POWER QUALITY IMPROVEMENT IN DISTRIBUTION NETWORK USING DSTATCOM WITH SMES

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Abstract— Due to growing complexity in the power system, voltage sag becoming one of the most significant power quality disturbances. Voltage sag is a short-duration reduction in RMS voltage caused by faults on the power system and the starting of large loads, such as motors. If voltage sags exceeds, then industrial units making use of sensitive electronic equipments are likely to be affected with major problems. This issues sometimes leads to ruin of resources like material and human as well as financial losses. This paper discusses about the Power quality improvement in non- linear distribution system using a Distribution Static Compensator (D-STATCOM) with a superconducting magnetic energy storage (SMES) as its source. Progress in both superconducting technologies and power electronics led to SMES systems having some tremendous performances particularly for use in power systems. DSTATCOM includes a Voltage Source converter and a DC link capacitor or source connected in shunt, capable of generating or absorbing reactive power. The proposed system allows the compensation of current harmonics and unbalances, and can be a much better solution than the conventional approach. This proposed system is analyzed and simulated using MATLAB/SIMULINK.

IndexTerms— Powerquality,Nonlinear load , DSTATCOM,SMES

I. INTRODUCTION

Power quality is a comprehensive term that squeezes all features related with amplitude, phase and frequency of the voltage and current waveforms existing in a power circuit. Power quality is utterly the interaction of electrical power with equipment. Thus the measure of power quality depends on the equipment that is supplied. The waveform of electric power at generation stage is purely sinusoidal at frequency 50Hz. Any notable divergence in magnitude, frequency or purity of waveform can be considered as power quality problem. The changes of the voltage supplied even for very short period of time is now very expensive due to their cause of improper operation. For getting the highest efficiency in production besides for sustaining of the most reasonable operating cost, electrical customers were now eager for the high power quality. Therefore, a proper study about the power quality disturbances should be conducted seriously as well as the extenuation manner, but also increase the reputation and quality of electrical power . From decades, power electronics have been introduced and developed further due to its economical and power saving advantages. Flexible AC Transmission System (FACTS) were introduces to solve power quality problems. The distribution static compensator based on the VSC has been used to perform the modeling and analysis of such controllers for a wide range of operating conditions based PWM control reported. It relies only on voltage measurements for its operation, i.e., it does not require reactive power measurements. DSTATCOM be a reactive power source compensator, which can properly cancel load harmonics fed to the supply, also power quality issues with appropriate controller designed, such as voltage sag, voltage swell, interruptions, harmonic, and transients. By applying appropriate controller, various power quality disturbances could be solved specifically, includes voltage sag.

II. SYSTEM UNDER STUDY

A. DSTATCOM

Distribution Static Compensator (DSTATCOM), which is schematically depicted in Figure 1.It consists of a Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network. DSTATCOM similar to a STATCOM but used at the Distribution level. The coupling of DSTATCOM is in parallel to network and load. It works as current sources connected in parallel with the nonlinear load. In order to compensate undesirable components of the load current, DSTATCOM injects currents into the point of common coupling. With an appropriated control strategy, it is also possible to correct power factor and unbalanced loads. The VSC connected in shunt with the ac system which can be used for up to three quite distinct purposes:

1. Compensation of reactive power and voltage regulation;
2. Power factor Correction; and
3. Elimination of current harmonics.

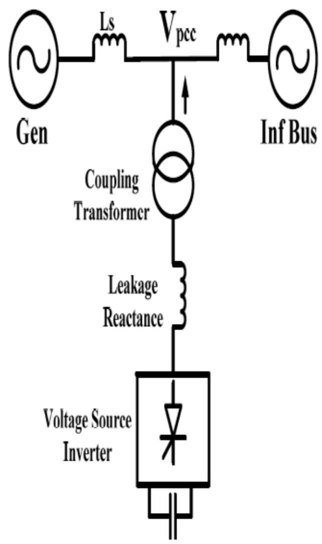


Fig.1: Schematic block diagram of DSTATCOM

DSTATCOM must be able to inject an unbalanced and harmonically distorted current to eliminate unbalances . It can offer very fast response to reactive power demand. It can be analogous to synchronous machine, which generates balanced three phase voltages at fundamental frequency with controllable amplitude and phase angle. In order to compensate undesirable components of the load current DSTATCOM injects currents into the point of common coupling.

