IMPROVEMENT OF VOLTAGE SAG USING FACTS DEVICE

[1]Basharat Ahmad Shah, [2]Dawood Masood, [3]Abhishake Jain
[1]PG SCHOLAR, [2] M Tech Power System, [3]ASSISTANT PROFESSOR
[1,3]DEPARTMENT OF ELECTRICAL ENGINERING,
[1,3]GANGA INSTITUTE OF TECHNOLOGY AND MANAGEMENT (MDU ROHTAK), HARYANA, INDIA

Abstract: **Power quality is one of major concerns in the present era. It has become important, especially, with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end user equipments. One of the major problems deal at here is the voltage sag/swell. A voltage sag or voltage dip is a short duration reduction in r.m.s. voltage which can be caused by a short circuit, overload or starting of electric motors. Voltage sag happens when the r.m.s. voltage decreases between 10 and 90 percent of nominal voltage for one-half cycle to one minute. The performance of a DSTATCOM in mitigating voltage sag/ swell is demonstrated with the help of MATLAB. The modeling and simulation results of a DSTATCOM are presented. D-STATCOM is promising device which is used for voltage sag, swell mitigation at distribution side.**

FACTS devices play an important role in improving the power quality problems, improving transmission capacity. To solve this problem, custom power devices are used. This paper illustrates modeling and simulation of Flexible AC Transmission System devices in distribution network is presented so as to mitigate the voltage sag at the network buses. One of those devices is the D-STATCOM which is the most efficient and effective modern custom power device used in power distribution networks. DSTATCOM compensator is a flexible device which can operate in current control mode for compensating voltage variation, unbalance and reactive power and in voltage control mode as a voltage stabilizer. The latter feature enables its application for compensation of dips coming from the supplying network. In addition, the regulated V_{rms} voltage showed a reasonably smooth profile. This paper explained the two level VSC based D-STATCOM and can be extended to multilevel inverter based D-STATCOM to reduce the harmonic content in current. The D-STATCOM can be designed using a current source inverter. An integrated D-STATCOM controller can be design for voltage regulation, reactive power compensation. This paper presents development, simulation and analysis of a D-STATCOM using MATLAB/ SIMULINK to enhance the voltage sag restoration capability of the D-STATCOM. Accordingly, simulations are first carried out to illustrate the use of D-STATCOM in mitigating voltage sag in a system. Simulation results prove that the facts devices are capable of mitigating voltage sag as well as improving power quality of a system.

IndexTerms – SAG/SWELL,POWER QUALITY, D-STATCOM, VSC, FACTS, MATLAB,

I. INTRODUCTION

In modern industrial devices among which most of devices are based on electronic devices such as programmable logic controllers and electronic drives. Due to high sensitive nature, power electronic devices become less tolerant to power quality problems such as voltage sags, swells and harmonics. In the entire problems associated with voltage dip is consider one of the most severe disturbances to the industrial equipment. Recent development of power electronics introduces the use of Flexible AC Transmission System (FACTS) Controllers in the power systems. FACTS devices using power electronics based converters have the task to increase the reliability and quality of electricity supply to consumers. Improving the power quality is usually achieved by means of reactive power control, load symmetry and active filtering of nonlinear load harmonics. The FACTS devices ability to control bus voltage magnitudes and phase angles depends on their rating and applied control strategies.

To solve the voltage sag problem, custom power devices are used. One of those devices is the D-STATCOM, which is the most efficient and effective modern custom power device used in power distribution networks. D-STATCOM provides injection of shunt current into the system to solve the problem of short term reduction in the root mean square voltage of the system. This dissertation presents development, simulation and analysis of a D-STATCOM using MATLAB/SIMULINK to enhance the voltage sag restoration capability of the system.

II. SAG/SWELL

Sag (dip) can be defined as, "A decrease to between 0.1 and 0.9pu in RMS voltage or current at the power frequency for durations of 0.5 cycles to 1 minute." Figure 1.

Swell can be defined as, "An increase to between 1.1pu and 1.8pu in RMS voltage or current at the power frequency durations from 0.5 to 1 minute."

According to the IEEE Std. 1995-2009 voltage sag is "A decrease in RMS voltage or current at the power frequency for duration of 0.5 cycles to 1 minute".

