Applied GIS

ISSN: 1832-5505
Vol-9 Issue-03 July 2021

ENHANCEMENT OF POWER QUALITY DISTRIBUTION SYSTEM USING FPID IND-STATCOM

C SUMALATHA, ASSISTANT PROFESSOR, sumalathacherukuri@gmail.com
S ASHIK ILAHI, ASSISTANT PROFESSOR, shaikashik@gmail.com
A SABIHA, ASSISTANT PROFESSOR, asabiha.227@gmail.com
Dept of Electrical and Electronics Engineering at Sri Venkateswara Institute of Technology,
N.H 44,Hampapuram, Rapthadu, Anantapuramu, Andhra Pradesh 515722

ABSTRACT

Thispaperpresentstheenhancementofvoltagesags, harmonicdistortionandlowpowerfactorusingDistributionStatic Compensator (D-STATCOM) with LCL Passive Filter in distribution system. This model is based on theVoltageSourceConverter(VSC)principle.The DSTATCOMinjectsacurrentintothesystemtomitigatevoltagesags. LCL Passive Filter was then added to D-STATCOM to improve harmonic distortion and low powerfactor. ThesimulationswereperformedusingMATLABSIMULINKversionR2007b.AnewPWM-basedcontrolscheme has been implemented to control the electric values in the D-STATCOM. The D-STATCOM has anadditional capability to sustain reactive current at low voltage and can be developed as a voltage and frequencysupport by replacing capacitors. Voltage sag is a short time event during which a reduction in rms voltagemagnitude occurs. Voltage sags are improved with insertion of D-STATCOM. When the value of fault resistanceisincreased, thevoltagesags will also increasefordifferent types of faults.Suitableadjustmentofthephaseandmagnitudeofthe DSTATCOMoutputvoltagesallowseffectivecontrolofactive and reactive power exchanges between D-STATCOM and AC system. The PI controller will process theerror signal to zero. The load rms voltage is brought back to the reference voltage by comparing the referencevoltage with rms voltages that had been measured at the load point. It also used to control the flow of reactivepower from the DC capacitor storage circuit. The PWM generator can produce the desired synchronizing signaltheis required. PWM generatoralso receives theerrorsignal angle from PIcontroller. The modulated signal is compared against a triangle signal in order to generate the switching signals for VSCvalues. To enhance the performance of distribution system D-STATCOM was connected to the distributionsystem. D-STATCOMwas designed using MATLAB SIMULINKversion R2007b.

INTRODUCTION

An increasing demand for high quality, reliable electrical power and increasing number of distorting loads mayleadstoanincreasedawarenessofpowerquality bothbycustomersandutilities.Themostcommonpowerqualityproblems today are voltage sags, harmonic distortion and low power factor. Voltage sags is a short time (10 msto 1 minute) event during which a reduction in RMS voltage magnitude occurs [4]. It is often set only by twoparameters, depth/magnitude and duration. The voltage sags magnitude is ranged from 10% to 90% of nominalvoltageand with duration from halfacycle to1min. Voltage sags is caused by a fault in the utility system, a fault within the customer's facility or a largeincreaseoftheloadcurrent,likestartingamotor ortransformerenergizing[2,3].Voltagesagsareone ofthemostoccurringpowerqualityproblems.Foranindustryvoltagesagsoccurmoreoftenand causeseverepropblemsandeconomical losses. Utilities often focus on disturbances from end-user equipment as the main power qualityproblems[5].

