Mitigation of Harmonics in Distribution System Using D - STATCOM

E.Rambabu, E.Praveena, Prof.P.V.Kishore

Abstract— This paper deals with the performance, analysis of, operating principles of a new generation of power electronics based equipment called Distribution Static Compensator (D-STATCOM) aimed at enchancing the reliability, and quality of power flow in low voltage distribution network. 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.LCL Passive Filter was then added to D-STATCOM to improve harmonic distortion and low power factor.

Index Terms— D-STATCOM, Power Quality, Voltage sag, Voltage source converter, harmonic distortion

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1 INTRODUCTION

In the early days of power transmission in the late 19th century problems like voltage deviation during load changes and power transfer limitation were observed due to reactive power unbalances. Today these Problems have even higher impact on reliable and secure power supply in the world of Globalization and Privatization of electrical systems and energy transfer. The development in fast and reliable semiconductors devices (GTO and IGBT) allowed new power electronic Configurations to be introduced to the tasks of power Transmission and load flow control. The FACTS devices offer a fast and reliable control over the transmission parameters, i.e. Voltage, line impedance, and phase angle between the sending end voltage and receiving end voltage. On the other hand, the custom power is for low voltage distribution, and improving the poor quality and reliability of supply affecting sensitive loads. Custom power devices are very similar to the FACTS. Most widely known custom power devices are DSTATCOM, UPQC, DVR among them DSTATCOM is very well known and can provide cost effective solution for the compensation of reactive power and unbalance loading in distribution system

The performance of the DSTATCOM depends on the control algorithm i.e. the extraction of the current components. For this purpose, there are many control schemes, which are reported in the literature, and some of these are instantaneous reactive power (IRP) theory, instantaneous compensation, instantaneous symmetrical components, synchronous reference frame (SRF) theory, computation based on per phase basis, and scheme based on neural network. Among these control schemes, instantaneous reactive power theory and synchronous rotating reference frame are most widely used. This paper focuses on the compensating the voltage sag, swells and momentary interruptions.

In this paper, the configuration and design of the DSTATCOM with LCL Passive Filter are analyzed. It is connected in shunt or parallel to the 11 kV test distribution system. It also is design to enhance the power quality such as voltage sags, harmonic distortion and low power factor in distribution system.

2 REACTIVE POWER IN VOLTAGE REGULATION

2.1 Voltage Disturbances

Voltage sag or dip represent a voltage fall to 0.1 to 0.9 p.u. and existing for less than one minute and voltage swell is the rise in voltage of greater than 1.1 p.u. and exists for less than one minute.

2.2 Voltage Cintrol by Reactive Power Compensation

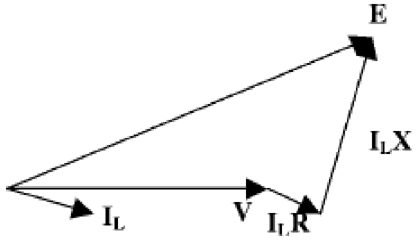

Fig: 2.1 Uncompensated Line with Single Load

First, we consider an uncompensated line.The current drawn by a load depends on the load itself and the line voltage. The current engenders the voltage drop in the transformer and the line reactance. It results in decrease in transmission voltage V_T and distribution voltage V_D. Figure 2.1 shows the vector diagram of a single load center connected to uncompensated line. The voltage drop in the line mainly depends on the current taken by the load as well as the resistance and inductance in the line.

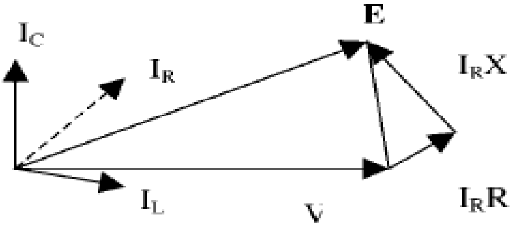

Fig: 2.2 Compensated Lines with Single Load

It can also be seen that the angle between the voltage and the current is playing a major role in maintaining the voltage. Let us consider the supply voltage is E. Now due to the voltage drops IR and IX the load voltage is V.