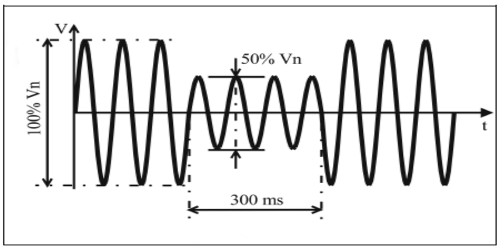

Figure 1Voltage Sag Depiction

According to the IEEE Std. 1995-2009 voltage sag is "A decrease in RMS voltage or current at the power frequency for duration of 0.5 cycles to 1 minute".

IEC has the following definition for a dip (IEC 61000-2-1, 1990) "A voltage dip is a sudden reduction of the voltage at a point in the electrical system, followed by a voltage recovery after a short period of time, from half a cycle to a few seconds".

The duration and amplitude value limits that are likely to cause problems with equipments are already defined by both the ANSI C84.1-1989 Utility Power Profile and the CBEMA (Computer and Business Equipment Manufacturers Association) curve. The smaller the amplitude of a sag or higher the value of a swell, the shorter the duration should be for equipment to follow through the disturbance, as in the following table 1 derived from such. The typical industrial utility power after building line losses is in the range of +6%, -13% from the nominal value.

Categories		**Typical Duration**	**Typical Magnitude**
Instantaneous	**Sag**	0.5- 30 cycles	0.1- 0.9pu
	Swell	0.5- 30 cycles	1.1-1.8pu
Momentary	**Interruption**	0.5- 3 cycles	<0.1pu
	Sag	0.5- 3 cycles	0.1- 0.9pu
	Swell	0.5- 3 cycles	1.1-1.8pu
Temporary	**Interruption**	3Sec-1 minute	<0.1pu
	Sag	3Sec-1 minute	0.1- 0.9pu
	Swell	3Sec-1 minute	1.1-1.8pu

Table 1 IEEE Std. 1995-2009 Instantaneous, momentary, and temporary illustration

III. D-STATCOM

The D-STATCOM is basically one of the custom power devices. It is nothing but a STATCOM but used at the Distribution level. It is a voltage or current source inverter based custom power device connected in shunt with the power system. It is connected near the load at the distribution systems. The key component of the D-STATCOM is a power VSC that is based on high power electronics technologies. Basically, the D-STATCOM system is comprised of three main parts: a VSC, a set of coupling reactors and a controller. The basic principle of a D-STATCOM installed in a power system is the generation of a controllable ac voltage source by a voltage source converter (VSC) connected to a dc capacitor (energy storage device). The ac voltage source, in general, appears behind a transformer leakage reactance. The active and reactive power transfer between the power system and the D-STATCOM is caused by the voltage difference across this reactance. The D-STATCOM is connected in shunt with the power networks at customer side, where the voltage-quality problem is a concern. All required voltages and currents are measured and are fed into the controller to be compared with the commands. The controller then performs feedback control and outputs a set of switching signals to drive the main semiconductor switches (IGBTs, which are used at the distribution level) of the power converter accordingly. The ac voltage control is achieved by firing angle control. Ideally the output voltage of the VSC is in phase with the bus voltage. In steady state, the dc side capacitance is maintained at a fixed voltage and there is no real power exchange, except for losses.

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 shows the schematic diagram of D-STATCOM.

$$I_{out} = I_L - I_S = I_L - \frac{V_{th}-V_L}{Z_{th}} \quad \text{(a)}$$

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

Referring to the equation (b), output current, will correct the voltage sags by adjusting the voltage drop across the system impedance, $(Z_{th} = R + JX)$. It may be mention that 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

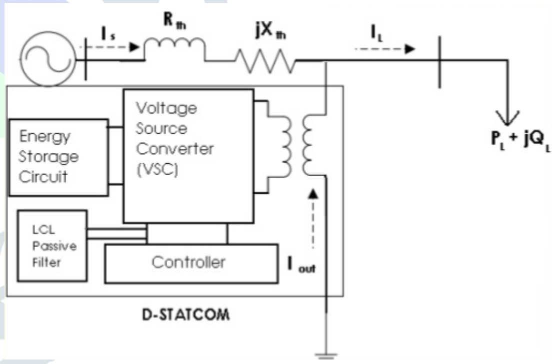

Figure 2 Schematic diagram of D-STATCOM

Reactive and active power that generated or (absorbed) by D-STATCOM respectively is given,

$$Q = \frac{V_S}{X}(V_S - V_i cos\delta)$$

$$P = \frac{V_S V_i}{X} sin\delta$$

Where X is reactance of coupling inductance and δ is phase angle between fundamental voltages of D-STATCOM and AC grid.

