Power Quality Enhancement in Distribution System Using D-STATCOM

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Abstract –. *This paper deals with the Power Quality enhancement in distribution system using distribution static compensator(D-STATCOM). Power Quality (PQ) has become very important aspect for the utility because electricity customer demands high quality power with reliability. Industrial consumers are highly affected due to PQ issues in terms of loss of revenue. In this paper Voltage sag is considered as PQ problem which can be experienced by different types of faults. D-STATCOM injects current into a system to mitigate the voltage sag at distribution side. The D-STATCOM model is based on Voltage source converter (VSC) principle. The simulations were performed in MATLAB/SIMULINK model R20007b with and without insertions of D-STATCOM.*

Key Words: Power quality, Voltage sag, Custom power device, D-STATCOM, Voltage source converter (VSC)

1. INTRODUCTION

Power Quality (PQ) has become important for industrial and commercial electric power customers, particularly as today's manufacturing and control processes rely on computerized equipment which are very sensitive to power system disturbances. Power quality problems such as transient, Voltage sags, swells interruptions, Harmonics and noise can affect the performance of the equipment at consumer. The types of PQ problems frequently experienced by customers are voltage sags and harmonics while the less frequent ones include transient, flicker and noise. Due to PQ disturbances the sensitive electronic equipment/devices may malfunction or fail to operate at all, which causes huge loss of revenue for the industrial consumers. Voltage sag is frequently experienced due to utility faults, transformer charging or heavy motor starting. Various custom power devices are available to mitigate PQ problems. Evolution has been seen in custom power devices such as D-STATCOMs for power factor correction, voltage regulation, compensation of excessive neutral current, and load balancing; DVRs for mitigating voltage quality problems in transient and steady-state conditions; and UPQCs as a combination of D-STATCOM and DVR for mitigating current and voltage quality problems in a number of applications. The voltage sag/swell magnitude is ranged from 10% to 90% of nominal voltage and with duration from half a cycle to 1 min. Distribution Static Compensator (D-STATCOM) is proposed for mitigation of voltage sag which is the most frequently experienced PQ issue.

2. Distribution Static Compensator

A D-STATCOM consists of a two-level VSC, a dc energy storage device, controller and a coupling transformer connected in shunt to the distribution network. Figure 2.1 shows the schematic diagram of D-STATCOM. It replaces conventional voltage and reactive power control elements. It can improve the voltage profile along feeders, reduce losses and is also capable of compensating for real power fluctuations on account of the presence of an energy storage system connected to the DC side. When voltage fluctuations occur, the D-STATCOM responds by injecting currents, With the proper phase angle and magnitude. Figure 2.1 shows the schematic diagram of D-STATCOM.

$$I_{out} = I_L - I_s \qquad (2.1)$$

$$\text{Where, } I_s = \frac{V_{th} - V_L}{Z_{th}} \qquad (2.2)$$

I_{out} =output current, I_L=load current, I_s=source current

V_L = load voltage, V_{th} = Thevenin Voltage, Z_{th} = impedance

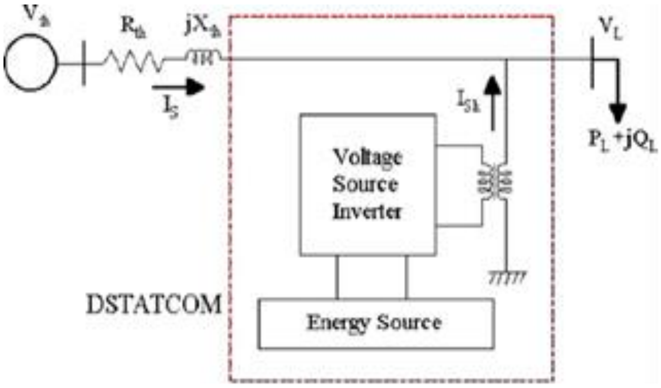

Fig.2.1 Schematic Diagram of D-STATCOM

As per equation 2.2, I_{out} will correct the voltage sags by adjusting the voltage drop across the system impedance, (Z_{th} =***R+jX***). The effectiveness of D-STATCOM in correcting voltage sags depends on:The value of Impedance, Z_{th}**= R+jX**,The fault level of the load bus.

