

Power Quality Improvement In Distribution System Using D-Statcom In Transmission Lines

Sai Kiran Kumar.Sivakoti
Gitam University

Y.Naveen Kumar
IIT , Kharagpur

D.Archana
Gokhul Engineering College

Abstract –

A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or a mis-operation of end user equipments. Utility distribution networks, sensitive industrial loads and critical commercial operations suffer from various types of outages and service interruptions which can cost significant financial losses. With the restructuring of power systems and with shifting trend towards distributed and dispersed generation, the issue of power quality is going to take newer dimensions. In developing countries like India, where the variation of power frequency and many such other determinants of power quality are themselves a serious question, it is very vital to take positive steps in this direction. The present work is to identify the prominent concerns in this area and hence the measures that can enhance the quality of the power are recommended.

This paper presents the enhancement of voltage sags/swell; harmonic distortion and low power factor using Distribution Static Compensator (D-STATCOM). The model is based on the Voltage Source Converter (VSC) principle. The D-STATCOM injects a current into the system to mitigate the voltage sags/swell. to improve harmonic distortion and low power factor. The simulations were performed using MATLAB SIMULINK version R2009b.

Keywords- D-STATCOM, Total harmonics Distortion (THD), Voltage Sag/swell, Voltage Source Converter (VSC).

1. INTRODUCTION

An electric distribution system is part of an electric system between the bulk power source or sources and the consumer's service switches. The bulk power sources are located in or near the load area to be served by the distribution system and may be either generating stations or power substations supplied over transmission lines. Distribution systems can, in general, be divided into six parts, namely, sub transmission circuits, distribution substations, distribution or primary feeders, distribution transformers, secondary circuits or secondary's, and consumer's service connections and meters or consumer's services. One of the most common power quality problems today is voltage sag/swell. It is often set only by two parameters, depth/magnitude and duration. The voltage sag/swell magnitude is ranged from 10% to 90% of nominal voltage and with duration from half a cycle to 1 min. In a three-phase system voltage sag is by nature a three-phase phenomenon, which affects both the phase-to-ground

and phase-to-phase voltages. Voltage sag 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. Typical faults are single-phase or multiple-phase short circuits, which leads to high currents. The high current results in a voltage drop over the network impedance. At the fault location the voltage in the faulted phases drops close to zero, whereas in the non-faulted phases it remains more or less unchanged.

Voltage sags are one of the most occurring power quality problems. For an industry voltage sags occur more often and cause severe problems and economical losses. Utilities often focus on disturbances from end-user equipment as the main power quality problems.[2]

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. 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 D-STATCOM. The D-STATCOM has additional capability to sustain reactive current at low voltage, and can be developed as a voltage and frequency support by replacing capacitors with batteries as energy storage. To enhance the power quality such as voltage sags/swell, harmonic distortion and low power factor in distribution system.

2. VOLTAGE SOURCE CONVERTER (VSC)

A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. Voltage source converters are widely used in adjustable-speed drives, but can also be used to mitigate voltage dips. The VSC is used to either completely replace the voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between the nominal voltage and the actual. The converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage. The solid-state electronics in the converter is then switched to get the desired output voltage. Normally the VSC is not only used for voltage sag/swell mitigation, but also for other power quality issues, e.g. flicker and harmonics.

3. ENERGY STORAGE CIRCUIT

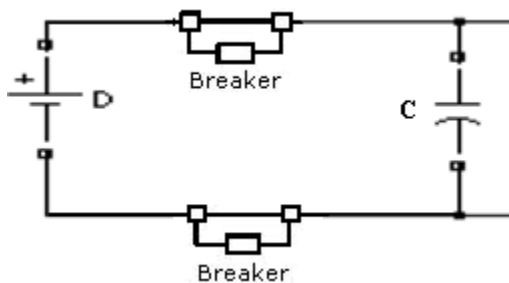


Fig.3.1.Circuit Diagram of DC Storage

From fig 3.1 DC source is connected in parallel with the DC capacitor. It carries the input ripple current of the converter and it is the main reactive energy storage element. This DC capacitor could be charged by a battery source or could be recharged by the converter itself.