Reactive power is produced when the current waveform is out of phase with the voltage waveform due to inductive or capacitive loads. Current lags voltage with an inductive load, and leads voltage with a capacitive load. Only the component of current in phase with voltage produces real or active power. Major industrial loads for example transformers, furnaces, induction motors etc. needs reactive power for sustaining magnetic field. The main reason for reactive power compensation is- the voltage regulation, increased system stability, better utilization of machines connected to the systems, reducing system losses associated with the system. The D-STATCOM (Distribution Static Compensator) is a device used to control the flow of reactive power in distribution systems. A D-STATCOM is a fast response device that provides flexible voltage control at the point connection to the distribution feeder for reactive power compensation.

IV. SIMULINK Model;

The test model of the distribution system is simulated in SimPowerSystem and SIMULINK Blockset of MATLAB which is shown in Figure 3. The SIMULINK model without D-STATCOM is used to study various PQ disturbances in power system due to system faults, heavy loads and capacitor switching. In this part, the PQ disturbances are simulated using SIMULINK models by applying various types of loads and faults such as short circuit faults and capacitor bank switching as shown in Fig 5.10.

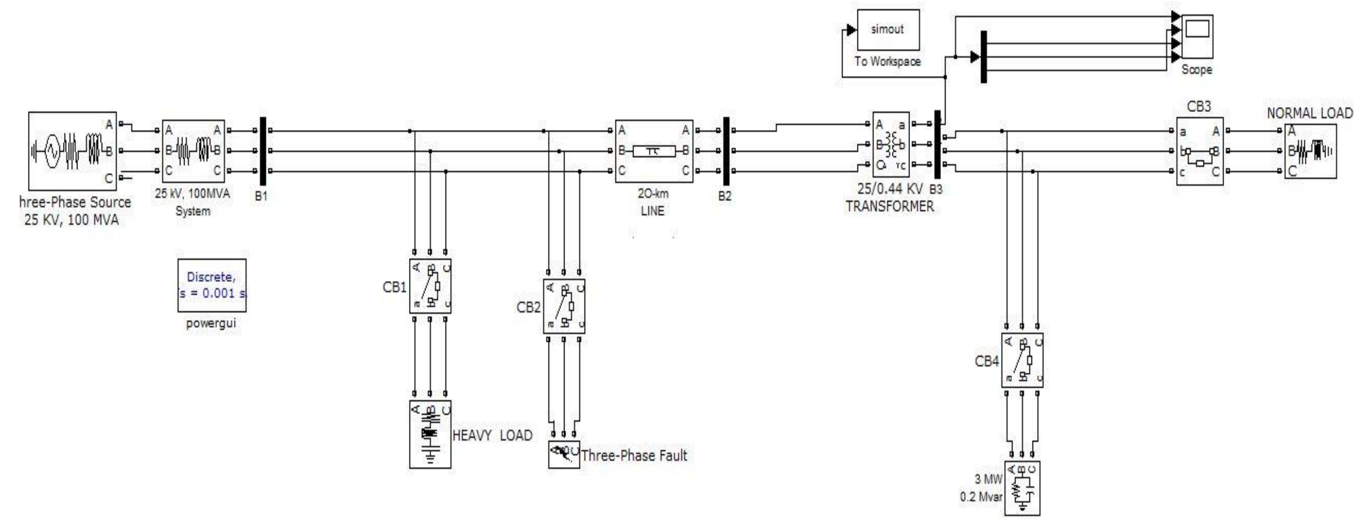

Figure 3 SIMULINK model without D-STATCOM

Each PQ waveform consists of 10 cycles and a frequency of 10 kHz. A distribution equivalent circuit with 25kV voltage source and 50 Hz frequency is shown in Fig 3. The transmission line is of 20 km length and π-model. The PQ disturbances are captured at the end of the load i.e. at bus B3. A single line-to ground fault is created at bus B1 which causes voltage sag and interruption in the faulty phase and swell in the non-faulty phase. A capacitor bank is connected at bus B. A variable load causes voltage flicker and fluctuation. The non-linear load creates steady-state distortions such as harmonics. The capacitor bank creates transients types of PQ disturbances. The simulation time for all disturbances is selected as 0.2s (10cycles).