The voltage source inverter (VSI) could convert DC voltage into AC sinusoidal voltage before injection of current back to the power system is done via injection transformer. Its advantage is that it of carries only the compensation current plus a small amount of active fundamental current supplied to compensate for system losses.

B. SUPERCONDUCTING MAGNETIC ENERGY STORAGE SYSTEM (SMES)

In Superconducting Magnetic Energy Storage system (SMES), the energy is stored in the magnetic field generated by the dc current flowing through superconducting coil. The energy is stored as circulating current and coil has been cryogenically cooled to a temperature below its normal temperature. The superconducting coil is maintained at cryogenic temperature. A power conversion/conditioning system connects the SMES unit to an ac power system and it is used to charge/discharge the coil as shown in Figure 2. There are two types of power conversion systems. First one uses a Current Source Converter (CSC) to both interface to the ac system and charge/discharge the coil and the second type uses a Voltage Source Converter (VSC) to interface to the ac system and a dc-dc chopper to charge/discharge the coil.

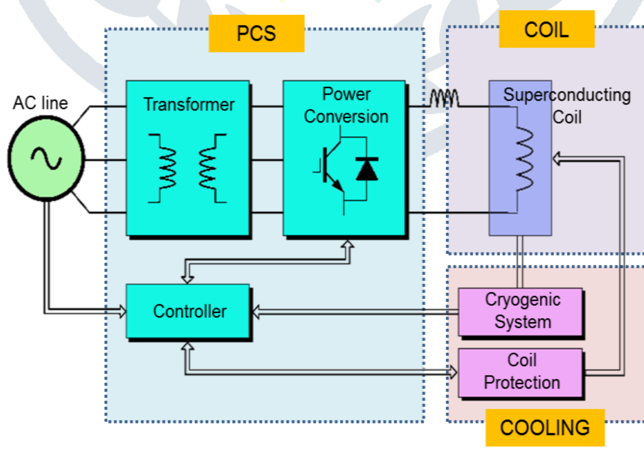


Fig.2: Block diagram of SMES System

Energy stored in a normal inductor will fade out quickly due to ohmic resistance in the coil when the power supply is disconnected. The SMES coil is charged or discharged by applying a positive or negative voltage across the superconducting coil. SMES system enters a standby mode when the average voltage across the coil is zero resulting constant current in coil. This is possible by lowering the temperature of the conductors using a cryogenically cooled refrigerating system, and by this making the conductors superconducting. The current in the coil can flow for infinite time when superconducting wire in zero resistance state . Thus the time constant of a coil τ,

$$\tau = L\ R \qquad (1)$$

where R is the ohmic resistance of the coil and L is the inductance of the coil. From equation (1) it is clear that when R goes to zero, then time constant of the coil goes to infinity. Once the superconducting coil is charged the current will be present permanently in the system. By discharging the superconducting coil, the stored energy can be released. SMES system is highly efficient (Overall efficiency of 95 percent) and therefore, it is most commonly used to improving power quality. As a result, SMES have attracted attention for applications in solving voltage stability and power quality problems for large industrial customers, electric utilities and the military

C. CONTROLLER

The most important part of DSTATCOM is its controller. By applying appropriate controller, various power quality disturbances could be solved specifically, includes voltage sag. The main purpose of the control scheme is to keep voltage magnitude fixed at the point where the power system is undergoing voltage sag problem. The main aim of the control strategy implemented to control a D-STATCOM used for voltage mitigation is to control the amount of reactive power exchanged between the DSTATCOM and the supply bus. When the PCC voltage is less than the reference (rated) value then the DSTATCOM generates reactive power and when PCC voltage is more than the reference (rated) value then the DSTATCOM absorbs reactive power. Also, PWM techniques could be applied with high switching frequencies so that its efficiency could be maximized and also the switching losses could be drastically reduced.

The controller of the DSTATCOM is designed to conduct the reactive power exchange between the inverter and the system line by modifying the phase angle between the inverter voltage and line voltage. The reactive power output of the DSTATCOM could either be inductive or reactive, depending on the operation mode.The control system element can only measured the RMS voltage magnitude that measured at the load point. The input for the controller system is an error signal.

This error signal is obtained from the reference signal measured at the terminal voltage and RMS voltage magnitude that measured at the load point as shown in Figure 3. Here the error signal will enter to the sequence analyzer block, which is functioning to measure the harmonic level in that signal. Then, the PI controller will process this error signal and come out with the output in term of the angle, ∂. This angle can drive the error to zero. Next, this angle will be summed with the phase angle of the supply voltage which is assumed to be 120˚ to produce the suitable synchronizing signal, required to operate the PWM generator. Then, this angle will be submitted to the PWM signal generator. PWM generator will generate the sinusoidal PWM waveform or signal.

