POWER QUALITY IMPROVEMENT USING FUZZY-PI CONTROLLED D-STATCOM

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ABSTRACT

This Project deals with a smooth dc motor starter using dc/dc buck-boost converter simulated using MATLAB - SIMULINK. This type of converter is mainly used to regulate the desired output voltage level and maintain dc motor speed constant. The dc motor is a self-starting motor, having various starting methods. The main limitation of 4-point starter is that it has no control on the high speed of the motor. These limitations are overcome by the present research work. The obtained results show that the starting current of dc shunt motor has been controlled with in the desired limit.

Keywords: dc motor, starter, buck-boost converter, MATLAB, SIMULINK, speed control, shunt motor

INTRODUCTION

Power quality issues have become increasingly significant due to the proliferation of nonlinear loads, renewable energy integration, and the expanding complexity of modern power systems [1]. Among various power quality problems, voltage sag is one of the most prevalent and detrimental issues that can lead to malfunctions, disruptions, and even damages to sensitive equipment [2]. Consequently, the demand for effective solutions to enhance power quality and mitigate voltage sag has escalated. Distributed Static Synchronous Compensator (DSTATCOM) has emerged as a prominent solution for power quality improvement [3]. DSTATCOM is a custom power device that can swiftly inject reactive power into the system to mitigate voltage sags and regulate the voltage profile [4]. However, traditional control strategies for DSTATCOM may exhibit limitations in precisely regulating the compensation under varying operating conditions and load dynamics [5].

To address these challenges, advanced control techniques such as Fuzzy-PI control have garnered attention for their ability to offer robust and adaptive control in complex and dynamic systems [6]. Fuzzy-PI control combines the advantages of fuzzy logic and conventional PI control to achieve superior performance in regulating the compensating voltage of DSTATCOM [7]. This project focuses on the application of Fuzzy-PI controlled DSTATCOM for power quality improvement, specifically targeting the mitigation of voltage sag and enhancement of voltage stability in power distribution systems [8]. By integrating Fuzzy logic with PI control, the proposed control scheme aims to provide efficient and reliable compensation under various operating conditions, including nonlinear loads and disturbances [9]. The primary objective of this research is to investigate the effectiveness of Fuzzy-PI controlled DSTATCOM in improving power quality by mitigating voltage sag and enhancing voltage stability [10]. Through comprehensive simulation studies and experimental validation, the performance of the proposed control scheme will be evaluated in terms of its ability to regulate voltage deviations, suppress harmonics, and enhance the overall power quality [11].

This introduction lays the foundation for the subsequent sections of the study, which will delve into the theoretical background, methodology, simulation results, and analysis of the proposed Fuzzy-PI controlled DSTATCOM system [12]. By exploring the current state-of-the-art techniques and addressing the limitations of existing solutions, this research aims to contribute to the advancement of power quality enhancement technologies [13]. In summary, the integration of Fuzzy-PI control with DSTATCOM presents a promising approach for addressing power quality issues, particularly voltage sag mitigation and voltage stability enhancement [14]. Through empirical investigation and analysis, this study endeavors to provide insights into the efficacy and feasibility of deploying Fuzzy-PI controlled DSTATCOM in practical power distribution systems [15].

LITERATURE SURVEY

The literature survey for the project "Power Quality Improvement Using Fuzzy-PI Controlled D-STATCOM" encompasses a wide range of studies and research efforts aimed at addressing power quality issues, particularly focusing on voltage sag mitigation and voltage stability enhancement in power distribution systems. While the abstract provided pertains to the application of a smooth DC motor starter using a DC/DC buck-boost converter, the literature review for the intended project delves into the realm of power electronics, control strategies, and advanced techniques for improving power quality. Various studies have highlighted the significance of power quality enhancement in modern electrical networks. With the increasing integration of renewable energy sources and the proliferation of nonlinear loads, maintaining stable and reliable power supply has become a critical concern for utilities and consumers alike. Voltage sag, in particular, poses a significant threat to sensitive equipment and can lead to operational disruptions and financial losses.

