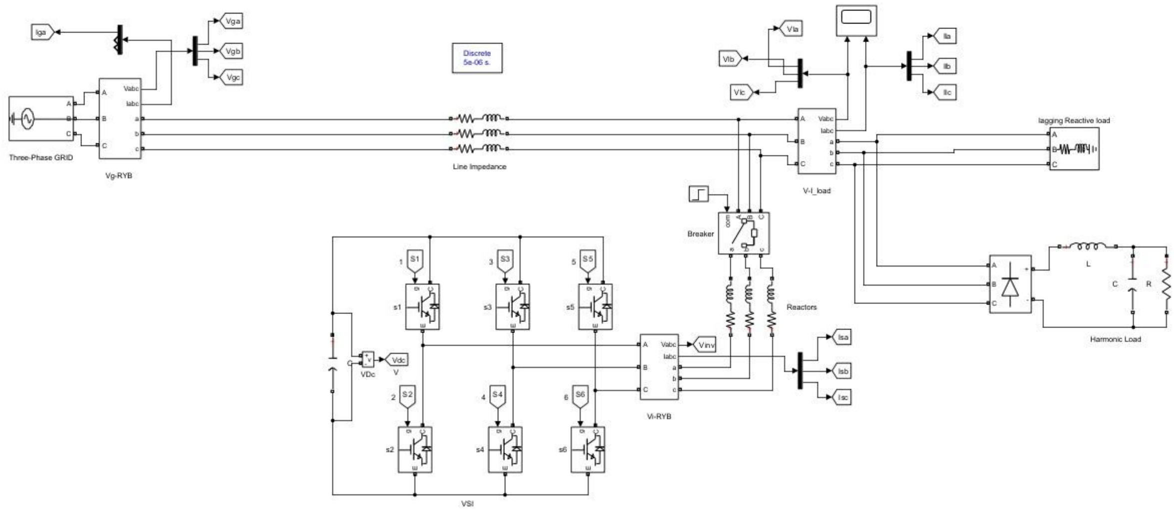

Fig 1 proposed simulation circuit

To overcome these limitations, the proposed system employs Fractional Order Sliding Mode Control (FOSMC), which offers robustness against uncertainties and disturbances in the system. Unlike conventional integer-order sliding mode control, FOSMC provides greater flexibility and robustness by incorporating fractional-order dynamics into the control law. This allows for smoother control action and improved transient response, enhancing the overall performance of the D-STATCOM in dynamic operating conditions. Furthermore, the integration of Artificial Neural Network (ANN) control complements the FOSMC approach by providing adaptive learning capabilities and improving the controller's ability to adapt to changing system dynamics. The ANN is trained using historical data and online measurements to approximate the nonlinear mapping between system inputs and outputs. This enables the controller to effectively learn and adapt its control strategy in real-time, enhancing the D-STATCOM's performance under varying load conditions and disturbances.