It is possible to bring V=E, just by making the current to lead so that the vector diagram will get modified as shown in figure 2.2. i.e by the use of shunt compensation (either at the transmission line or at the distribution line) the voltage at the load end can be regulated.

The same principle can be used in case of capacitive load also. If the load is capacitive, a lagging current will help in regulation of voltage.

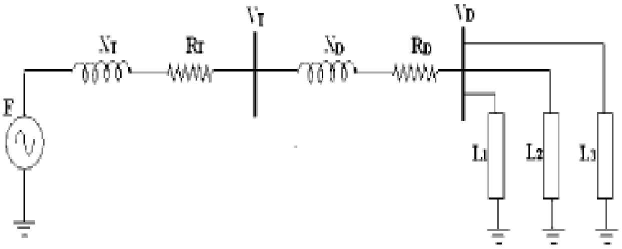

Fig: 2.3 A Simple power line without DSTATCOM

From the above figure 2.3 it is clear that the voltage will get dropped both at the transmission side as well as at the distribution side.

$$E < V_T < V_D$$

Hence by the use of reactive power compensation V_D can be increased to that of the supply voltage E.

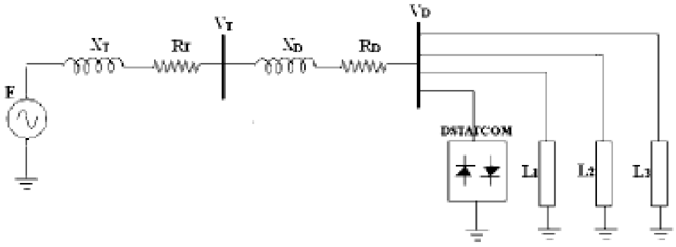

Fig: 2.4 A Simple power line with DSTATCOM

As DSTATCOM is the shunt device the shunt –injected current (leading or lagging) corrects the voltage by adjusting the voltage drop and

$$V_D = E$$

The indictive or capacitive reactive power required by the load is provided at the load point itself by the STATCOM without the use of reactors and capacitive banks.

3 DSTATCOM

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 3.1 shows the schematic diagram of D-STATCOM.

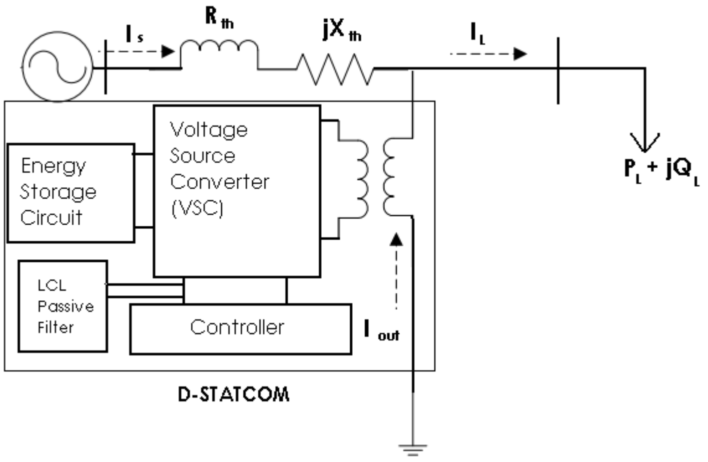

Fig: 3.1 Schematic diagram of a DSTATCOM

$$I_{out} = I_L - I_S = I_L - ((V_{th} - V_L)/Z_{th}) \quad (1)$$

$$I_{out} < \gamma = I_L < (-\theta) - (V_{th}/Z_{th}) < (\delta-\beta) + V_L/Z_{th} < (-\beta) \quad (2)$$

I_{out} =*Output current*
I_S = *Source current*
I_L = *Load current*
V_{th} = *Thevenin voltage*
V_L = *Load voltage*
Z_{th} = *Impedance*

Referring to the equation 2.2, output current, I_{out}will correct the voltage sags by adjusting the voltage drop across the system impedance, (Z_{th} **=*R+jX***). It may be mentioning that the effectiveness of D-STATCOM in correcting voltage sagsdepends on:

a) The value of Impedance, Z_{th} **= *R+jX***
b) The fault level of the load bus

3.1 Voltage Source Converter

A voltage-source converter is a power electronic device that connected in shunt or parallel to the system. It can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. The VSC 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. It also converts the DC voltage across storage devices into a set of three phase AC output voltages [8, 9].