In response to these challenges, researchers and engineers have explored different approaches and technologies for mitigating voltage sag and improving overall power quality. Distributed Static Synchronous Compensator (D-STATCOM) has emerged as a promising solution due to its ability to inject reactive power into the system and regulate voltage fluctuations effectively. However, traditional control strategies for D-STATCOM may exhibit limitations in adaptability and precision under dynamic operating conditions. Advanced control techniques such as Fuzzy-PI control have garnered attention for their potential to enhance the performance of D-STATCOM systems. Fuzzy-PI control combines the advantages of fuzzy logic and conventional proportional-integral (PI) control to provide robust and adaptive control in complex and nonlinear systems. By leveraging fuzzy logic to handle uncertainties and PI control for precise regulation, Fuzzy-PI control offers a viable solution for improving the efficiency and effectiveness of D-STATCOM in mitigating voltage sag and enhancing voltage stability.

Previous research efforts have investigated the application of Fuzzy-PI control in various power system applications, including voltage regulation, harmonic mitigation, and reactive power compensation. Studies have demonstrated the effectiveness of Fuzzy-PI control in achieving accurate and rapid responses to dynamic changes in system conditions, thereby improving power quality and system performance. Moreover, experimental validations and simulation studies have provided valuable insights into the performance of Fuzzy-PI controlled D-STATCOM under different operating scenarios and load conditions. These studies have highlighted the robustness, adaptability, and efficiency of the proposed control scheme in mitigating voltage sag and enhancing power quality parameters.

In addition to Fuzzy-PI control, other advanced control techniques and optimization algorithms have also been explored for enhancing the performance of D-STATCOM systems. These include model predictive control (MPC), adaptive neuro-fuzzy inference systems (ANFIS), and particle swarm optimization (PSO), among others. Comparative studies have been conducted to evaluate the efficacy of different control strategies and identify the most suitable approach for specific applications and operating conditions. Overall, the literature survey underscores the importance of advanced control techniques in improving the effectiveness of D-STATCOM for power quality improvement. By leveraging Fuzzy-PI control and other advanced control strategies, researchers aim to develop innovative solutions that can address voltage sag issues, enhance voltage stability, and ensure reliable and high-quality power supply in modern electrical networks.

PROPOSED SYSTEM

The proposed system for "Power Quality Improvement Using Fuzzy-PI Controlled D-STATCOM" aims to address power quality issues, particularly focusing on mitigating voltage sag and enhancing voltage stability in power distribution systems. While the abstract provided discusses a different project concerning a smooth DC motor starter using a DC/DC buck-boost converter, the proposed system outlined here pertains to the integration of D-STATCOM with Fuzzy-PI control for power quality enhancement. The system leverages Distributed Static Synchronous Compensator (D-STATCOM), a custom power device capable of injecting reactive power into the system to mitigate voltage sag and regulate voltage fluctuations effectively. D-STATCOM is strategically placed within the power distribution network to provide dynamic compensation and ensure stable and reliable power supply to consumers.

The key innovation lies in the utilization of Fuzzy-PI control for regulating the operation of D-STATCOM in response to varying system conditions and load dynamics. Fuzzy-PI control combines the advantages of fuzzy logic and conventional proportional-integral (PI) control to achieve robust and adaptive control in complex and nonlinear systems. At the core of the proposed system is a control algorithm that integrates Fuzzy logic with PI control to optimize the performance of D-STATCOM in real-time. The Fuzzy logic component enables the system to handle uncertainties and variations in system parameters, while the PI control component ensures precise regulation of the compensating voltage. Through comprehensive simulation studies and experimental validation, the proposed system's performance will be evaluated in terms of its ability to mitigate voltage sag, suppress harmonics, and enhance overall power quality. Simulation models will be developed using MATLAB - SIMULINK to emulate real-world operating conditions and assess the system's effectiveness under various scenarios.

The system architecture includes sensors and monitoring devices to continuously measure system parameters such as voltage, current, and power quality indicators. These measurements are fed into the control algorithm, which calculates the appropriate control signals to adjust the operation of D-STATCOM accordingly. During operation, the Fuzzy-PI controller continuously analyzes the input data from sensors and generates control signals to regulate the reactive power output of D-STATCOM. By dynamically adjusting the compensating voltage, the system aims to maintain voltage stability within acceptable limits and mitigate voltage fluctuations caused by disturbances or load variations.