4. CONTROLLER

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system only measures the r.m.s voltage at the load point, i.e., no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. Since custom power is a relatively low-power application, PWM methods offer a more flexible option than the Fundamental Frequency Switching (FFS) methods favored in FACTS applications. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses.

The controller input is an error signal obtained from the reference voltage and the value rms of the terminal voltage measured. Such error is processed by a PI controller the output is the angle δ , which is provided to the PWM signal generator. It is important to note that in this case, indirectly controlled converter, there is active and reactive power exchange with the network simultaneously: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point. The PI controller process the error signal generates the required angle to drive the error to zero, i.e., the load rms voltage is brought back to the reference voltage.

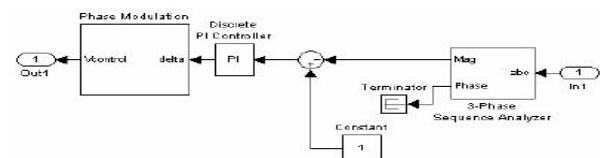


Fig.4.1. Simulink Model of D-STATCOM Controller

5. Distribution Static Compensator (DSTATCOM)

A D-STATCOM (Distribution Static Compensator), which is schematically depicted in Figure-5.1, consists 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. 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 the D-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 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. Voltage regulation and compensation of reactive power.
2. Correction of power factor and
3. Elimination of current harmonics.

The value of I_{sh} can be controlled by adjusting the output voltage of the converter.

The shunt injected current I_{sh} can be written as,

$$I_{sh} = I_L - I_S = I_L - \frac{V_{th} - V_L}{Z_{th}} \quad (5.1)$$

$$I_{sh} \angle \eta = I_L \angle -\theta - \frac{V_{th}}{Z_{th}} \angle (\delta - \beta) + \frac{V_L}{Z_{th}} \angle -\beta \quad (5.2)$$

I_{out} = output current I_L = load current

I_S = source current V_{th} = thevenin voltage

V_L = load voltage Z_{th} = impedance

Referring to the equation 5.2, output current, will correct the voltage sags by adjusting the voltage drop across the system impedance,

$$(Z_{th} = R + jX).$$

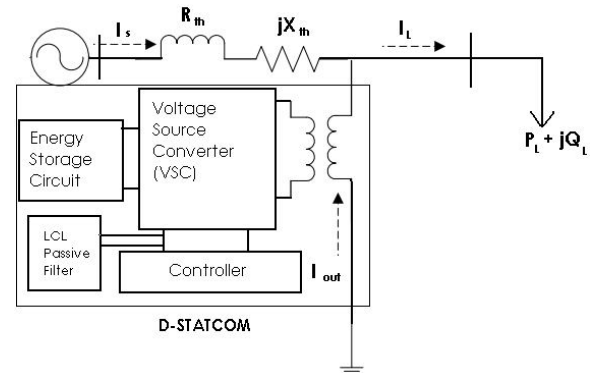


Fig.5.1. Schematic Diagram of D-STATCOM

6. METHODOLOGY

To enhance the performance of distribution system, D-STATCOM was connected to the distribution system. D-STATCOM was designed using MATLAB simulink version R2009b.

The test system shown in figure 6.1 comprises a 230kV, 50Hz transmission system, represented by a Thevenin equivalent, feeding into the primary side of a 3-winding transformer connected in Y/Y/Y, 230/11/11 kV. A varying load is connected to the 11 kV, secondary side of the transformer. A two-level D-STATCOM is connected to the 11 kV tertiary winding to provide instantaneous voltage support at the load point. A 750 μ F capacitor on the dc side provides the D-STATCOM energy storage capabilities. Circuit Breaker is used to control the period of operation of the D-STATCOM.