Harmonic currents in distribution system can cause harmonic distortion, low power factor and additional lossesas well as heating in the electrical equipment. It also can cause vibration and noise in machines and malfunctionof the sensitive equipment. The development of power electronics devices such as Flexible AC TransmissionSystem(FACTS) and customs power devices have introduced and emerging branch of technology providing thepower system with versatile new control capabilities [1].There are different ways to enhance power qualityproblems in transmission and distribution systems. Among these, the D-STATCOM is one of the most effectivedevices. A new PWM-based control scheme has been implemented to control the electronic valves in theDSTATCOM. 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] Inthispaper,theconfigurationanddesignoftheDSTATCOMwithLCLPassiveFilterareanalyzed.Itisconnectedin shunt or parallel to the 11 kV test distribution system. It also is design to enhance the power quality such asvoltagesags, harmonic distortion and low power factor indistribution 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 StaticCompensator), which is schematically depicted in Figure, consistsofatwo-

Applied GIS

ISSN: 1832-5505
Vol-9 Issue-03 July 2021

levelVoltageSourceConverter(VSC),adcenergystoragedevice,acouplingtransformerconnectedinshunt to the distribution network through a coupling transformer. The VSC converts the dc voltage across thestorage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the acsystemthroughthereactanceofthecouplingtransformer.Suitableadjustmentofthephaseandmagnitudeofthe D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOMandtheacsystem.Suchconfigurationallowsthedevicetoabsorborgeneratecontrollableactiveandreactivepower.

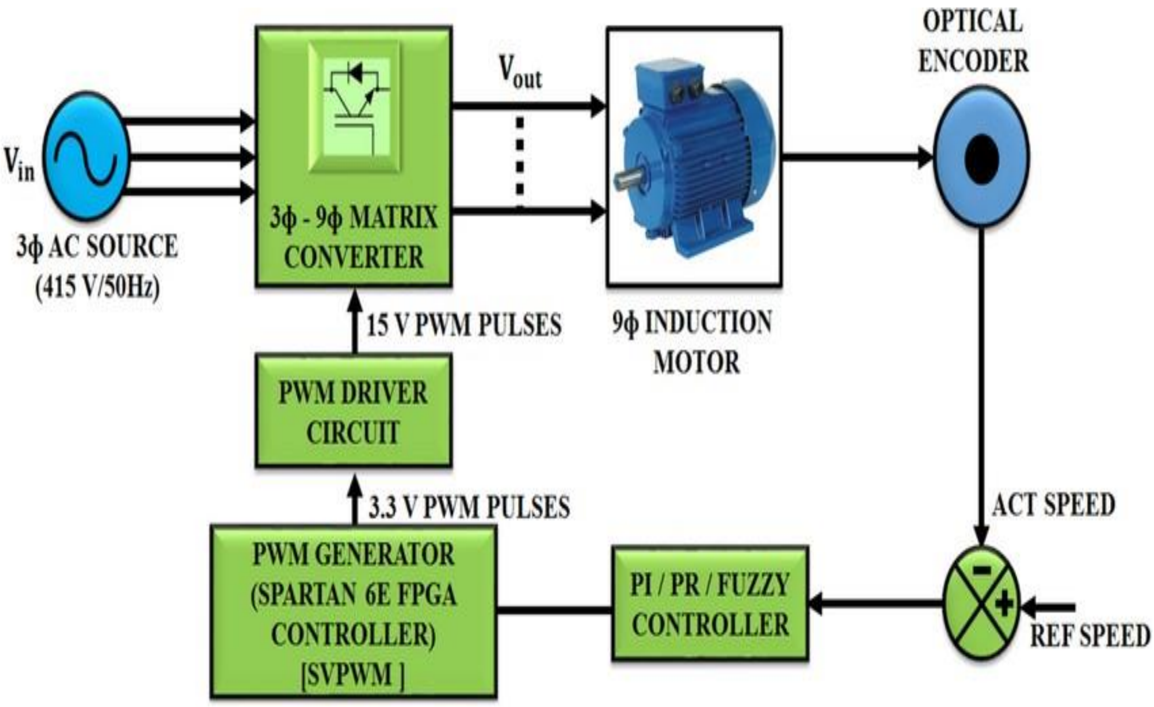
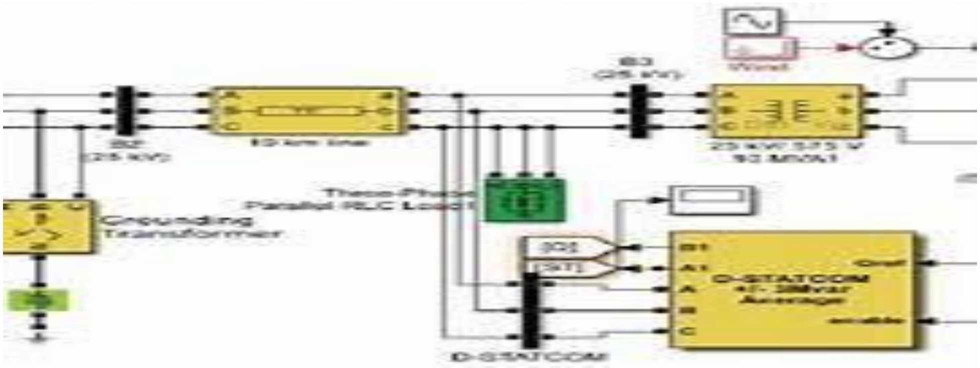