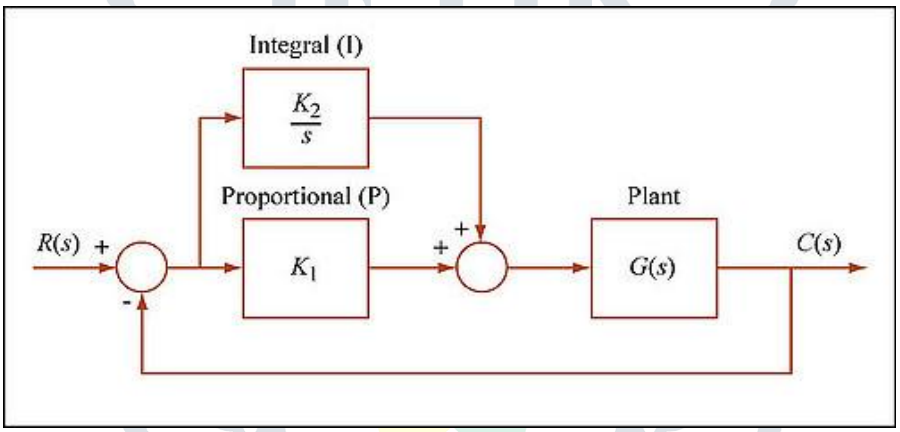


Fig.3: Implementation of PI Controller

D. SMES SOURCED DSTATCOM

As shown in Figure 4, the compensator should be shunted with the line and it consists of a three-phase inverter in order to compensate for load current. Power distribution systems ought to deliver their customers with an associate degree uninterrupted flow of energy with smooth sinusoidal voltage at the contracted magnitude level and frequency, but the distribution systems, have several nonlinear loads, which significantly affect the quality of power supplies. DSTATCOM is a shunt compensator, based on power electronic converter. It is connected in shunt at PCC to protect critical loads from all load side disturbances. Here, DSTATCOM is an effective device to reduce current variations and harmonics from the distribution network is sourced with a SMES.The most important part of DSTATCOM is its controller. By applying controller, different power quality problems could be solved specifically, includes voltage sag. The main purpose of the control scheme is to keep voltage magnitude fixed at the point where the power system is undergoing voltage sag problem. The objective of this work is to achieve power quality improvement in distribution network .The basic idea of DSTATCOM sourced with SMES can be seen in Figure 4.

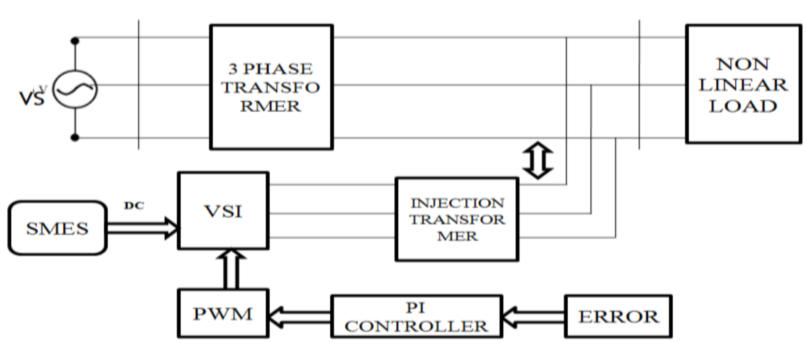


Fig.4: Test system for SMES Sourced DSTATCOM

A distribution system may experiences from current as well as voltage related power quality problems, which include poor power factor, distorted source current and voltage disturbances. DSTATCOM sourced with SMES is connected to the point of common coupling has been utilized to mitigate problems like voltage sag . A load works satisfactorily for a permissible voltage range. While maintaining 1.0-p.u. voltage, DSTATCOM compensates for the voltage drop in feeder. The PWM offers simplicity and good response.

III SYSTEM IMPLEMENTION OF MATLAB

The test system consists of 11kV, 50 Hz, 3-phase generation system supplying into the distribution network as shown in the Figure 4. Variable- loads are connected to 11kV transmission line. A three phase fault box is inserted at the load end of the 11 kV circuit to create three phase faults in the system for producing voltage sags through a fault resistance of 12 Ω during the period 400-600ms.