2.1 Voltage Source Converter (VSC)

It is an electronic device. VSC is the most important component in D-STATCOM and it can generate a sinusoidal voltage waveform with any required magnitude, with any required phase angle and also with any required frequency. VSC is used to replace the voltage or to inject the 'missing voltage'. The missing voltage can be defined as the difference between the actual voltage and the nominal voltage.

2.2 Energy Storage Circuit

From fig 2.2 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.

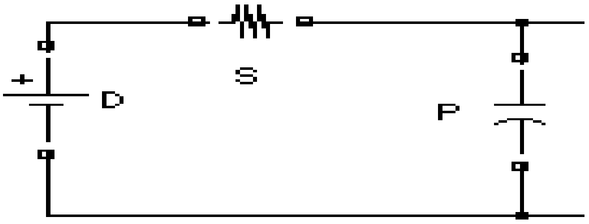

Fig.2.2 Schematic Diagram of Energy Storage Circuit

2.3 Controller

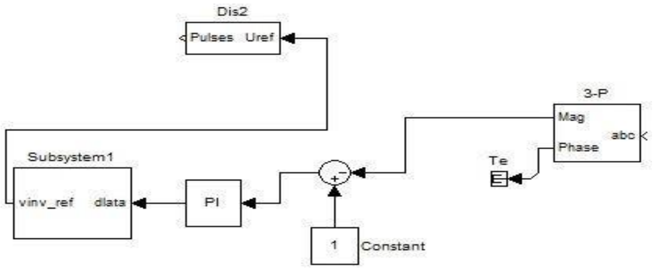

Fig.2.3 Controller design for MATLAB model

The aim of the controller system is to maintain the constant voltage magnitude at the point where a sensitive load is connected under system disturbances. The control system element can only measure 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. 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 voltage which is assumed to be 120° to produce the suitable synchronizing signal, required to operate the PWM generator. Then, this angle will be fed to the PWM signal generator. PWM generator will generate the sinusoidal PWM waveform or signal.

3. Methodology

The methodology and Simulink models to implement this project is depicted. It describes to generate a voltage sags by creating faults and to solve it by using D-STATCOM mechanism. MATLAB/Simulink software has been used and 11kV distribution scheme has been implemented in MATLAB/Simulink software. first of all, the distribution system with two feeders has been designed. Then to make voltage sags, three phase faults has been applied at one of the feeders. After that, run the simulation between 0 until 1 second to see the voltage sags waveform. Then, to mitigate voltage sags, D-STATCOM device is inserted into the distribution system. The wave shape from the scope was observed and compared for voltage sag with and without insertion of D-STATCOM in the Circuit. Figure 3.1 shows the simulation process flow. That flow chart clarifies about general process of the simulation. Initially, the most important circuit of distribution system was applied in MATLAB/Simulink. Next, to generate voltage sags, three phase faults with different resistance values were applied on the system. Next, start the simulation between 0 up to 1 second. at that time, to advance the voltage sag, D-STATCOM was inserted into the distribution system. If the sags is still less than 0.9 p.u after the addition of D-STATCOM, run another time the simulation until the result give details that the sags get better greater than 0.9 p.u. Then the outcome from the scope can be studied

