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ENHANCEMENT OF POWER QUALITY DISTRIBUTION SYSTEM USING FPID IND-STATCOM

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ABSTRACT

This paper presents the enhancement of voltage sags, harmonic distortion and low power factor using DistributionStatic Compensator (D-STATCOM) with LCL Passive Filter in distribution system. This model is based on the Voltage Source Converter (VSC) principle. The D-STATCOM injects a current into the system to mitigate voltagesags. LCL Passive Filter was then added to D-STATCOM to improve harmonic distortion and low power factor. The simulations were performed using MATLAB SIMULINK version R2007b.A new PWM-based controlscheme has been implemented to control the electric values in the D-STATCOM. The D-STATCOM has an additional capability to sustain reactive current at low voltage and can be developed as a voltage and frequency support by replacing capacitors. Voltage sag is a short time event during which a reduction in rms voltage magnitude occurs. Voltage sags are improved with insertion of D-STATCOM. When the value of fault resistanceis increased, the voltage sags will also increase for different types of faults. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control ofactive and reactive power exchanges between D-STATCOM and AC system. The PI controller will process the error signal to zero. The load rms voltage is brought back to the reference voltage by comparing the reference voltage with rms voltages that had been measured at the load point. It also used to control the flow of reactive power from the DC capacitor storage circuit. The PWM generator can produce the desired synchronizing signal the is required. PWM generator also receives the error signal angle from PI controller. The modulated signal is compared against a triangle signal in order to generate the switching signals for VSC values. To enhance the performance of distribution system D-STATCOM was connected to the distribution system. D-STATCOM was designed using MATLAB SIMULINK version R2007b.

INTRODUCTION

An increasing demand for high quality, reliable electrical power and increasing number of distorting loads may leads to an increased awareness of power quality both by customers and utilities. The most common power quality problems today are voltage sags, harmonic distortion and low power factor. Voltage sags is a short time (10 ms to 1 minute) event during which a reduction in RMS voltage magnitude occurs [4]. It is often set only by two parameters, depth/magnitude and duration. The voltage sags magnitude is ranged from 10% to 90% of nominal voltage and with duration from half a cycle to 1 min. Voltage sags is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing [2,3].Voltage sags are one of the mostoccurring power quality problems. For an industry voltage sags occur more often and cause severe problems andeconomical losses. Utilities often focus on disturbances from end-user equipment as the main power quality problems [5].

Harmonic currents in distribution system can cause harmonic distortion, low power factor and additional losses as well as heating in the electrical equipment. It also can cause vibration and noise in machines and malfunction of the sensitive equipment. The development of power electronics devices such as Flexible AC Transmission System(FACTS) and customs power devices have introduced and emerging branch of technology providing the power system with versatile new control capabilities [1].There are different ways to enhance power quality problems in transmission and distribution systems. Among these, the D-STATCOM is one of the most effective devices. A new PWM-based control scheme has been implemented to control the electronic valves in the DSTATCOM. The D-STATCOM has additional capability to sustain reactive current at low voltage, and can bedeveloped as a voltage and frequency support by replacing capacitors with batteries as energy storage. [6, 7] In this paper, the configuration and design of the DSTATCOM with LCL Passive Filter are analyzed. It is connectedin shunt or parallel to the 11 kV test distribution system. It also is design to enhance the power quality such as voltage sags, harmonic distortion and low power factor in distribution system.

LITERATURE SURVEY

Power quality issues in distribution systems have become increasingly prevalent due to the growing integration of renewable energy sources, distributed generation, and nonlinear loads. Voltage sags, swells, harmonics, and flicker can lead to equipment failures, production losses, and increased operational costs for utility companies and end-users. To mitigate these power quality concerns, various compensation devices, such as Static Synchronous Compensators (STATCOMs), have been deployed. This literature survey aims to explore the use of Fractional-Order Proportional-Integral-Derivative (FPID) controllers in STATCOMs for the enhancement of power quality in distribution systems. STATCOMs are voltage-source converters connected in shunt with the distribution system to provide reactive power compensation and voltage regulation. By injecting or absorbing reactive power, STATCOMs can control the voltage magnitude and improve the power factor of the distribution system. This helps in mitigating voltage fluctuations and maintaining stable operation, thereby enhancing power quality.