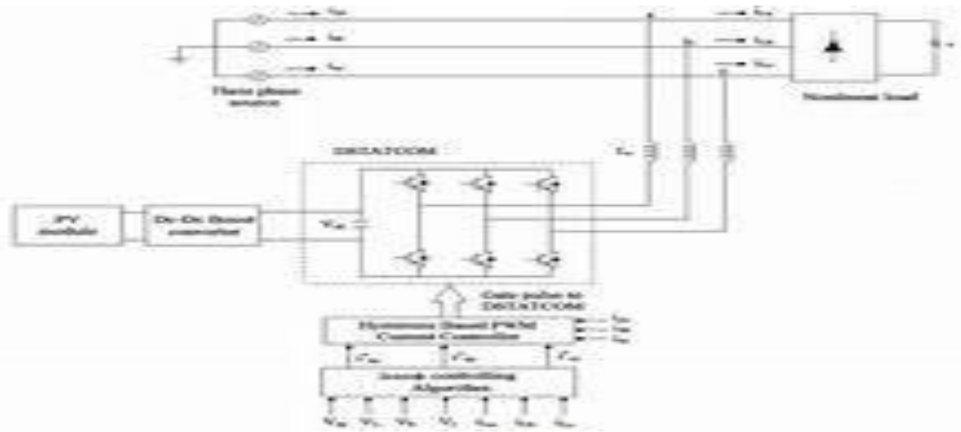
Fig 1 Proposed System Block Representation

TheVSCconnectedinshunt withtheacsystemprovides amultifunctionaltopologywhichcan beusedforuptothreequitedistinct purposes: Voltageregulationand compensationofreactivepower; Correctionofpowerfactor;and Eliminationofcurrent harmonics. Here,suchdeviceisemployed toprovidecontinuousvoltageregulation usinganindirectlycontrolledconverter. It may be mentioned that the effectiveness of the D-STATCOM in correcting voltage sag depends on the valueof Z_{th}or fault level of the load bus. When the shunt injected current $I_{sh}$is kept in quadrature with V_{L}, the desiredvoltage correction can be achieved without injecting any active power into the system. On the other hand, whenthevalueofI_{sh}isminimized,thesamevoltagecorrectioncanbeachievedwithminimumapparentpowerinjectionintothesystem.ThecontrolschemefortheD-STATCOMfollowsthesameprincipleasforDVR.Theswitchingfrequencyis set at 475 Hz.

ISSN: 1832-5505
Vol-9 Issue-03 July 2021



SimulinkmodelofD-STATCOM testsystem.



Proposed system with DSTATCOM

The Power Quality Enhancement in a Sensitive Local Distribution Grid with Interval Type-1 Fuzzy LogicControlled DSTATCOM is replaced with Interval Type-2 Fuzzy Logic Controlled DSTATCOM. Here, theType-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 inmoreprecisecontrolactions.Type-2FuzzyLogicoutperformType-1,maintainingbetterpowerqualityenhancement in highly dynamic environments. DSTATCOM is a shunt device which hast the capability toinject 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 DSTATCOMmoresuitablerather thanusing capacitors.