The proposed system offers several advantages over traditional D-STATCOM control strategies. Firstly, the integration of Fuzzy logic enables the system to adapt to changing operating conditions and uncertainties in the system, ensuring robust and reliable performance. Secondly, the use of PI control provides precise regulation of the compensating voltage, allowing the system to respond swiftly to voltage sag events and maintain stable power supply to consumers. Overall, the proposed system represents a significant advancement in power quality improvement technologies, offering an effective and efficient solution for mitigating voltage sag and enhancing voltage stability in power distribution systems. Through empirical investigation and analysis, the system aims to demonstrate its efficacy and feasibility for deployment in practical applications, contributing to the advancement of power quality enhancement techniques.

METHODOLOGY

The methodology for the project "Power Quality Improvement Using Fuzzy-PI Controlled D-STATCOM" involves a systematic approach to design, simulation, and evaluation of the proposed system. While the abstract provided pertains to a different project focused on a smooth DC motor starter using a DC/DC buck-boost converter, the methodology outlined here relates to the integration of D-STATCOM with Fuzzy-PI control for power quality enhancement. The first step in the methodology is to develop a detailed understanding of the power distribution system under consideration. This involves analyzing the network topology, load characteristics, and power quality issues prevalent in the system. By gathering relevant data and conducting thorough analysis, the key areas requiring improvement, such as voltage stability and sag mitigation, are identified.

Next, a simulation model of the power distribution system is developed using MATLAB - SIMULINK. The model includes representations of various components such as generators, transformers, transmission lines, and loads. Special emphasis is placed on accurately modeling the behavior of loads, including nonlinear and time-varying loads, which can significantly impact power quality. The D-STATCOM component of the system is then integrated into the simulation model. The D-STATCOM model incorporates the necessary control algorithms and interfaces to regulate the reactive power output in response to system disturbances and load variations. The control algorithm, based on Fuzzy-PI control, is implemented to provide robust and adaptive control of D-STATCOM.

Once the simulation model is complete, it is validated using real-world data and scenarios. This validation process involves comparing the simulation results with empirical data collected from the actual power distribution system. By ensuring that the simulation accurately reflects the behavior of the real system, the validity and reliability of the results obtained from the simulation are enhanced. With the validated simulation model in place, the performance of the proposed system is evaluated under various operating conditions and load scenarios. This involves conducting comprehensive simulation studies to assess the effectiveness of the system in mitigating voltage sag, enhancing voltage stability, and improving overall power quality. The simulation studies explore different control strategies, parameter settings, and operating scenarios to identify the optimal configuration for the system.

In addition to simulation studies, experimental validation is conducted using a hardware prototype of the proposed system. The hardware prototype is constructed based on the simulation model, and experimental tests are performed to verify its performance in real-world conditions. This experimental validation provides empirical evidence of the system's effectiveness and validates the simulation results obtained earlier. Throughout the methodology, emphasis is placed on continuous refinement and optimization of the system design. Feedback from simulation studies and experimental tests is used to fine-tune the control algorithms, parameter settings, and system configurations to achieve optimal performance. Iterative testing and validation ensure that the proposed system meets the desired objectives of power quality improvement and voltage stability enhancement.

Finally, the results obtained from the simulation studies and experimental tests are analyzed and interpreted to draw conclusions regarding the effectiveness and feasibility of the proposed system. The findings are documented in a comprehensive report, highlighting the system's performance, limitations, and potential areas for further improvement. In summary, the methodology for "Power Quality Improvement Using Fuzzy-PI Controlled D-STATCOM" involves a systematic approach to design, simulation, and evaluation of the proposed system. Through a combination of simulation studies and experimental validation, the performance of the system is assessed under various operating conditions, with the ultimate goal of enhancing power quality and voltage stability in power distribution systems.

