ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 6, April 2017

Review on Power Quality Improvement in Distribution Network Using DSTATCOM with SMES

Haritha.M.S
PG Scholar
Mohandas College of Engineering and Technology
Thiruvananthapuram, India
harithams23@gmail.com

Divya.S.Nair
Assistant Professor, Dept of EEE
Mohandas College of Engineering and Technology
Thiruvananthapuram, India
divyaperoor@gmail.com

***Abstract*- Power quality has becoming increasingly concerned by both electric utilities and end users of electrical power. The exponential use of non linear loads will lead to deterioration of power quality. Active Power Filters are commonly used for compensating these problems. Among them Distribution Static Compensator (DSTATCOM) provides effective protection against harmonic problems. This controlled reactive source which includes a Voltage Source Converter and a DC link capacitor or source connected in shunt capable of generating and or absorbing reactive power. This paper presents power quality improvement in distribution network by DSTATCOM with superconducting magnetic energy storage system (SMES). Advances in both superconducting technologies and power electronics led to SMES systems having some excellent performances in power system. The simulations are done in MATLAB/SIMULINK.**

Keywords—Powerquality,Nonlinear load , DSTATCOM,SMES

I. INTRODUCTION

The problem in the power sector delivery is not cramped to only energy efficiency but more on the quality and continuity of supply. Power quality is simply the interaction of electrical power with electrical equipment. Thus the measure of power quality depends on the need of equipment that is supplied. The waveform of electric power at generation stage is purely sinusoidal at frequency 50Hz and free from any distortion. 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, which were not really mostly taken attention by public, is now very expensive due to their cause of improper operation. For the purpose of 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. For instance, disturbances like voltage sag, which was introduced by the higher fault on the network, will influenced more number of customer victims. Therefore, a proper study about the power quality disturbances should be conducted seriously as well as the extenuation manners not only to fulfill customers demand, but also increase the reputation and quality of electrical power .

From decades to decades, power electronics have been introduced and developed further due to its economical and power saving advantages. Flexible AC Transmission System (FACTS) are widely used to solve power quality disturbances and Distribution Static Compensator (DSTATCOM) is one of the members of FACTS devices family which is effective and flexible. DSTATCOM is a fast-respond reactive power source compensator, which can properly solve varies power disturbances with appropriate controller designed, such as voltage sag, voltage swell, flicker, harmonic, and transient. Also, its control system act very fast so it could alter the magnitude and phase of voltage almost instantly

II. SYSTEM UNDER STUDY

A. DSTATCOM

Distribution Static Compensator (DSTATCOM), which is schematically depicted in Fig. 1. It is composed of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. Each one of this component play an important role to ensure that D-STATCOM can operate wisely without have any problems.

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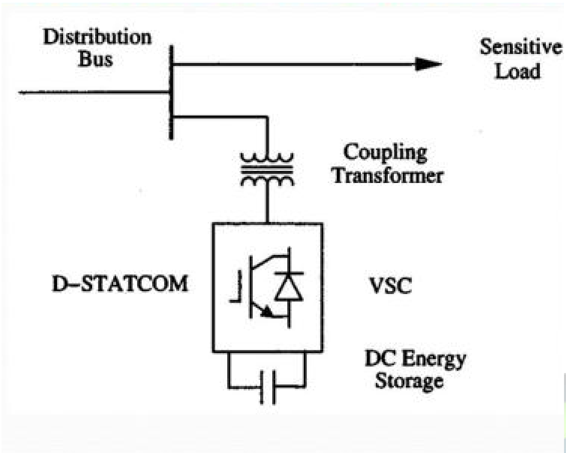

Figure 1: Schematic block diagram of DSTATCOM

Suitable adjustment of the phase and magnitude of the DSTATCOM 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 and reactive power. The VSC connected in shunt with the ac system provides a multifunctional topology 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.

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 is analogous to an ideal synchronous machine, which generates balanced three sinusoidal voltages at fundamental frequency with controllable amplitude and phase angle.