Handling Uncertainty: Type 2 fuzzy logic controllers can handle uncertainties more effectively by usingintervaltype-2fuzzysets.Thisallowsforbetteradaptationtochangingconditionsandvariationsinthesystem.

RobustControl:Thecombinationoftype2fuzzylogiccontrollerswithFPIDenablesrobustcontrol ofcomplexsystems.Itcanhandlenonlinearities, uncertainties,anddisturbances,makingitsuitableforchallengingcontroltasks.

Improved Adaptability: Type 2 fuzzy logic controllers with FPID have enhanced adaptability due to theirabilitytoadjustthecontrollerparametersdynamically.Thishelpsinachievingbettercontrolperformanceevenindynamic and uncertainenvironments.

Enhanced Stability: The FPID component in the controller helps in achieving stability by providing integralandderivativeactionalongwithproportionalcontrol.Thisleadstobettertrackingandregulationofthesystemoutput.

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

WITH PI CONTROLLER

CONCLUSION:

The performance of FPID based DSTATCOM has been validated in this work and satisfactory resultscorroborateitseffectivenesswhensensitiveloadsareconnectedtothegrid. Withproficientbehaviorofcontrolalong with its fast response, it has been proved effective in mitigating harmonics. The simulated results andtabulationhighlighttheefficacyoftheproposedcontrolleroverconventionalones. IntegrationofFPID basedDSTATCOMinthesystemsignificantlyreducesthetotalharmonicdistortioninthesystemandtheRLSfilterhelps in fine-tuning it to the acute levels. Summarized results show that THD levels are less when comparedwithPl controller and FPID at various time instant**.**

REFERENCES

[1] G. Yalienkaya, M.H.J. Bollen, P.A. Crossley, "Characterization of Voltage Sags in Industrial Distribution Systems," IEEE Transactions on Industry Applications, vol. 34, no. 4, pp. 682-688, July/August 1999.

[2] M.H. Haque, "Compensation of Distribution System Voltage Sags by DVR and D-STATCOM," Proceedings of Power Tech, IEEE Porto, vol. 1, pp. 10-13, September 2001.

[3] O. Anaya-Lara, E. Acha, "Modeling and Analysis of Custom Power Systems by PSCAD/EMTDC," IEEE Transactions on Power Delivery, vol. 17, no. 2, pp. 266-272, 2002.

[4] M.H.J. Bollen, "Voltage Sags in Three-Phase Systems," IEEE Power Engineering Review, vol. 21, no. 9, pp. 11-15, September 2001.

[5] M. Madrigal, E. Acha, "Modeling of Custom Power Equipment Using Harmonics Domain Techniques," IEEE, 2000.

[6] R. Meinski, R. Pawelek, I. Wasiak, "Shunt Compensation for Power Quality Improvement Using a STATCOM Controller: Modeling and Simulation," IEEE Proceedings, vol. 151, March 2004.

[7] J. Nastran, R. Cajhen, M. Seliger, P. Jereb, "Active Power Filters for Nonlinear AC Loads," IEEE Transactions on Power Electronics, vol. 9, no. 1, pp. 92-96, January 2004.

[8] L.A. Moran, J.W. Dixon, R. Wallace, "A Three-Phase Active Power Filter with Fixed Switching Frequency for Reactive Power and Current Harmonics Compensation," IEEE Transactions on Industrial Electronics, vol. 42, pp. 402-408, August 1995.

[9] L.T. Moran, P.D. Ziogas, G. Joos, "Analysis and Design of Three-Phase Current Source Solid-State VAR Compensator," IEEE Transactions on Industry Applications, vol. 25, no. 2, pp. 356-365, 1989.