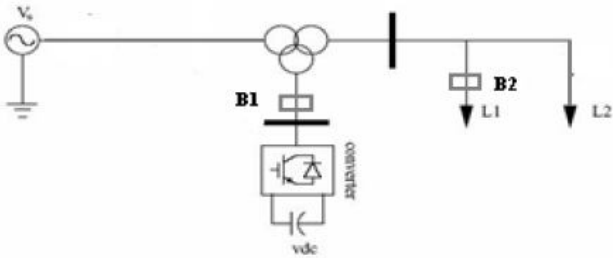
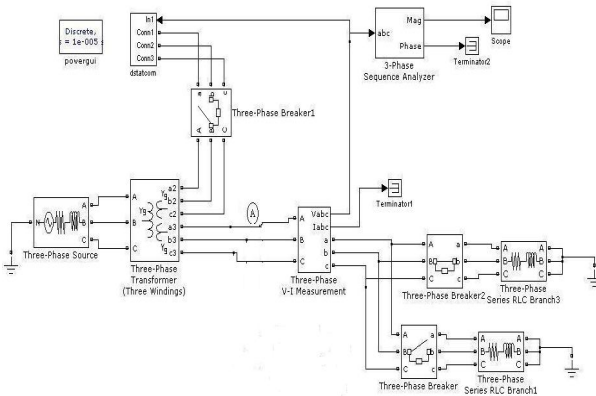


Fig.6.1. Single line Diagram of Test System

7. SIMULINK MODEL FOR THE TEST SYSTEM



8. RESULTS

8.1 Simulation results of voltage sag during single line to ground fault

In this case, D-STATCOM is not connected and a single line to ground fault is applied at a point 'A' with a fault resistance of 1.06 Ω . The voltage sag is shown in fig.8.1. with a time period of 500ms-900ms.

From the fig.8.2. the voltage sag is mitigated with an energy storage of 18.2 kv, when the D-STATCOM is connected to the system.

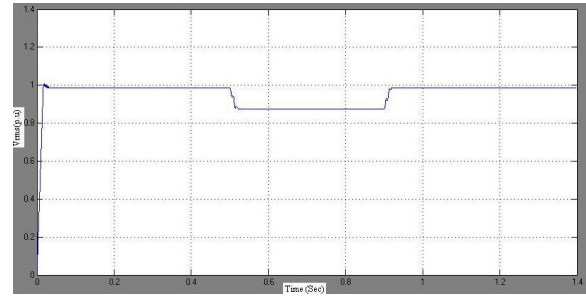


Fig.8.1.Voltage Vrms at the load point without DSTATCOM

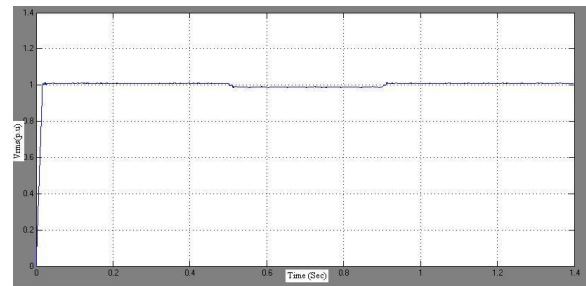


Fig.8.2.Voltage Vrms at the load point with DSTATCOM: with energy storage of 18.2 kv.

8.2 Simulation results of Voltage Interruption during Three-Phase fault

In this case, D-STATCOM is not connected and a three-phase fault is applied at a point 'A' with a fault resistance of 0.96 Ω . The voltage sag is shown in fig.8.3. with a time period of 500ms-900ms.

As the simulation is carried out with a D-STATCOM connection as shown in the fig.8.4. The voltage sag is mitigated with energy storage of 18.2 kv,

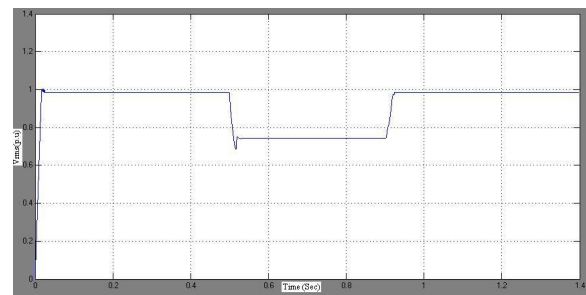


Fig.8.3.Voltage V_{rms} at the Load point without DSTATCOM.