The voltage sag, swell and interruption types of PQ disturbances are created in the power distribution supply system due to short circuit faults, switching of starting of large induction motors. Figure 4 shows a three phase voltage waveform at bus B3.

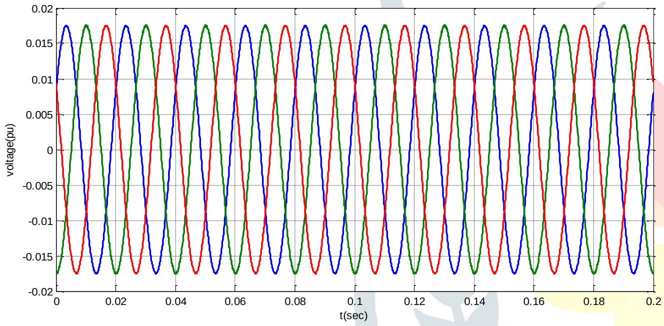

Figure 4 Three-phase waveform

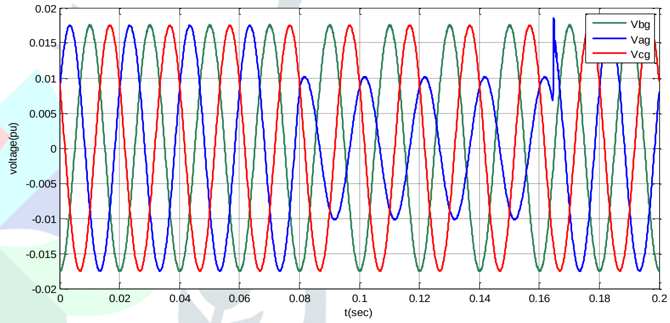

Figure 5 Voltage sag due to single line to ground fault

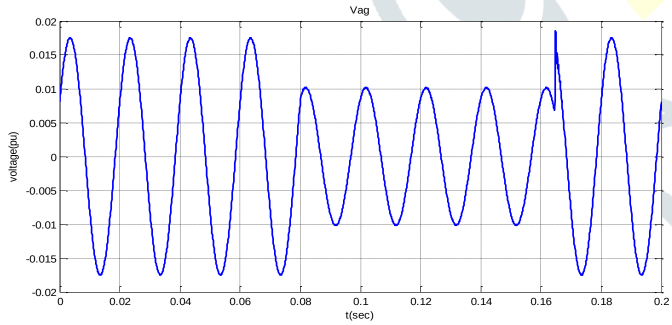

Figure 5 a Phase-A waveform

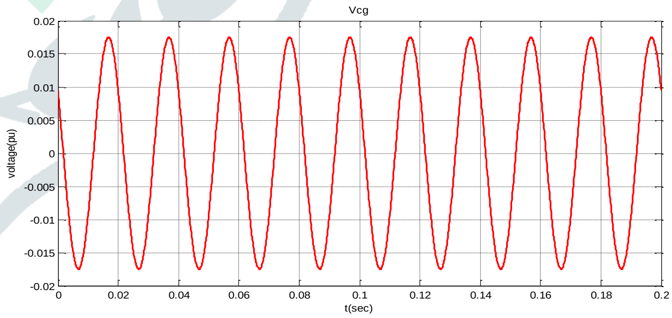

Figure 5 c Phase-C waveform

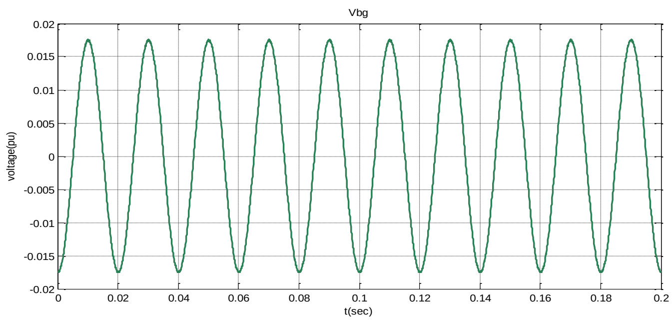

Figure 5 b Phase-B waveform

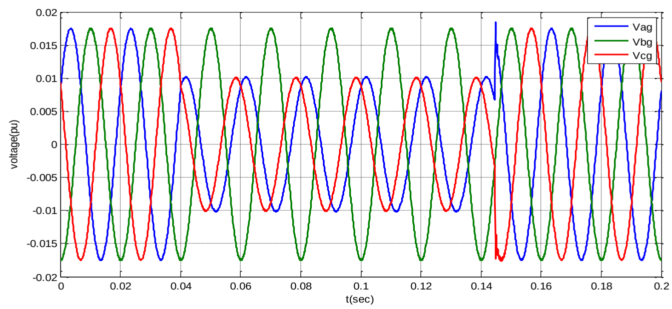

Figure 6 Voltage sag and swell due to line to line fault

The voltage sag is created in the phase-A due to single-phase to ground fault occurred at 0.08s and cleared at 0.16s as shown in Figure 5. When the fault is cleared at 0.16s, the voltage in the all phases is normal. In Fig 5, line to line fault is created in phases A and C for a period of 0.08s to 0.16s. Therefore sag is produced in phases A and C where as swell in phase B. Fig 6 shows interruption in phase A and swell in phases B and C between 0.04s and 0.14s due to heavy load on phase A.