In addition, D-STATCOM is also capable to generate or absorbs reactive power. If the output voltage of the VSC is greater than AC bus terminal voltages, D-STATCOM is said to be in capacitive mode. So, it will compensate the reactive power through AC system and regulates missing voltages. These voltages are in phase and coupled with the AC system through the reactance of coupling transformers.

Suitable adjustment of the phase and magnitude of the DSTATCOM output voltages allows effectives control of active and reactive power exchanges between D-STATCOM and AC system. In addition, the converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage [10].

3.2 Controller

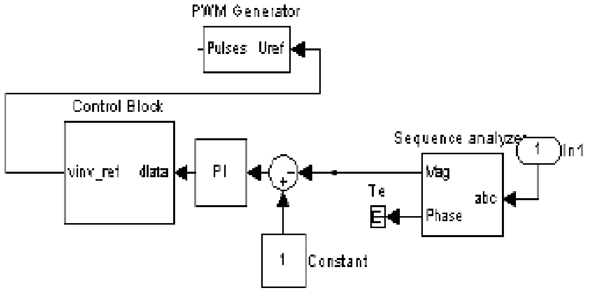

Fig: 3.2 Bolck diagram of Controller System

Figure 2.2 shows the block diagram of Controller sy tem.The controller system is partially part of distribution sy tem.

Proportional-integral controller (PI Controller) is a feedback controller which drives the system to be controlled with a weighted sum of the error signal (difference between the output and desired set point) and the integral of that value.

In this case, PI controller will process the error signal to zero. The load r.m.s voltage is brought back to the reference voltage by comparing the reference voltage with the r.m.s voltages that had been measured at the load point. It also is used to control the flow of reactive power from the DC capacitor storage circuit.

PWM generator is the device that generates the Sinusoidal PWM waveform or signal. To operate PWM generator, the angle is summed with the phase angle of the balance supply voltages equally at 120 degrees. Therefore, it can produce the desired synchronizing signal that required. PWM generator also received the error signal angle from PI controller. The modulated signal is compared against a triangle signal in order to generate the switching signals for VSC valves.

4 TEST SYSTEM

For the simulation study a three phase source is treated as primary distribution substation and the distribution line is treated as the lumped inductance in series with the resistance. Let us consider a fixed load is connected to the distribution line and a heavy inductive and capacitive load is connected at the required instants to study the performance the DSTATCOM in case of voltage sag and swell conditions. The DSTATCOM circuit is connected in shunt with the distribution system nearer to the load point through a star/delta transformer.