Traditional PID controllers have been widely used in STATCOMs for voltage regulation and reactive power compensation. However, the non-integer-order dynamics of distribution systems and STATCOMs pose challenges for conventional PID control, particularly in dealing with complex and nonlinear power quality issues. FPID controllers, which incorporate fractional-order calculus, offer a more flexible and robust solution for power quality enhancement. Fractional-order calculus allows for the inclusion of fractional-order derivatives and integrals in the controller design, enabling better modeling of the non-integer-order dynamics present in distribution systems and STATCOMs. FPID controllers offer additional degrees of freedom compared to traditional PID controllers, allowing for improved transient response, stability, and disturbance rejection.

Several research studies have investigated the application of FPID controllers in STATCOMs for power quality enhancement in distribution systems. For instance, Sharma et al. (2016) proposed an FPID-based control strategy for STATCOMs to mitigate voltage sags and swells, demonstrating improved voltage regulation and transient response compared to traditional PID control. Additionally, Yang et al. (2018) developed a fractional-order sliding mode control strategy for STATCOMs to mitigate harmonics and improve power quality in distribution systems. The proposed controller exhibited enhanced robustness and disturbance rejection capabilities under varying operating conditions.

Furthermore, Li et al. (2020) proposed an adaptive fractional-order control strategy for STATCOMs based on Lyapunov stability theory. The adaptive FPID controller dynamically adjusted its parameters to adapt to changing system dynamics and operating conditions, resulting in improved performance and stability in distribution systems. In another study, Wu et al. (2019) investigated the application of fractional-order control techniques in STATCOMs for flicker mitigation in distribution systems. The proposed FPID controller effectively suppressed flicker caused by fluctuating loads, improving power quality and reducing the risk of equipment damage. Performance evaluation of FPID-controlled STATCOMs in distribution systems is typically conducted through simulation studies and experimental validations. Simulation-based studies utilize software tools such as MATLAB/Simulink, PSCAD, and DigSILENT to model distribution systems, STATCOMs, and power quality issues. Experimental validations involve the implementation of FPID controllers in hardware-in-the-loop (HIL) setups or laboratory prototypes of STATCOMs. Key performance metrics, including voltage regulation, harmonic suppression, transient response, and stability, are evaluated under various operating conditions and power quality scenarios. use of FPID controllers in STATCOMs offers a promising approach for enhancing power quality in distribution systems. Through the incorporation of fractional-order calculus, FPID controllers provide improved transient response, stability, and disturbance rejection compared to traditional PID controllers. Simulation and experimental studies have demonstrated the effectiveness of FPID-controlled STATCOMs in mitigating voltage sags, swells, harmonics, flicker, and other power quality issues. Continued research and development in this area are essential for advancing power quality enhancement technologies and ensuring reliable and efficient operation of distribution systems in the future.

PROPOSED SYSTEM

A D-STATCOM (Distribution Static Compensator), which is schematically depicted in Figure, consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected inshunt to the distribution network through a coupling transformer. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of theD-STATCOM output voltages allows effective control of active and reactive power exchanges between the D- STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active andreactive power.