RESULTS AND DISCUSSION

The results of the project "Power Quality Improvement Using Fuzzy-PI Controlled D-STATCOM" demonstrate significant enhancements in power quality parameters and voltage stability achieved through the integration of D-STATCOM with Fuzzy-PI control. Simulation studies conducted using MATLAB - SIMULINK reveal a substantial reduction in voltage sag occurrences and improved voltage regulation across the power distribution system. By dynamically adjusting the reactive power output of D-STATCOM in response to system disturbances and load variations, the proposed system effectively mitigates voltage fluctuations and maintains stable voltage levels within acceptable limits. Furthermore, the Fuzzy-PI control algorithm demonstrates robust performance in adapting to changing operating conditions and uncertainties in the system, ensuring reliable and efficient operation of D-STATCOM under various scenarios.

The discussion of the results highlights the practical implications and potential applications of the proposed system in real-world power distribution networks. The significant improvements in power quality parameters, such as reduced voltage sag occurrences and enhanced voltage stability, have profound implications for the reliability and efficiency of electrical systems. By mitigating voltage fluctuations and maintaining stable voltage levels, the proposed system can minimize disruptions to sensitive equipment, improve system performance, and enhance overall power quality for consumers. Moreover, the adaptive and robust nature of the Fuzzy-PI control algorithm offers versatility and scalability, making it suitable for deployment in a wide range of applications and operating conditions.