5 SIMULINK MODEL OF THE SYSTEM

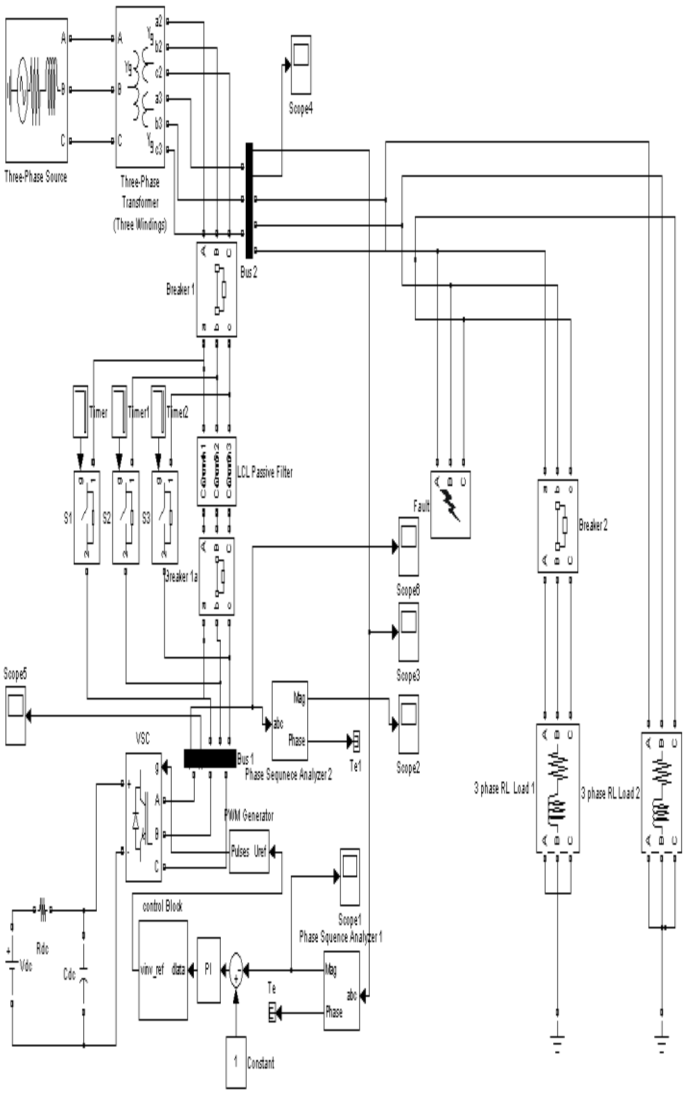

Fig: 5.1 Simulink diagram of main power system network

6 SIMULATION RESULTS

In this paper inorder to create a disturbance in the system we used a three phase fault block from simulink. The different faults created in the system are Single Line to Ground (SLG), Line to Line (LL), Double Line to Ground (DLG), Three phase to Ground (TPG).