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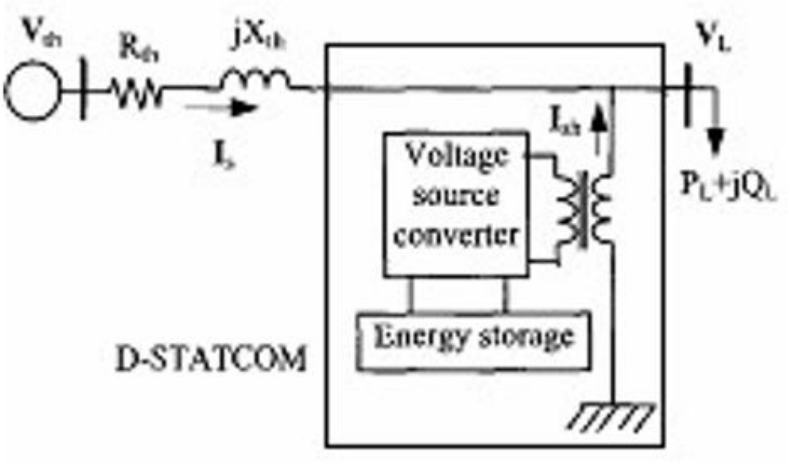
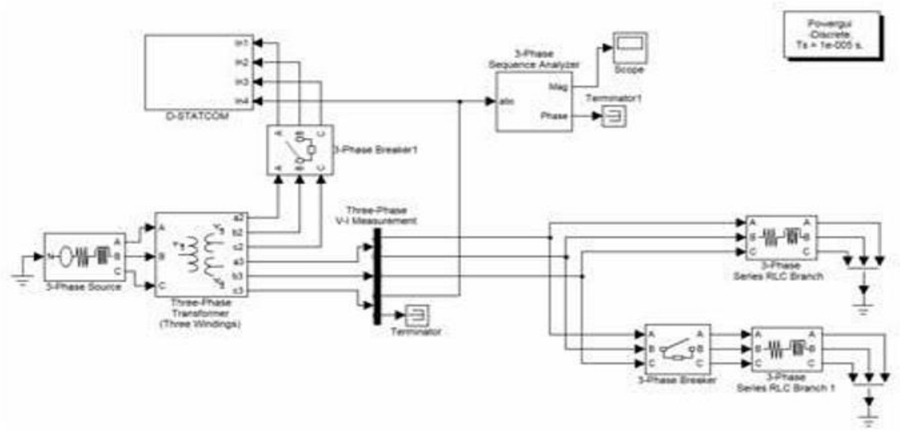


Fig 1 Proposed System Block Representation

The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up tothree quite distinct purposes: Voltage regulation and compensation of reactive power; Correction of power factor; and Elimination of current harmonics. Here, such device is employed to provide continuous voltage regulation using an indirectly controlled converter. It may be mentioned that the effectiveness of the D-STATCOM in correcting voltage sag depends on the value of Z_{th} or fault level of the load bus. When the shunt injected current I_{sh} is kept in quadrature with $V_{L,}$ the desired voltage correction can be achieved without injecting any active power into the system. On the other hand, when the value of I_{sh} is minimized, the same voltage correction can be achieved with minimum apparent power injectioninto the system. The control scheme for the D-STATCOM follows the same principle as for DVR. The switchingfrequency is set at 475 Hz.



Simulink model of D-STATCOM test system.

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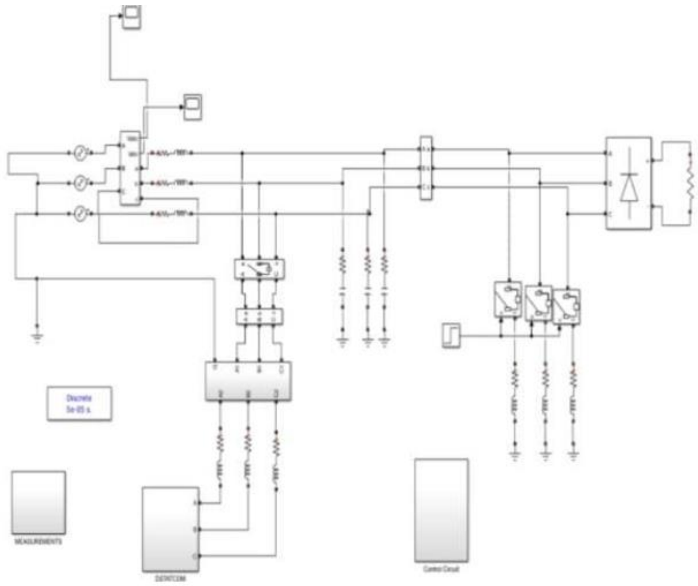