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. The total replacement of voltage or insertion of voltage to fill the dipped voltage could be done by implementation of this voltage source converter or specifically named as inverter.

B. SUPERCONDUCTING MAGNETIC ENERGY STORAGE SYSTEM (SMES)

A Superconducting Magnetic Energy Storage (SMES) system stores energy in a superconducting coil in the form of a magnetic field. Magnetic field created by the flow of DC current in the coil. The superconducting coil has been cryogenically cooled to a temperature below its normal temperature. SMES system includes four parts, Superconducting coil, Power conditioning system ,control unit and a cryogenically cooled refrigerator as shown in Fig. 2.

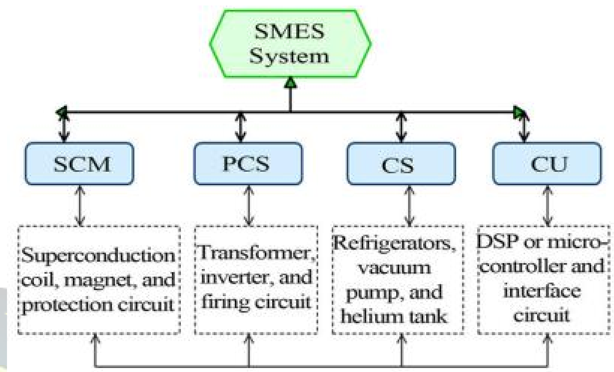

Figure 2: Block diagram of SMES System

Energy stored in a normal inductor will fade out quickly due to ohmic resistance in the coil when the power supply is disconnected. But this will not be an acceptable energy storage for use in a power system. The ohmic resistance has to be removed before an inductor can work for this purpose. This is possible by lowering the temperature of the conductors using a cryogenically cooled refrigerating system, and by this making the conductors superconducting. A superconducting wire is in a state where the resistance of the wire is zero. In this state the current in the coil can flow for infinite time. This can also be seen from the time constant of a coil τ.

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

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.

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In modern controller, not only controller for voltage sag compensation, but also some other low-power application use PWM technique instead of Fundamental Frequency Switching (FFS) methods because PWM is more flexible, simple, and good response. 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. For the controller system there is no requirements of the reactive power measurements. 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 Fig. 3. First of all, this 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.

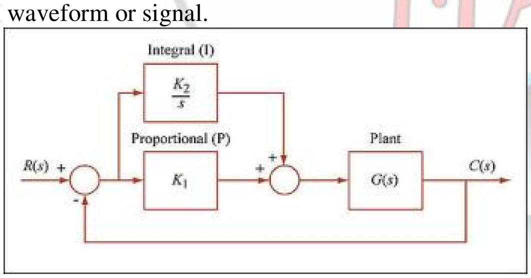

Figure 3: Implementation of PI Controller

D. SMES SOURCED DSTATCOM

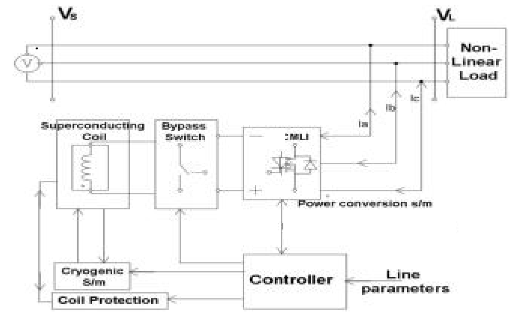

Figure 4: Test system for SMES Sourced DSTATCOM

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. Nonlinear or unbalanced load is connected to the distribution system.

For the test system a three phase diode rectifier is connected for representing a non-linear or unbalanced load. In our system, D-STATCOM in distribution system is sourced with a SMES. The SMES is an advanced technology for the storage and transfer of energy in a reliable manner with a superconducting coil. A cryogenically cooled refrigerator is provided for cooling the coil below its critical temperature. The super conducting coil is protected through a protection system as shown in fig 4.