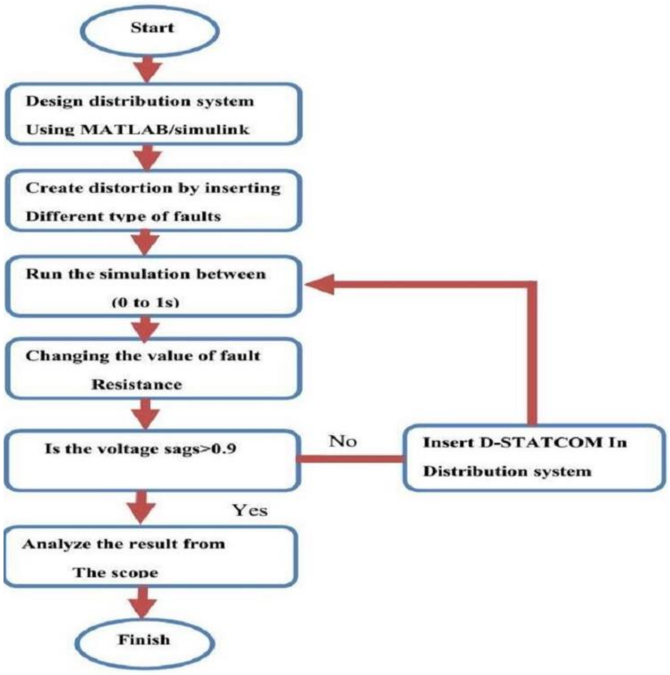

Fig.3.1 Flow chart for the methodology

3.1Test System

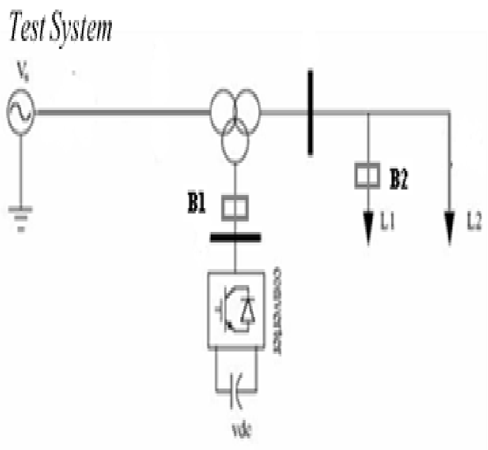

Fig.3.2 single line diagram of test system

Figure3.2 shows the Single line diagram of the test system The test system shown in figure 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.. Breaker 1 is used to control the period of operation of the D-STATCOM and breaker 2 is used to control the connection of load 1 to the system.

3.2 System implementation in MATLAB/Simulink

Based on the scope of this project, the simulation was experienced on the distribution system. The experiment system consists of a 230 kV transmission system, feeding into the primary side of a 3-winding transformer. A differentiating load is connected to the 11 kV, secondary side of the transformer. In order to examine the sags (dips) event, three lines to the ground fault was created. Then, automatically voltage sags (dips) will happen. therefore, we can analyze the result of using Distribution Static Compensator (D-STATCOM) and how D-STATCOM systems enhance the sags (dips). Initially, the major circuits were designed and fulfilled in the MATLAB/Simulink. Figure 3.3(a) illustrates the main circuit of distribution network without setting up of D-STATCOM systems. Figure 3.3(b) shows the circuit implemented with insertion of D-STATCOM.The linked load to the system is balanced loads and thus load is connected to the 11 kV, secondary side of the transformer. A three-phase fault creator was located on feeder B. The run time for the entire system is 1 second where sags (dips) happen in feeder A for the period of 0.3 second to 0.6 second.