A. SYSTEM FOR VOLTAGE SAG

The Figure 5 shows simulink model for sag in distribution network. The voltage sag at the load point is seen with respect to the reference voltage. Simulation results are shown in Figure 6.

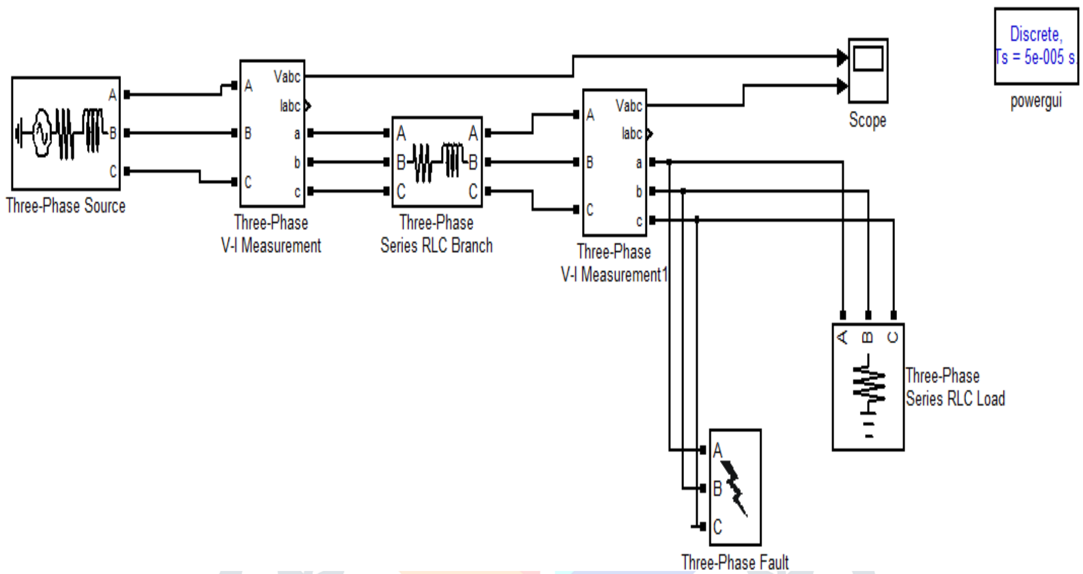


Fig.5: Simulink model for Voltage Sag

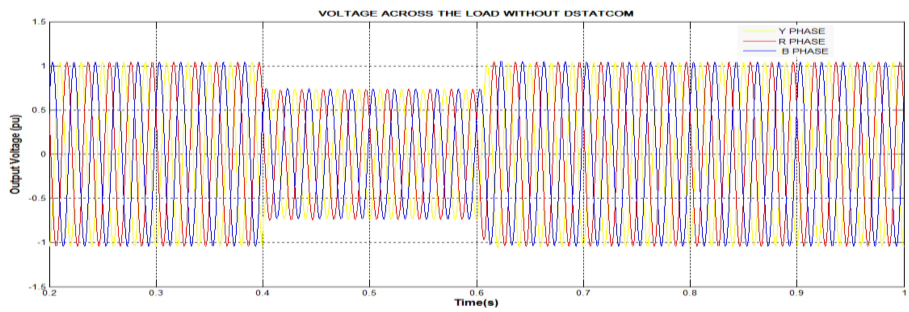
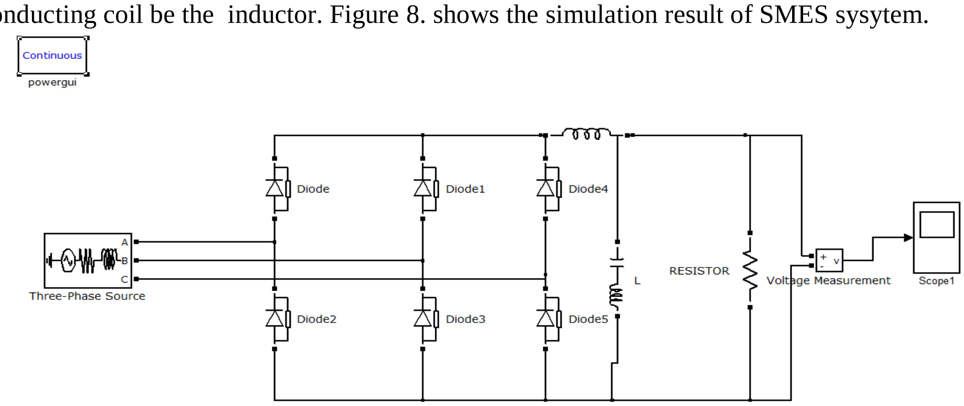


Fig.6: Simulation results for Voltage Sag

B. IMPLEMENTATION OF SMES

The Figure 7. shows the simulink model of superconducting magnetic energy storage system . An AC-DC converter with an inductor acting as SMES. Here the superconducting coil be the inductor. Figure 8. shows the simulation result of SMES sysytem.