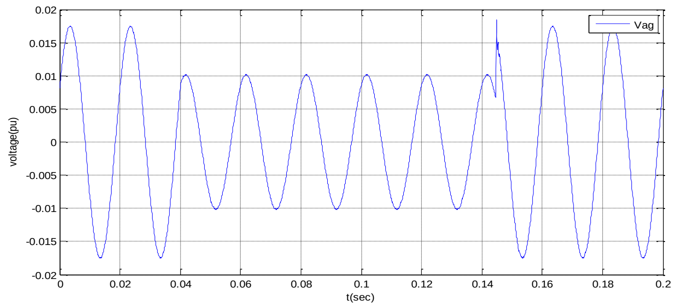

Figure 6 a Phase-A waveform

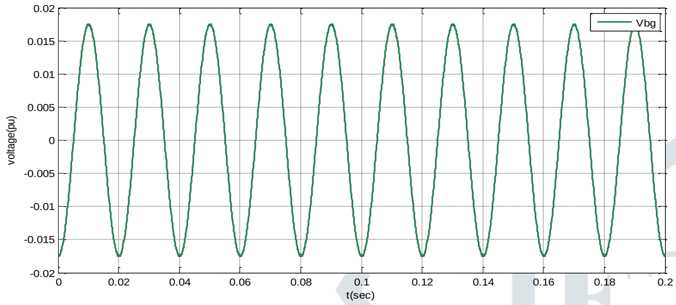

Figure 6 b Phase-B waveform

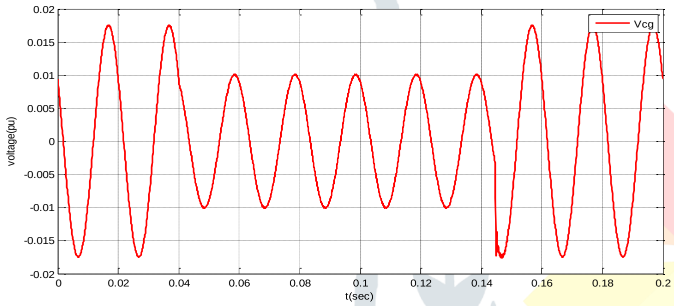

Figure 6 c Phase-C waveform

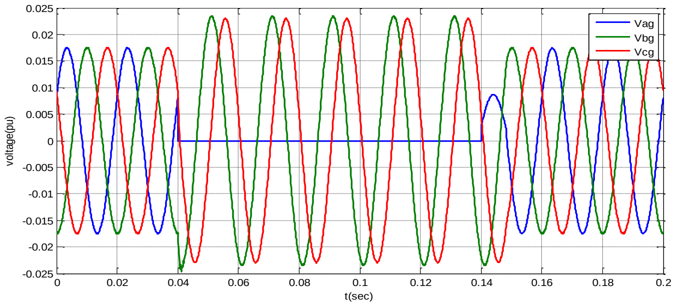

Figure 7 Voltage swell and interruption due to heavy load

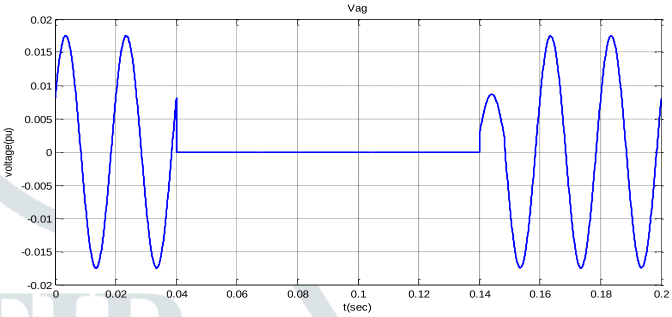

Figure 7 a Phase-A waveform

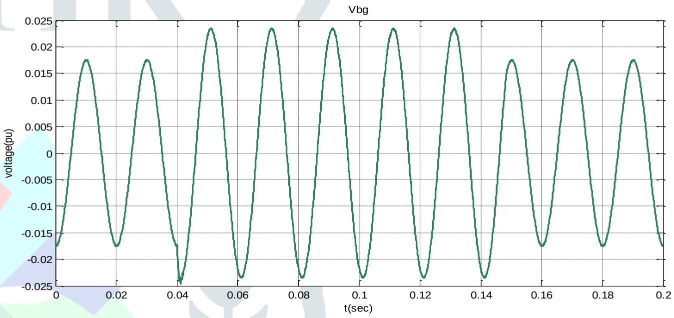

Figure 7 b Phase-B waveform

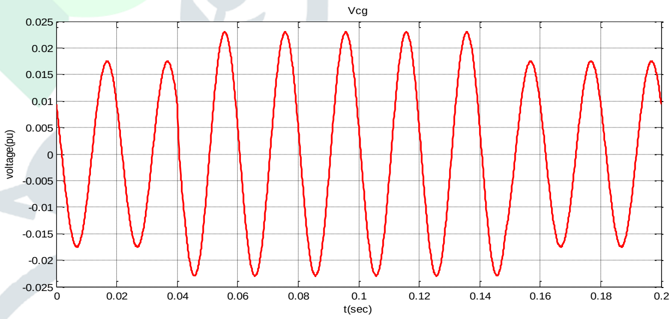

Figure 7 c Phase-C waveform

Figure 7 shows the interruption due to heavy load and swell caused at time 0.04s.

V. ELECTRICAL POWER DISTRIBUTION MODEL WITH D-STATCOM:

In this test model of the distribution system is simulated in SimPowerSystem and SIMULINK Blockset of MATLAB which is shown in Figure 8. The SIMULINK model D-STATCOM is used for the improvement of various PQ disturbances in power system due to system faults, heavy loads and capacitor switching.

In this part, the PQ disturbances are simulated using D-STATCOM for the improvement of various PQ disturbances in power system using SIMULINK models. The PQ disturbances in system occurs by applying various types of loads and faults such as short circuit faults and capacitor bank switching as shown in model.