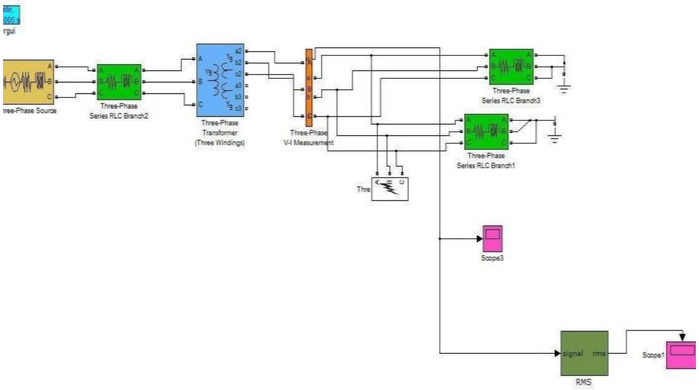

Fig.3.3(a) Simulation circuit without D-STATCOM

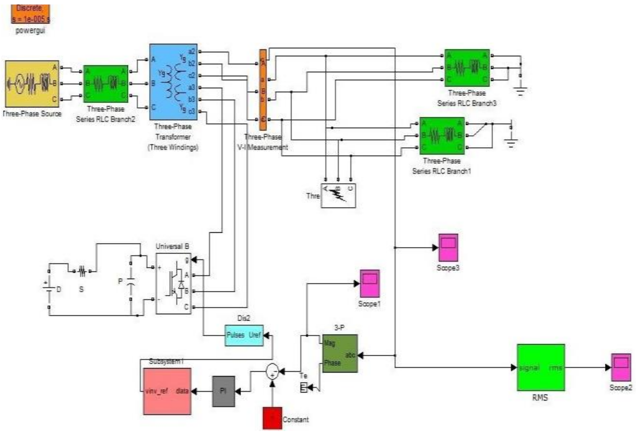

Fig.3.3 (b) Simulation circuit with D-STATCOM

4 Results and Discussion

Three different types of fault were applied in the distribution system and the value of the fault resistance was varied. From the table 4.1 to 4.3, it can be observed that voltage sags improved with the insertion of D-STATCOM. The value of voltage sag is between 0.940 pu until 0.997 pu.

Table 4.1Voltage sag for different values of resistances Fault: TLG (Triple line to ground)

Resistance(Ω)	Voltage sag (pu)without D-STATCOM	Voltage sag (pu)with insertion of D-STATCOM
0.66	0.467	0.940
0.76	0.502	0.953
0.86	0.531	0.961
0.96	0.554	0.968

Table 4.2Voltage sag for different values of resistances Fault: DLG (Double line to ground)

Resistance(Ω)	Voltage sag (pu)without D-STATCOM	Voltage sag (pu)with insertion of D-STATCOM
0.66	0.467	0.981
0.76	0.502	0.987
0.86	0.531	0.992
0.96	0.555	0.995

Table 4.3Voltage sag for different values of resistances Fault: SLG (Single line to ground)

Resistance(Ω)	Voltage sag (pu)without D-STATCOM	Voltage sag (pu)with insertion of D-STATCOM
0.66	0.467	0.985
0.76	0.502	0.990
0.86	0.531	0.994
0.96	0.555	0.997

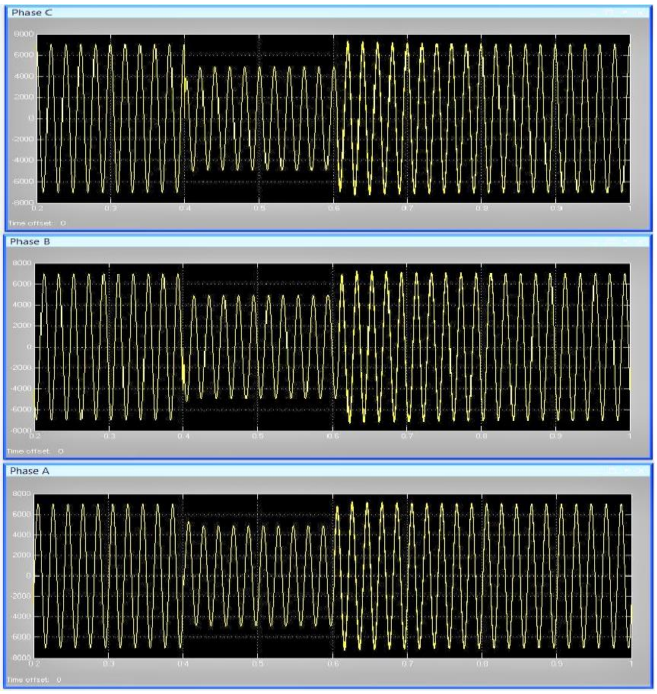

Figure 4.1Output voltage at feeder A without compensation for each phase. Phase A, Phase B and Phase C respectively