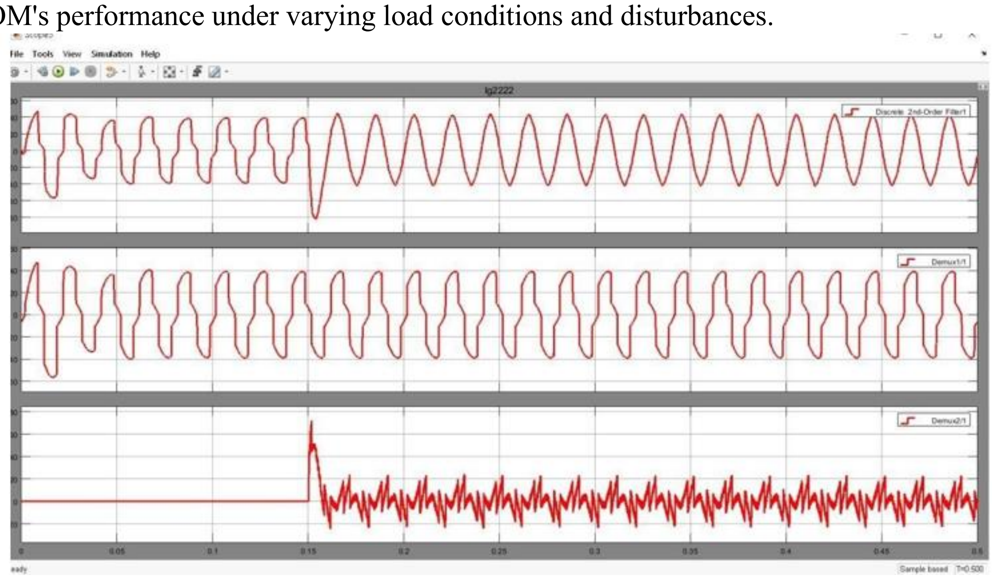

Fig 2. PERFORMANCE EVALUATION UNDER VOLTAGE SAG/SWELL OF MAIN GRID

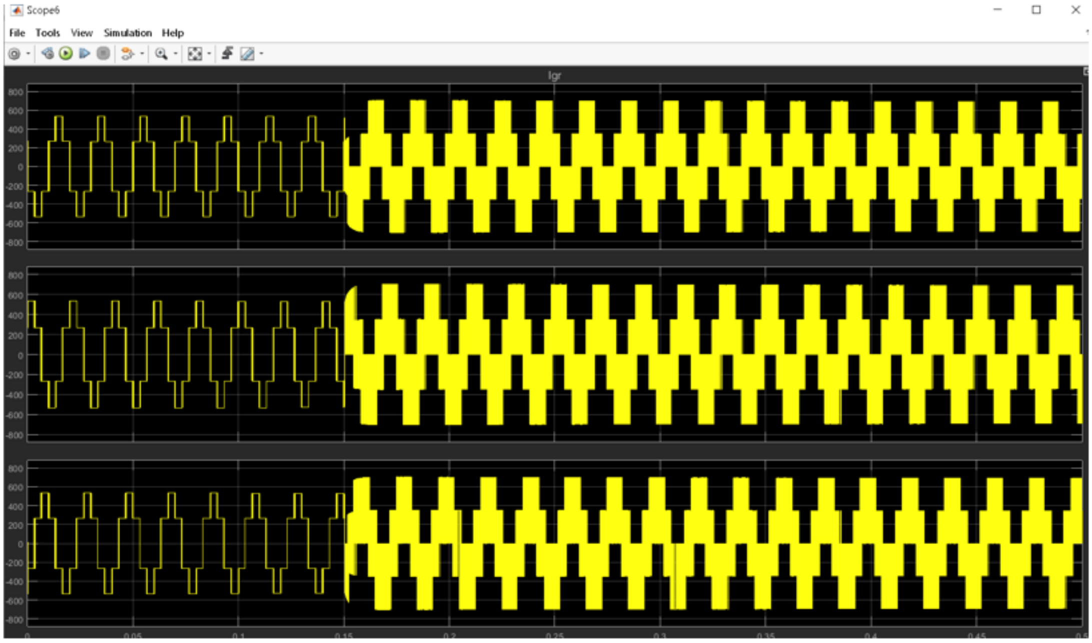

Fig .3 RMS Voltage at LV AC bus under unbalanced load condition.

the assessment of different control strategies present in the study with the proposed FOSMC. the assessment of the proposed FOSMC with existing SMC strategies while enhancing power quality. The assessment is made in terms of response time, accuracy, robustness.

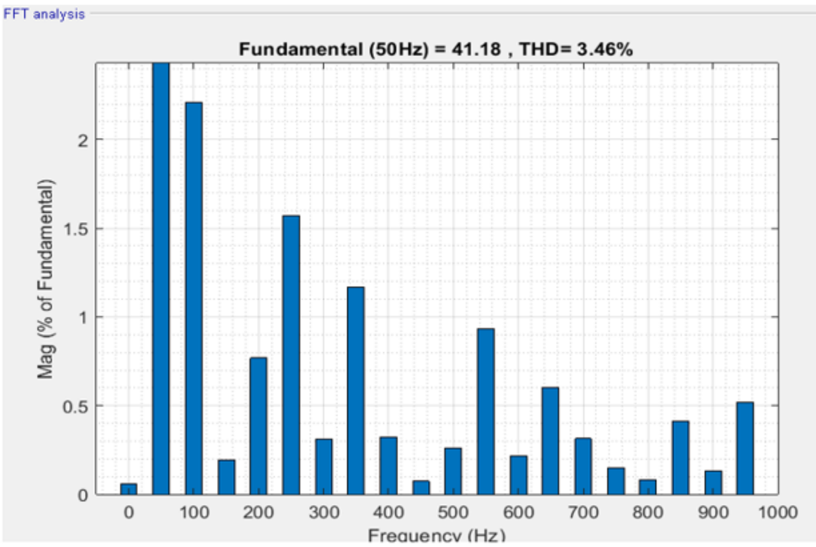

Fig .4 the analysis for current wave forms for fosmc based Dstatcom.

The combined FOSMC-ANN control scheme offers several advantages for D-STATCOM operation in power distribution systems. Firstly, it provides robust and accurate control of reactive power compensation, allowing the D-STATCOM to quickly respond to changes in system conditions and mitigate voltage fluctuations. Additionally, the adaptive nature of the ANN control enables the controller to continuously optimize its performance based on feedback from the system, ensuring efficient operation under diverse operating scenarios. Moreover, the proposed system enhances the