6.1 Without D-SATACOM

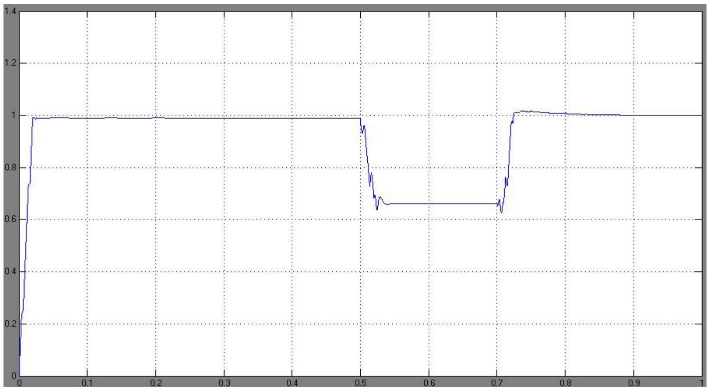

Fig: 6.1(a) Simulation result for TGP

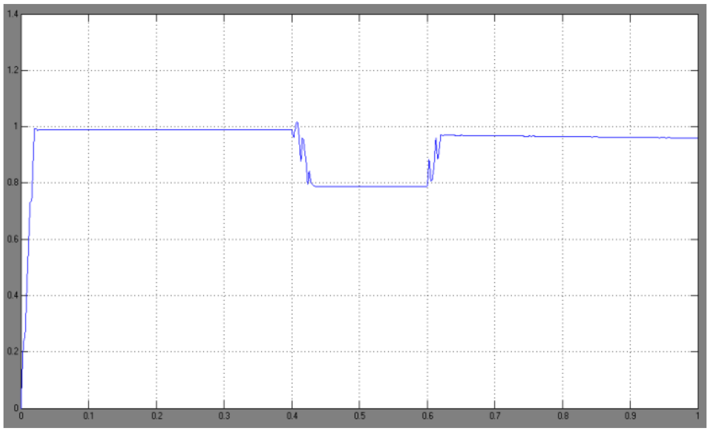

Fig: 6.1(b) Simulation result for DLG

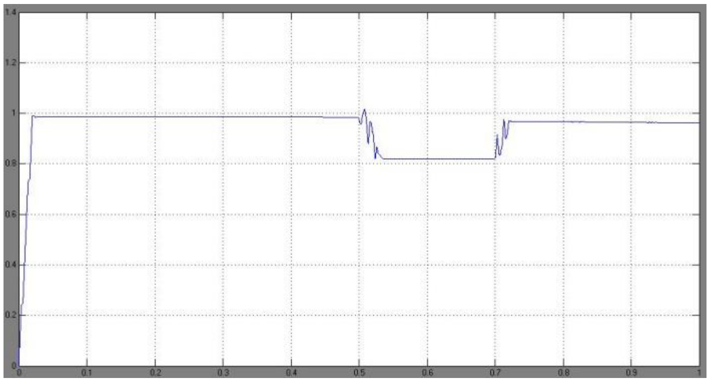

Fig: 6.1(c) Simulation result for LL

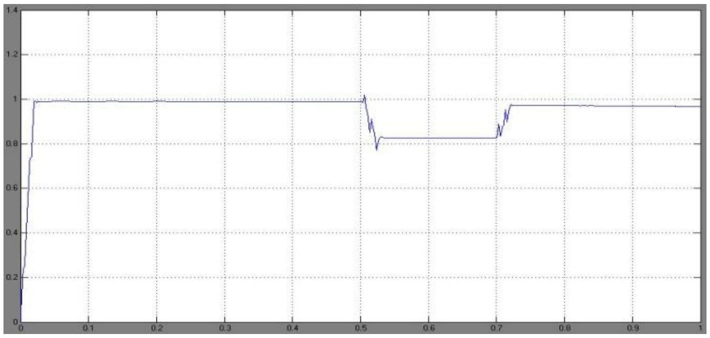

Fig: 6.1(d) Simulation result for SLG

TABLE 1
VOLTAGE SAGS FOR DIFFERENT FAULT CONDITIONS

Fault Resistance Rf(Ω)	Volyage sags fot TGP Fault	Volyage sags fot DLG Fault	Volyage sags fot LL Fault	Volyage sags fot SLG Fault
0.66	0.66	0.70	0.75	0.82
0.76	0.71	0.74	-.79	0.84
0.86	0.75	0.78	0.82	0.86

The above table shows the overall results of voltage sags in p.u. for different types of fault. From the table, it can be observed that when the value of fault resistance is increase, the voltage sags will also increased for different types of fault.