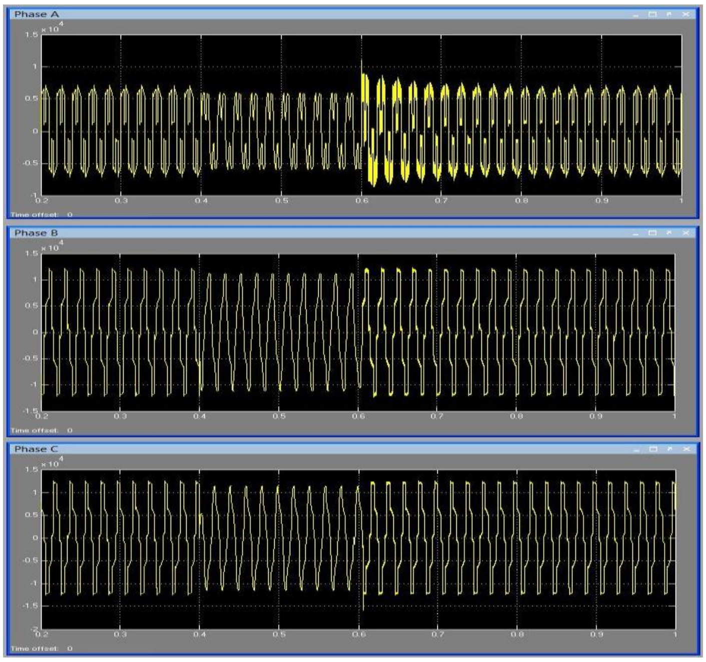

Figure 4.2: Output voltage at feeder A after compensation for each phase. Phase A, Phase B and Phase C respectively.

Figure 4.3 (a) 4.3 (c) show the results of voltage sags after compensation for different types of fault measure at the load point when the value of fault resistance is R = 0.66Ω. The fault occurs between 0.4s until 0.6s.

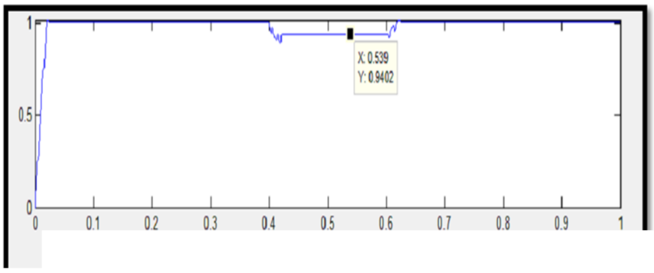

Fig4.3(a) Voltage at load point is 0.9402pu for TLG fault

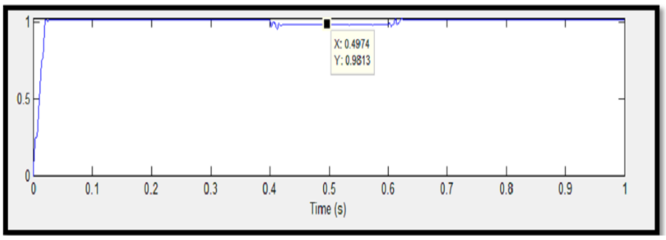

Fig4.3(b) Voltage at load point is 0.9813pu for DLG fault

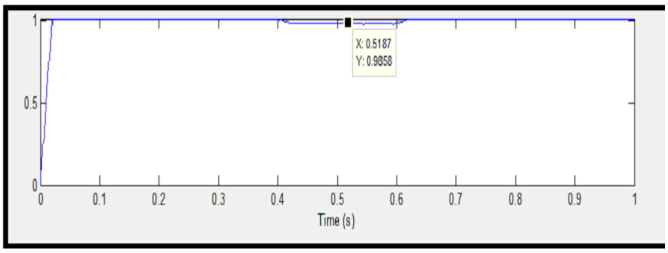

Fig.4.3(c) Voltage at load point is 0.9858pu for SLG fault

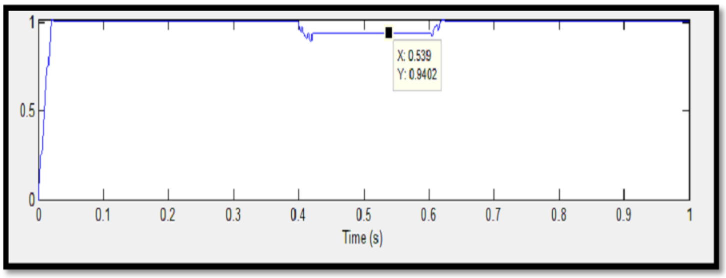

Figure 4.10 (a) : Voltage at load point is 0.9402 pu for **TLG** fault

Conclusion

Simulation results are separated in two parts as voltage sag without insertion of D-STATCOM and with insertion of D-STATCOM in the test system. Voltage sag was created by various faults viz. SLG, DLG and TLG. It can be seen from the results that the voltage at distribution side has been improved. Thus, power quality is enhanced using D-STATCOM in distribution side.

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