A bypass switch is provided for avoiding the wastage of energy from superconducting coil, when the system does not consumes energy and also protect the coil. This converter is used the switching based on a sinusoidal PWM method. The PWM offers simplicity and good response. Christo Ananth et al.[4] presented a brief outline on Electronic Devices and Circuits which forms the basis of the Clampers and Diodes.

III SYSTEM IMPLEMENTATION IN MATLAB

The test system composes a 230 kV, 50 Hz generation system feeding into the primary side of a 3-winding transformer. A varying load is connected to the 11 kV, secondary side of the transformer. In the absence of DSTATCOM we can see the voltage sag due to the three phase fault .

A. SYSTEM FOR VOLTAGE SAG

The Fig. 5 shows simulation contains no D-STATCOM and a three phase fault is applied at point A, via a fault resistance of 0.6 fl, during the period 400-600 ms. The voltage sag at the load point is seen with respect to the reference voltage.

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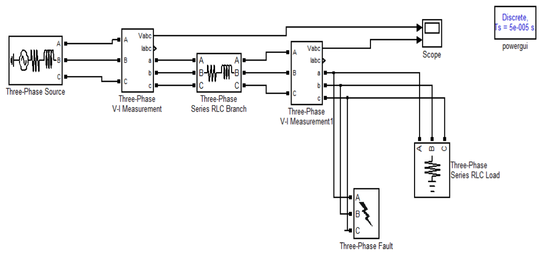

Figure 5: Test system for Voltage Sag

Simulation results are shown in Fig.6

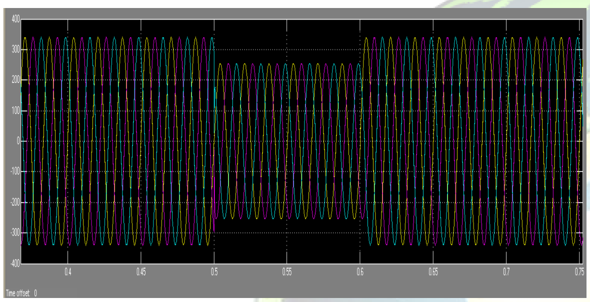

Figure 6: Simulation results for Voltage Sag

B. IMPLEMENTATION OF SMES

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

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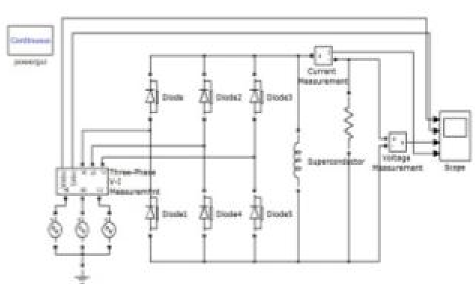

Figure 7: Implementation Of SMES

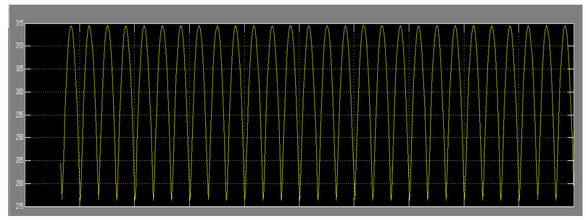

Figure 8: Simulation results for SMES

C. SYSTEM WITH DSTATCOM

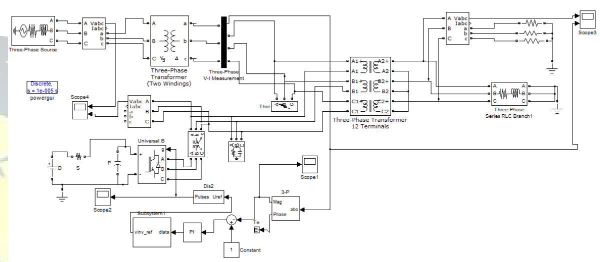

Figure 9: System with DSTATCOM

The simulation contains D-STATCOM and a three phase fault is applied at point A, via a fault resistance of 0.6ohm, during the period 400-600 ms as shown in Fig. 9.The improved voltage sag at the load point is seen with respect to the reference voltage.

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.

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