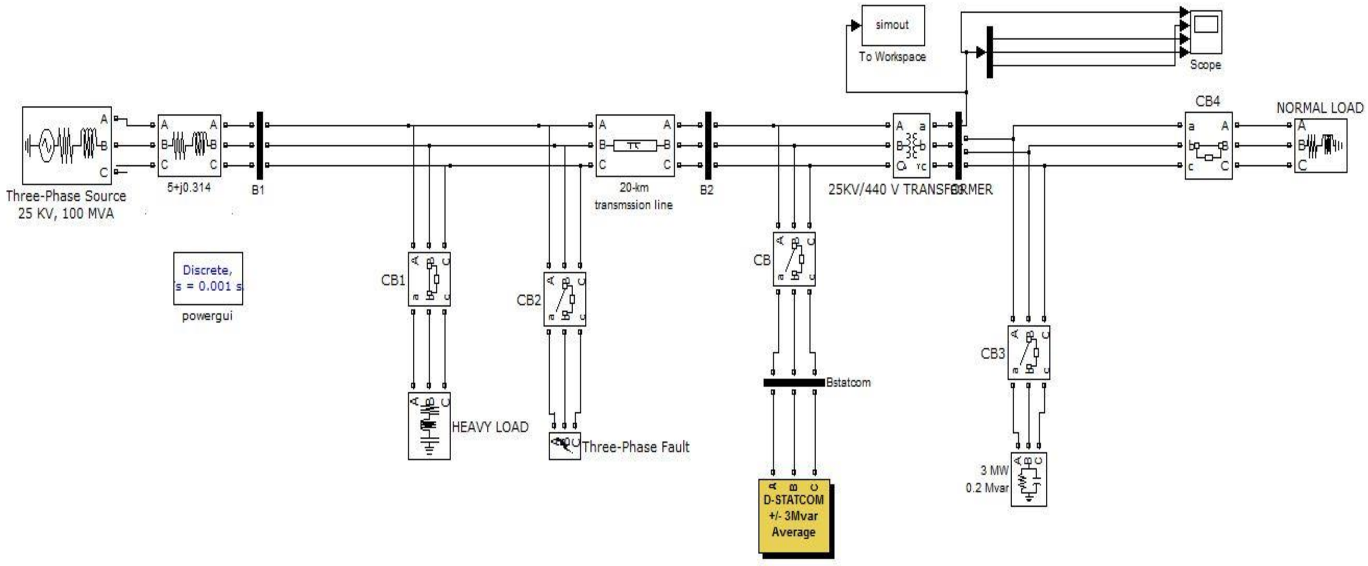

Figure 8 SIMULINK model with D-STATCOM

Figure 9 shows a three phase voltage waveform at bus B3, when the system is simulated with D-STATCOM connected as shown in Fig 8. When a single line to ground fault is applied on the system at time 0.08s, STATCOM is also switched at the same time. Results in the Figure 9 shows the improvement in voltage profile of the system when D-STATCOM is switched .The sag and swell condition shown in the Figure 5 due to single line to ground fault and Figure 7 due to switching a heavy load on the system is mitigated as seen from Figure 9. The transient behavior in the waveform is due to switching of D-STATCOM at time 0.08s.