. Fig.7: Simulink model of SMES

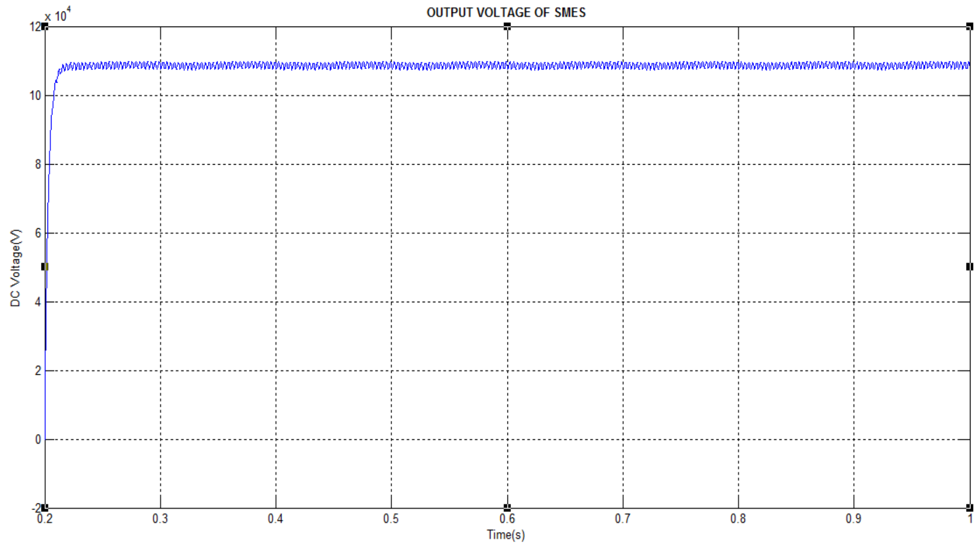


Fig.8: Simulation results for SMES

C. SYSTEM WITH DSTATCOM

The test system consists of 11 kV, 50 Hz, 3-phase generation system, supplying to the primary side of the 3-winding transformer 11/110KV. The secondary is connected to a varying load and the sag is create here by providing the switching for the interval of 0.4-0.6 sec. SMES provides required DC for DSTATCOM as shown in Figure 9. An AC-DC converter with an inductor acting as SMES. The SMES sourced DSTATCOM is connected shunt to consumer side through an injection transformer 11/110 KV for compensating voltage sag as shown .Simulation results are shown in Figure 10.