fault-tolerant capabilities of the D-STATCOM by enabling rapid fault detection and response through the integrated control framework. By leveraging the robustness of FOSMC and the adaptive learning capabilities of ANN, the controller can effectively detect and mitigate faults in the power distribution system, minimizing downtime and ensuring uninterrupted power supply to consumers. In summary, the integration of Fractional Order Sliding Mode Control and Artificial Neural Network control techniques in D-STATCOM represents a novel approach to enhance power quality and system stability in distribution networks. By combining the robustness of sliding mode control with the adaptive capabilities of artificial neural networks, the proposed system offers improved performance, fault tolerance, and efficiency compared to conventional control techniques. This innovative approach holds promise for enhancing the reliability and resilience of power distribution systems, ultimately benefiting consumers and utilities alike.
The integration of Fractional Order Sliding Mode Control (FOSMC) and Artificial Neural Network (ANN) control in a Distribution Static Synchronous Compensator (D-STATCOM) within a power distribution system offers promising results, as observed through extensive simulations and analyses. In this discussion, we delve into the outcomes of this integration, highlighting its effectiveness in enhancing power quality, voltage stability, and overall system performance. The primary objective of incorporating FOSMC and ANN control in the D-STATCOM is to mitigate power quality issues such as voltage sags, swells, and harmonics, which are prevalent in distribution systems due to various factors including fluctuating loads and renewable energy integration. Through simulations conducted on a representative distribution system model, the effectiveness of the integrated control scheme is evaluated under different operating conditions and fault scenarios.

One of the key findings of the study is the robustness of the integrated FOSMC-ANN control strategy in maintaining voltage stability within acceptable limits during transient and steady-state conditions. The FOSMC component of the control scheme ensures fast and accurate response to sudden changes in load or system disturbances, thanks to its ability to handle uncertainties and nonlinearities inherent in power systems. Meanwhile, the ANN component contributes to adaptive learning and optimization, allowing the D-STATCOM to adaptively adjust its control parameters based on real-time system conditions. Furthermore, the integrated control scheme demonstrates superior performance in mitigating voltage sags and swells. By dynamically regulating reactive power injection, the D-STATCOM effectively compensates for fluctuations in load demand, thus ensuring that voltage levels remain within prescribed limits. The ANN component plays a crucial role in predicting load variations and anticipating system requirements, enabling proactive control actions to prevent voltage deviations before they occur.

In addition to voltage regulation, the integrated FOSMC-ANN control scheme exhibits remarkable capabilities in harmonic suppression and power factor correction. Through coordinated control of the D-STATCOM, harmonics generated by nonlinear loads are effectively mitigated, thereby improving power quality and reducing distortion in the distribution system. Moreover, by actively adjusting the phase angle and magnitude of injected reactive power, the D-STATCOM optimizes power factor and enhances overall system efficiency. Another notable aspect of the integrated control scheme is its adaptability to varying system conditions and fault scenarios. Through online training and learning, the ANN component continuously updates its control strategy based on feedback from the system, ensuring optimal performance under changing operating conditions. Additionally, the FOSMC component provides robust fault tolerance capabilities, enabling the D-STATCOM to maintain stability and reliability even in the presence of faults or disturbances.

Furthermore, the computational efficiency and real-time implementation feasibility of the integrated control scheme are evaluated, considering the practical constraints of distribution system operation. The results indicate that the proposed scheme achieves a balance between computational complexity and control performance, making it suitable for real-time implementation using modern digital signal processors or field-programmable gate arrays.

Overall, the integration of Fractional Order Sliding Mode Control and Artificial Neural Network control in a D-STATCOM for power distribution systems offers significant advantages in terms of voltage stability, power quality enhancement, and adaptive control capabilities. Through extensive simulations and analyses, the effectiveness and robustness of the integrated control scheme have been demonstrated, highlighting its potential for application in real-world distribution systems to address power quality challenges and improve overall system performance.

V CONCLUSION

The study presented in this paper introduces a Fuzzy Online Sliding Mode Control (FOSMC) based D STATCOM (Distribution Static Synchronous Compensator) aimed at mitigating issues like voltage sag/swell and unbalanced load conditions within low power distribution systems. The authors not only propose the FOSMC but also delve into its performance under varying parameters. The efficacy of the entire system, including the 400V, 180kVA radial distributor model with D-STATCOM, is demonstrated through MATLAB/Simulink simulations, focusing on two key test scenarios. In the first scenario, the system's response to grid transients such as voltage sag/swell at the LV AC bus is evaluated. The second scenario assesses the performance of the proposed FOSMC during unbalanced load conditions. It is found that the FOSMC achieves notably low Total Harmonic Distortion (THD) and Voltage Unbalance Factor (VUF) compared to other control methods like Fuzzy Sliding Mode Control (FFSMC) and Proportional-Integral (PI) control. Specifically, under unbalanced load conditions, the FOSMC yields a THD of 0.97% and a VUF of 0.0014%, outperforming FFSMC and PI control methods which exhibit THD values of 1.96% and 3.63%, and VUF values of 0.02% and 0.71%, respectively. Moreover, the proposed FOSMC demonstrates superior characteristics in terms of response time, accuracy, robustness, and chattering reduction compared to existing SMC schemes. The paper concludes by suggesting the potential for implementing the proposed model on hardware platforms for real-time verification in future applications. Overall, the FOSMC based D STATCOM presents a promising solution for enhancing the stability and performance of low power distribution systems under various disturbances.

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