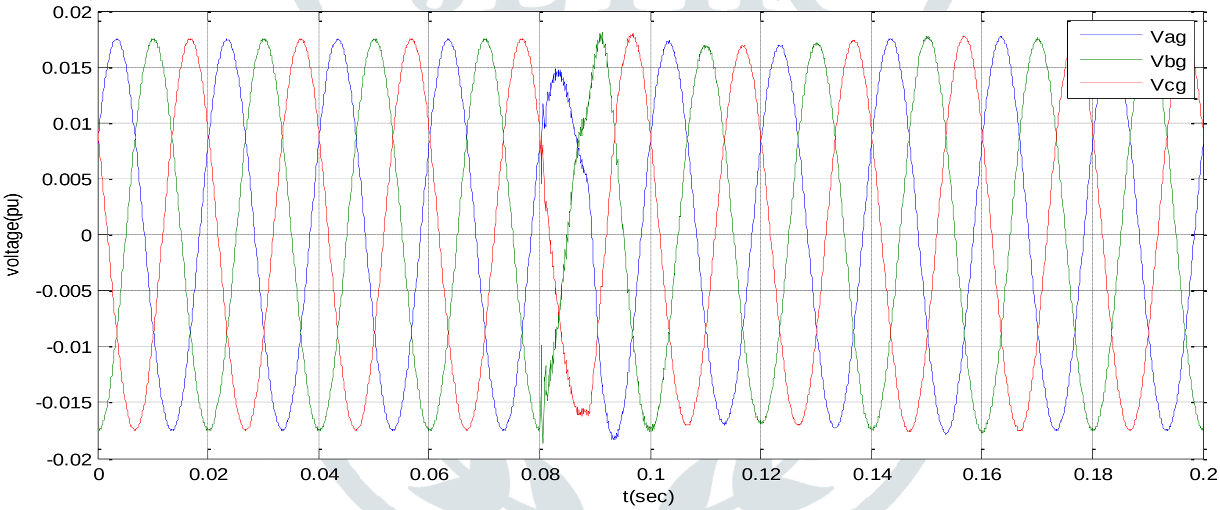

Figure 9 Improvement in voltage sag due to single line to ground fault

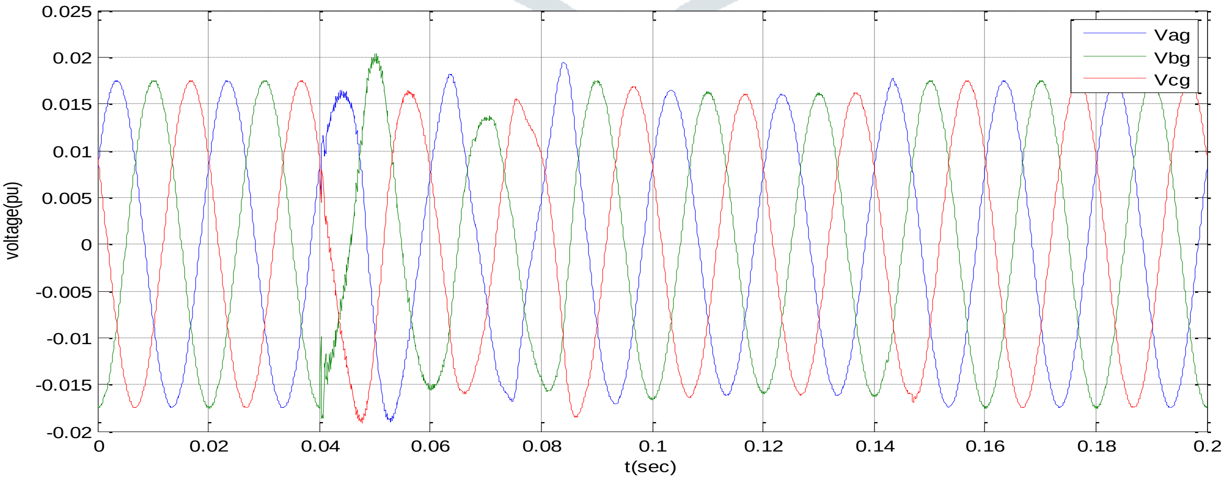

Figure 10 Improvement in voltage sag due to line to line fault

Similarly, the voltage waveforms shown in Fig 10 also shows the improvement in voltage profile of the system measured at bus 3.The D-STATCOM is switched at time 0.04s same time at while line to line fault is applied as shown in Figure 6. Results show the improvement in voltages.

VI. CONCLUSION:

The PQ disturbances of voltage magnitude variation such as sag, swell and interruption are created by applying different types of faults and heavy load in the power distribution model. The non-stationary or transient PQ disturbances are produced by applying a capacitor switching bank in distribution model.

FACTS devices play an important role in improving the power quality problems, improving transmission capacity. To solve this problem, custom power devices are used. This dissertation illustrates modeling and simulation of Flexible AC Transmission System devices in distribution network presented so as to mitigate the voltage sag at the network buses. The process has been done without connecting any FACTS device and then repeated once again by connecting D-STATCOM.

The D-STATCOM can be designed using a current source inverter. An integrated D-STATCOM controller can be design for voltage regulation, reactive power compensation. This work presents development, simulation and analysis of a D-STATCOM using MATLAB/SIMULINK to enhance the voltage sag restoration capability of the D-STATCOM. Accordingly, simulations are first carried out to illustrate the use of D-STATCOM in mitigating voltage sag in a system. Simulation results prove that the facts devices are capable of mitigating voltage sag as well as improving power quality of a system.

VII. FUTURE SCOPE:

a) Optimal placement of D-STATCOM for voltage sag mitigation using an ANFIS (Artificial Neuro fuzzy inference system) based approach for power quality enhancement.

b) The power quality problem like voltage sags/swells in low voltage distribution systems and on the transmission side due to sensitive loads, the terminology used for the compensation devices is different. Dynamic Voltage Restorer (DVR) is one of the equipment's for voltage disturbance mitigation in power systems.

c) The neural network controller based D-STATCOM for voltage sag mitigation and power quality issue.

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