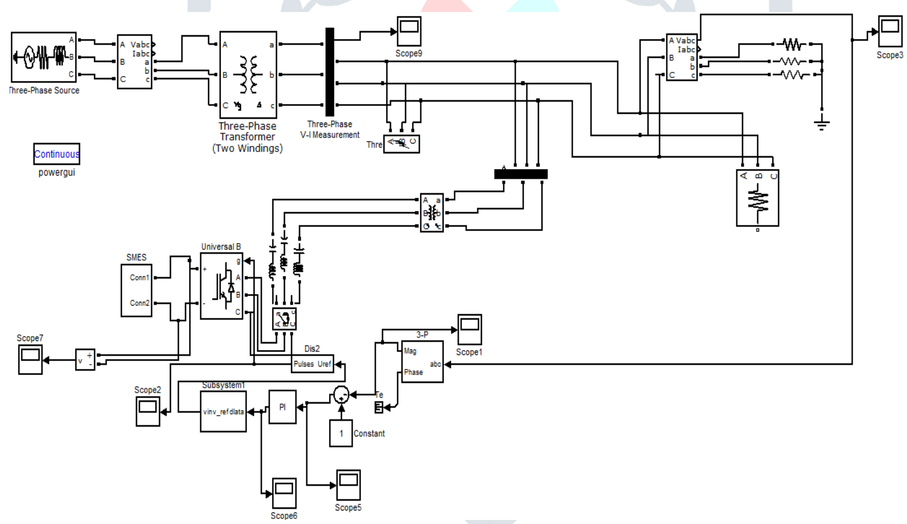


Fig.9: Simulink model of DSTATCOM with SMES

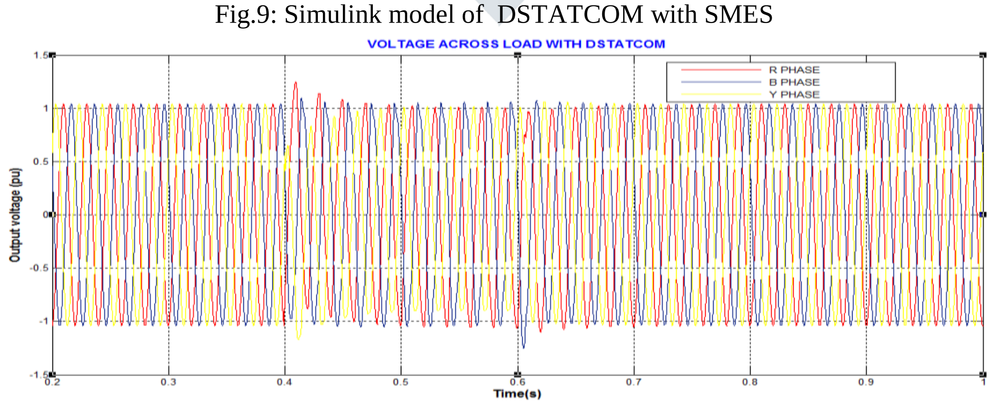


Fig.10: Simulation results of DSTATCOM with SMES

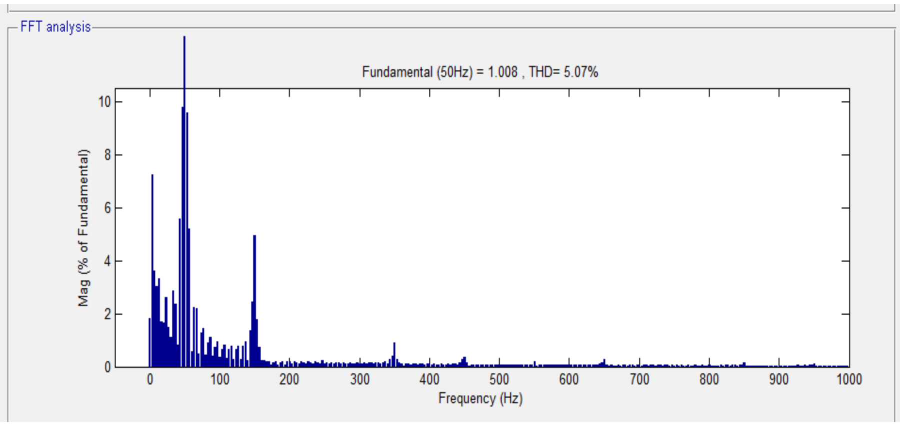


Fig.11. THD value of DSTATCOM with SMES

It is shown that DSTATCOM sourced SMES system have an excellent resistance against the power quality problems like voltage sag with THD value 5%.

IV CONCLUSION

Custom power devices can be used for power quality improvement in the distribution system. DSTATCOM can effectively be used to improve the power quality in the distribution network.The Voltage Source Inverter (VSI) was implemented with the help of Pulse Width Modulation (PWM). The control scheme was tested under a wide range of operating condition. The simulations carried out are showed that the DSTATCOM provides relatively better voltage regulation capabilities, and it was observed to be very robust in every case.

APPENDIX

Three Phase Voltage Source	11KV,50Hz
Three Phase Two Winding Transformer	250MVA,11/110KV,50Hz
Three Phase Fault	3 Phase Fault, 0.4s -0.6s
DSTATCOM	IGBT based, 3 arms, 6 pulse,
Inverter parameters	carrier Frequency=1080Hz
LC Filter	L=1H, C=0.09F
Three Phase Breaker	Breaker Resistance- 0.01ohm
Injection Transformer	250MVA,11/110KV,50Hz
PI Controller	
Proportional Constant(Kp)	2
Integral Constant (Ki)	0.1
SMES	110KV, 50Hz
Three Phase Voltage Source	Diode, 3 arms
Three Phase Diode Rectifier	1H
Superconducting Coil	0.1ohm
Coil Resistance	L= 0.005H,C= 250μF
LC Filter	

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