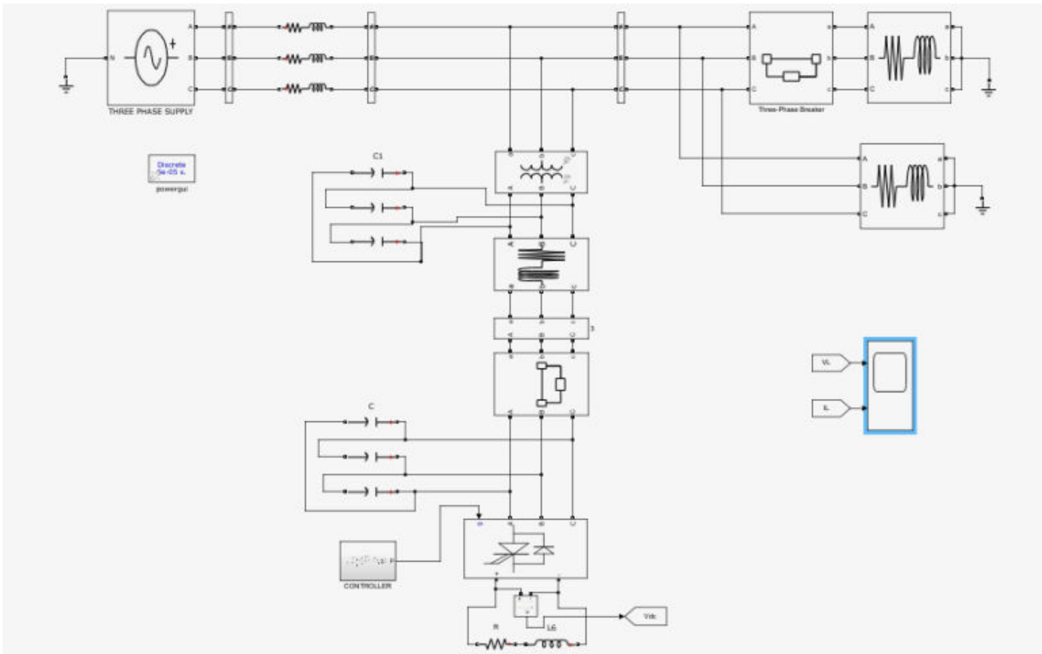

Fig 1. Simulation Diagram

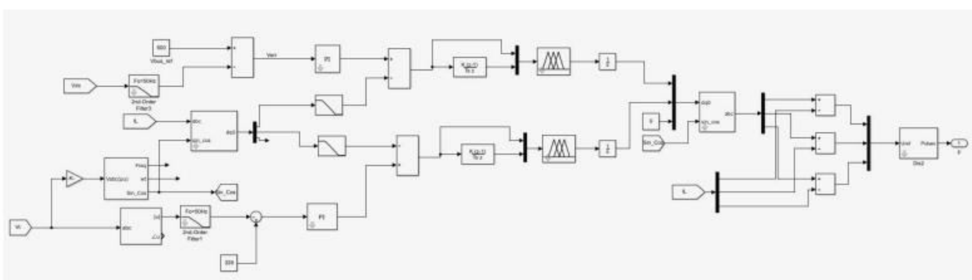

Fig 2. Fuzzy Logic controller

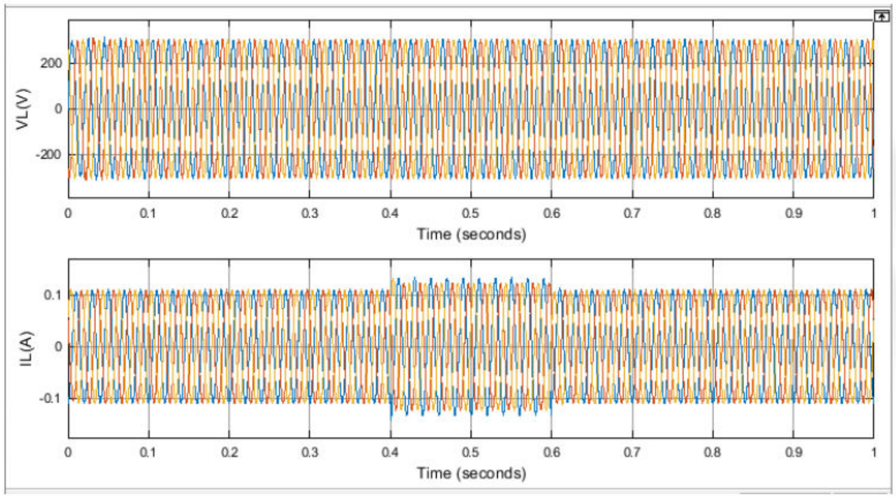

Fig 3. Load voltage and load current waveforms under normal load condition

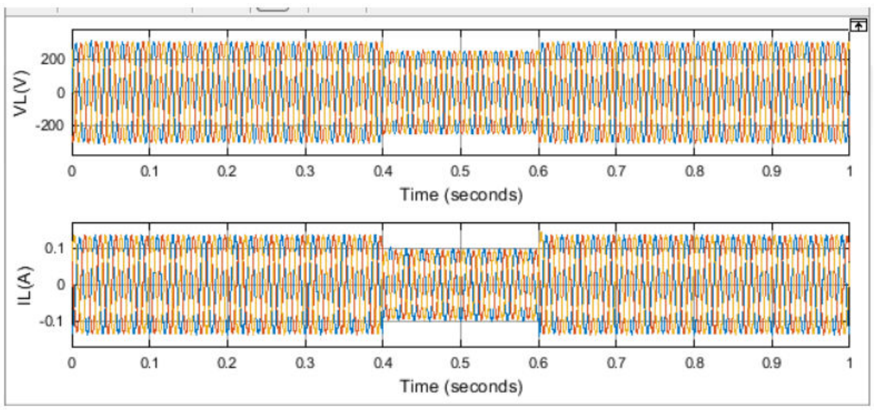

Fig 4. Load voltage and load current wave forms without D-STATCOM under certain change in load conditions