6.2 With D-SATACOM

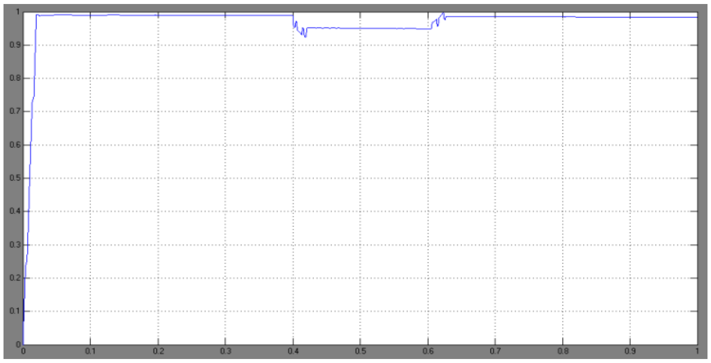

Fig: 6.2(a) Simulation result for TGP

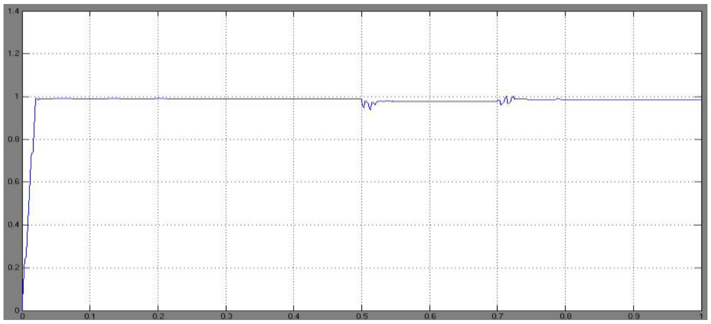

Fig: 6.2(b) Simulation result for DLG

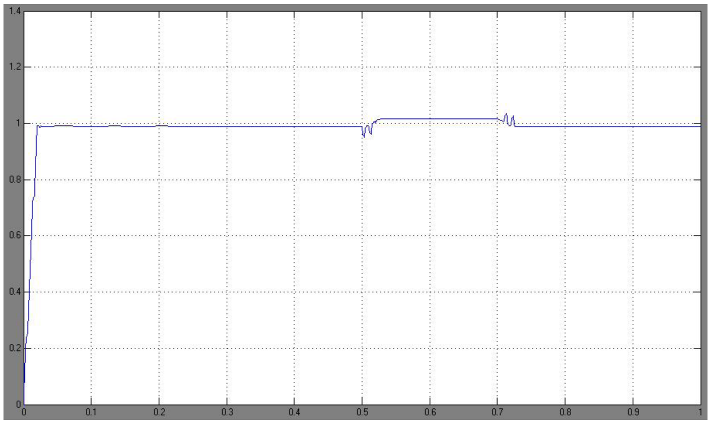

Fig: 6.2(c) Simulation result for LL

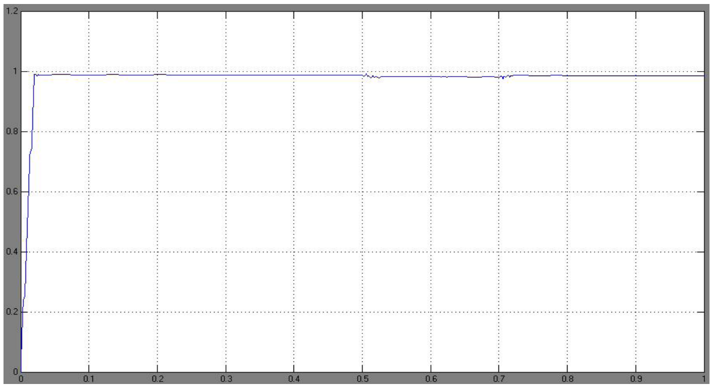

Fig: 6.2(d) Simulation result for SLG

TABLE 2
VOLTAGE SAGS FOR DIFFERENT FAULT CONDITIONS

Fault Resistance Rf(Ω)	Volyage sags for TGP Fault	Volyage sags for DLG Fault	Volyage sags for LL Fault	Volyage sags for SLG Fault
0.66	0.9367	0.9800	1.0168	0.9837
0.76	0.9450	0.9806	1.0142	0.9817
0.86	0.9543	0.9858	1.0152	0.9863

Table 2 shows the overall results of voltage sags in p.u with different types of fault. From the table, it can be observed that voltage sags improved with insertion of D-STATCOM. The value of voltage sags is between (0.9 to 1.02 p.u.)

TABLE 3
DIFFERENT TYPES OF FAULTS BEFORE AND AFTER D-STATCOM WHEN RF = 0.6Ω

Types of fault	Without DSTATCOM (p.u)	With DSTATCOM (p.u)	Percentage of improvement (%)
TPG	0.6600	0.9367	27.67
DLG	0.7070	0.9800	27.30
LL	0.7587	1.0168	25.81
SLG	0.8259	0.9837	15.78

7 CONCLUSION

The power Quality improvement by using Distribution Static Compensator is presented in this paper.The results validate the principle if D-STATCOM for voltage regulateon applications. The simulation results show that the voltage sags can be mitigate by inserting D-STATCOM to the distribution system.

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