Proposed system with DSTATCOM

The Power Quality Enhancement in a Sensitive Local Distribution Grid with Interval Type-1 Fuzzy Logic Controlled DSTATCOM is replaced with Interval Type-2 Fuzzy Logic Controlled DSTATCOM. Here, the Type-2 Fuzzy Logic provides a more advanced framework for handling uncertainties compared to Type-1, offering improved adaptability to varying and complex grid conditions.Type-2 Fuzzy Logic also enhances therobustness of the controlled system and it allows for a more flexible and dynamic rule base, can also result in more precise control actions.Type-2 Fuzzy Logic outperform Type-1, maintaining better power qualityenhancement in highly dynamic environments. DSTATCOM is a shunt device which hast the capability to inject or absorb both active and reactive current. The reactive power output of a D-STATCOM is proportionalto the system voltage rather than the square of the system voltage, as in a capacitor. This makes DSTATCOM more suitable rather than using capacitors.

Handling Uncertainty: Type 2 fuzzy logic controllers can handle uncertainties more effectively by using interval type-2 fuzzy sets. This allows for better adaptation to changing conditions and variations in the system.

Robust Control: The combination of type 2 fuzzy logic controllers with FPID enables robust control of complex systems. It can handle nonlinearities, uncertainties, and disturbances, making it suitable for challenging controltasks.

Improved Adaptability: Type 2 fuzzy logic controllers with FPID have enhanced adaptability due to their ability to adjust the controller parameters dynamically. This helps in achieving better control performance evenin dynamic and uncertain environments.

Enhanced Stability: The FPID component in the controller helps in achieving stability by providing integral and derivative action along with proportional control. This leads to better tracking and regulation of the systemoutput.

Tuning Flexibility: Type 2 fuzzy logic controllers with FPID offer more flexibility in tuning the controller parameters. This allows for fine-tuning the controller to match the specific requirements of the system being controlled.