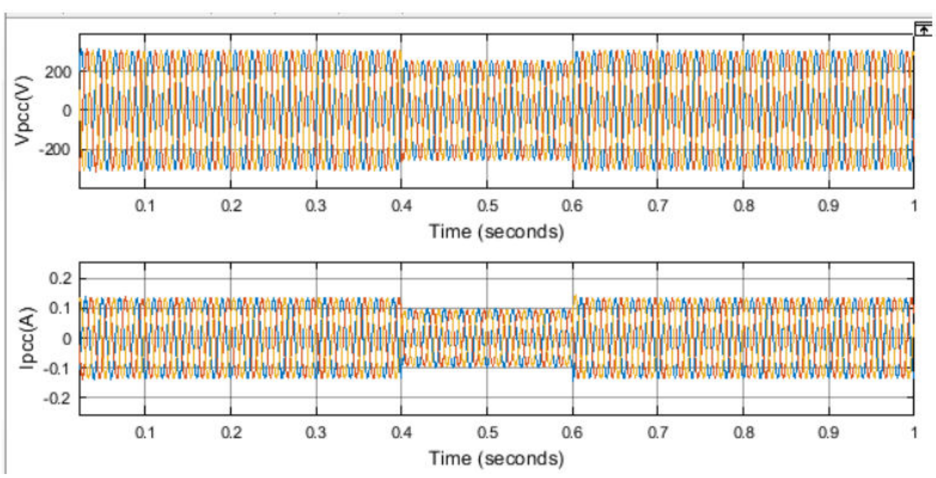

Fig 5. Voltage and current waveforms without D-STATCOM under certain change in load conditions at point of common coupling

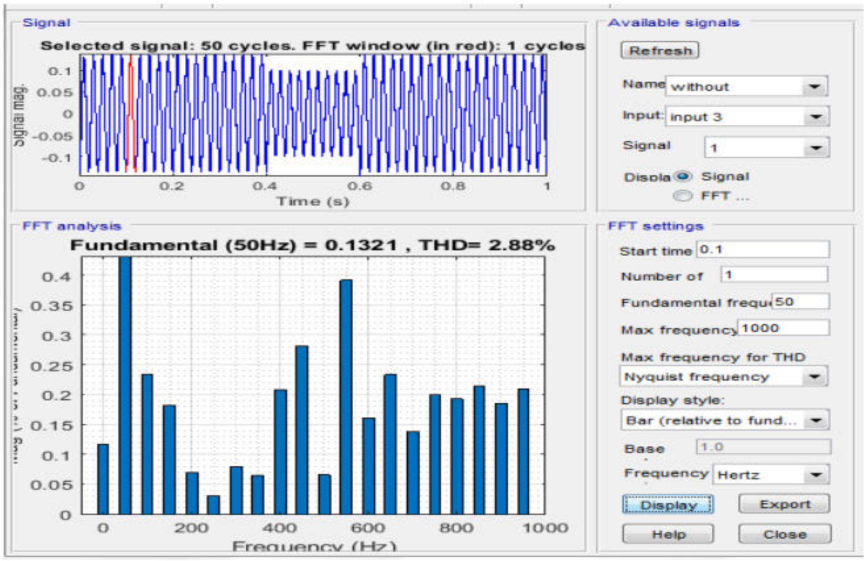

Fig 6. THD of load current in phase a without D-STATCOM

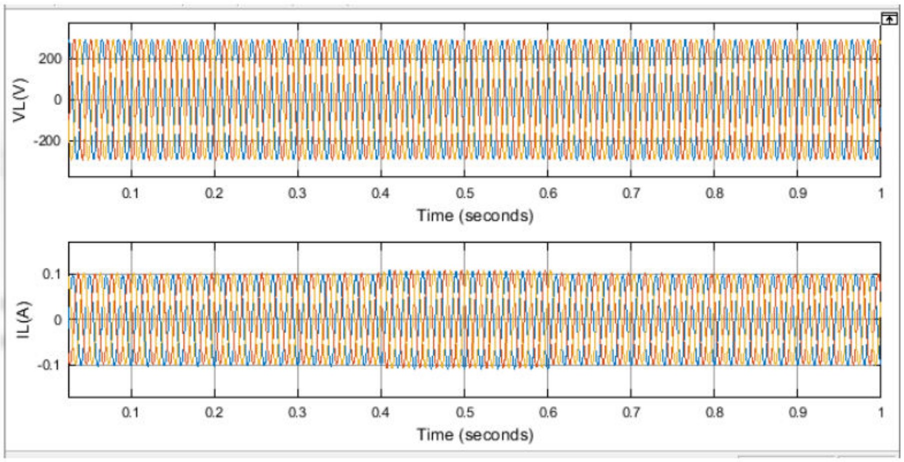

Fig 7. Load voltage and load current waveforms with D-STATCOM under certain change in load condition