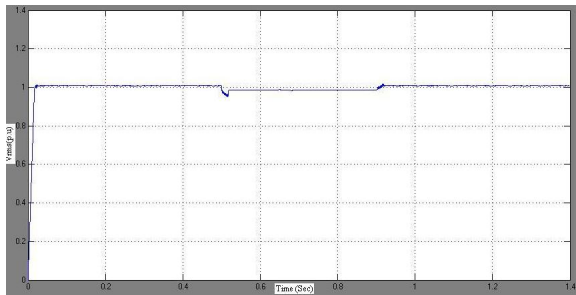


Fig.8.4.Voltage V_{rms} at the Load point with DSTATCOM with energy storage of 18.2 kv.

8.3 Simulation results of Voltage swell

In this case, D-STATCOM is not connected and a capacitive load is applied at a point 'A'. The voltage swell is shown in fig.8.5. with a time period of 500ms-900ms.

As the simulation is carried out with a D-STATCOM connection as shown in the fig.8.6. The voltage swell is mitigated with energy storage of 13.2 kv,

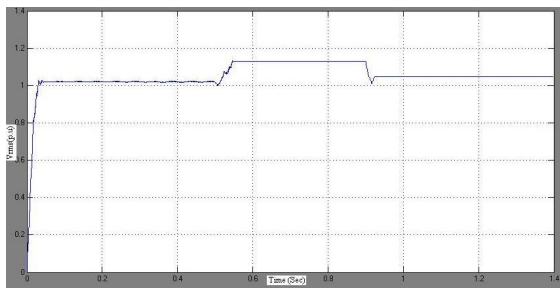


Fig. 8.5.Voltage V_{rms} at the load point without D-STATCOM

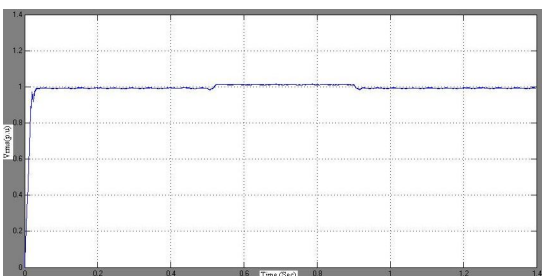


Fig.8.6. Voltage V_{rms} at the load point with D-STATCOM: with Energy storage of 13.2 kv.

V.CONCLUSION

A single-phase to ground fault, three-phase fault and voltage swell are occurred in a time period of 500ms-900ms at different inductive and capacitive loads. D-STATCOM is designed by the combination of two-level VSC and PWM-based control. Here the voltage measurement is controlled by PWM-controller. So by using D-STATCOM sag of 13%, interruption of 25% and swell of 11% conditions are mitigated.

9. REFERENCES

- [1] G. Yaleinkaya, M.H.J. Bollen, P.A. Crossley, "Characterization of voltage sags in industrial distribution systems", IEEE transactions on industry applications, vol.34, no. 4, July/August, pp. 682-688, 1999.
- [2] Haque, M.H., "Compensation of distribution system voltage sag by DVR and D-STATCOM", Power Tech Proceedings, 2001 IEEE Porto, vol.1, pp.10-13, Sept. 2001.
- [3] Anaya-Lara O, Acha E., "Modeling and analysis of custom power systems by PSCAD/EMTDC", IEEE Transactions on Power Delivery, Vol.17, Issue: 1, Jan. 2002, Pages:266 – 272.
- [4] Bollen, M.H.J.," Voltage sags in three-phase systems" Power Engineering Review, IEEE, Vol. 21, Issue: 9, Sept. 2001, pp: 8 - 11, 15.
- [5] R.Mienski,R.Pawelek and I.Wasiak., "Shunt Compensation for Power Quality Improvement Using a STATCOM controller: Modelling and Simulation", IEEE Proce., Vol.151, No.2, March 2004.