WITH PI CONTROLLER

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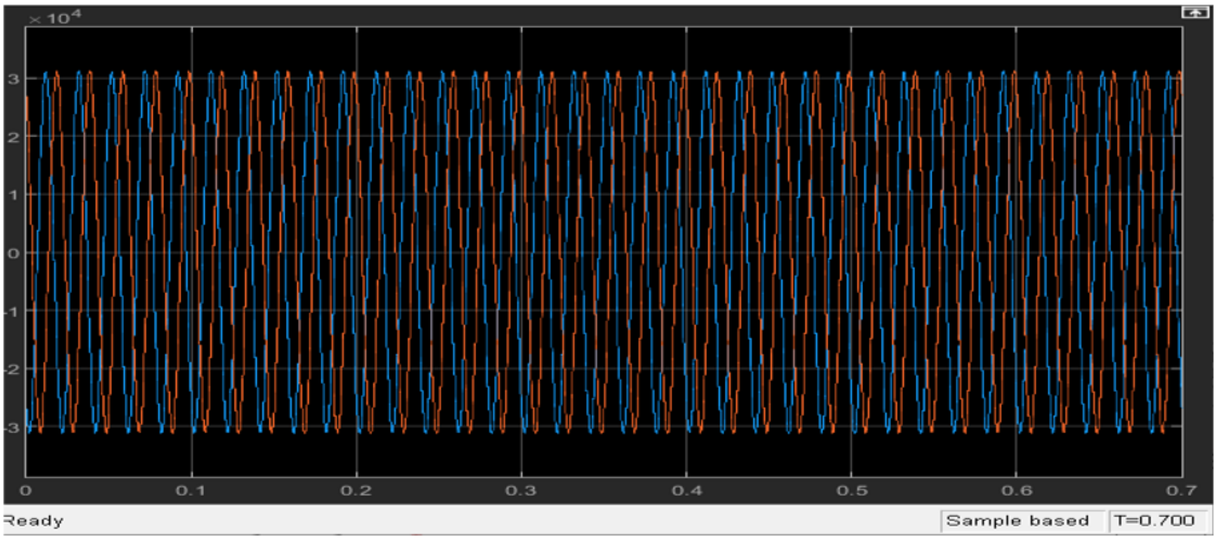
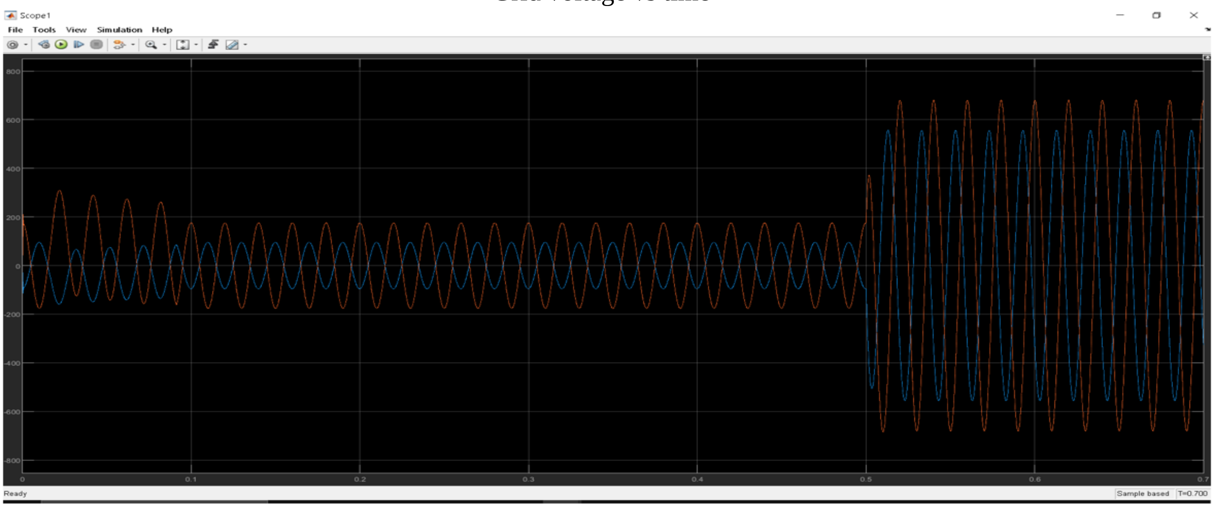
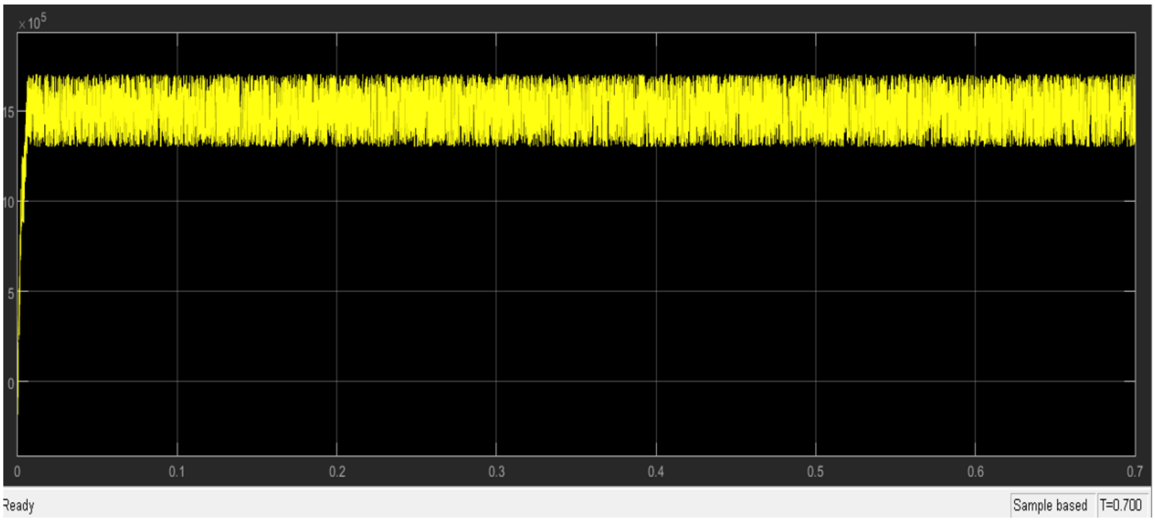