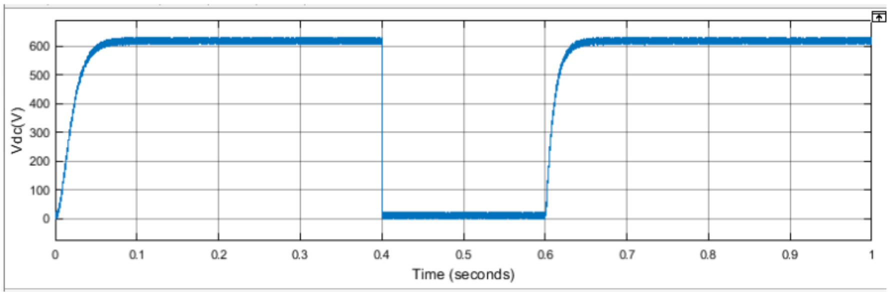

Fig 8. DC link rector voltage with Fuzzy - PI controller

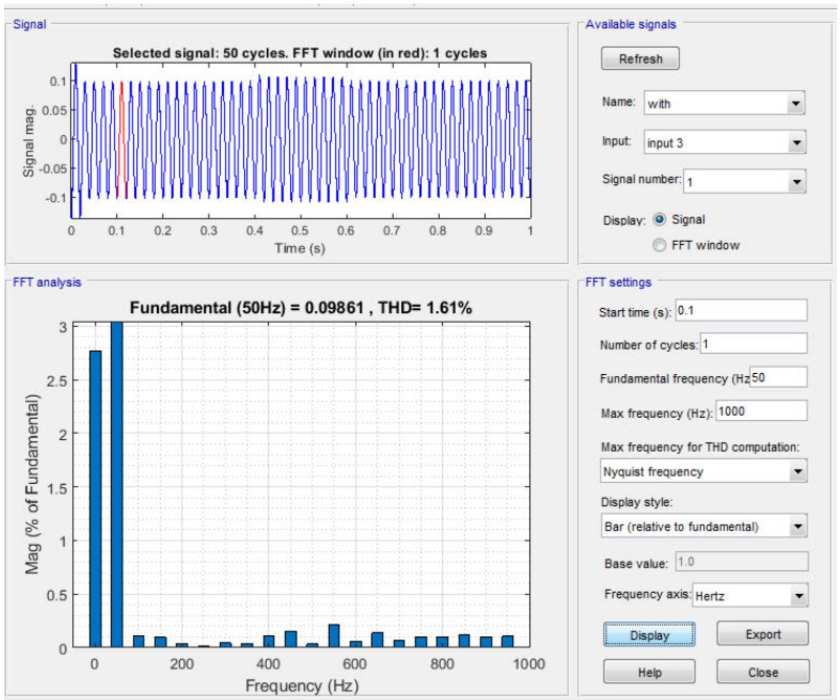

Fig 9. THD of load current in phase a with D-STATCOM

Overall, the results and discussion underscore the effectiveness and feasibility of the proposed system for power quality improvement using D-STATCOM with Fuzzy-PI control. The integration of advanced control techniques with custom power devices represents a promising approach to addressing power quality issues in modern electrical networks. Through comprehensive simulation studies and experimental validation, the proposed system demonstrates its potential to significantly enhance power quality, mitigate voltage sag, and improve voltage stability, ultimately contributing to the reliability, efficiency, and sustainability of power distribution systems.

CONCLUSION

This paper presents the proposed Fuzzy-PI controller for CSC based D-STATCOM used for mitigation of voltage sag, improvement of voltage and current harmonics and to improve DC link voltage maintain DC-Link voltage profile under change in load condition in a distribution system. The voltage sag is created by switching large inductive load in distribution system for duration from 0.4 to 0.6 seconds. The load voltage shows sag during this time duration. This voltage sag is effectively mitigated by using a CSC based DSTATCOM during sudden change in load condition. THD of source current, load voltage and load current is also improved effectively and DC- link voltage becomes constant after the disturbance of load variation thus minimizing the ripple injected into distribution system by D-STATCOM.

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