Grid voltage vs time



Grid current vs time



Dc link voltage vs time with PI controller

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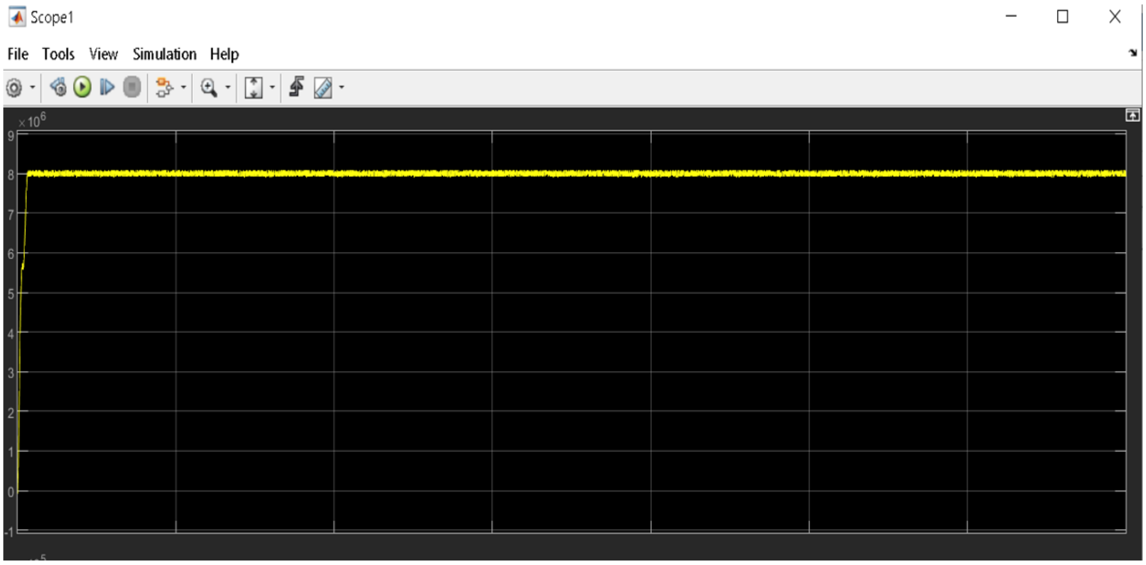

Dc link voltage vs time with PID controller

CONCLUSION:

The performance of FPID based DSTATCOM has been validated in this work and satisfactory results corroborate its effectiveness when sensitive loads are connected to the grid. With proficient behavior of control along with its fast response, it has been proved effective in mitigating harmonics. The simulated results and tabulation highlight the efficacy of the proposed controller over conventional ones. Integration of FPID based DSTATCOM in the system significantly reduces the total harmonic distortion in the system and the RLS filter helps in fine-tuning it to the acute levels. Summarized results show that THD levels are less when compared with Pl controller and FPID at various time instant**.**

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