International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869 (O) 2454-4698 (P), Volume-7, Issue-5, May 2017

Implementation of SPWM Technique in D-STATCOM for mitigating Power Quality Problem - Voltage Sag and Swell

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***Abstract*— This paper presents the implementation of Sinusoidal Pulse width modulation (SPWM) technique to mitigate major power quality problems, voltage sag and swell using Distribution STATCOM. Power quality is perfect power supply that is noise free and is always within the voltage and frequency tolerance limits. Synchronization involves voltage, frequency and phase angle controlling for better performance of electrical systems. Voltage sag and swell use to be the major problems associated with Distribution system. To solve these problems, custom power devices are used. One of the most effective and efficient custom power device is Distribution STATCOM (D-STATCOM). D-STATCOM is setup to backup the power system during voltage sag and swell conditions. The control of the Voltage Source Converter (VSC) is done with the help of Sinusoidal PWM technique. This paper analyses the improvement in the power during voltage sag and swell while using D-STATCOM in different fault conditions. The proposed D-STATCOM is modeled and simulated using MATLAB/SIMULINK software.**

***Index Terms*— Distribution STATCOM (D-STATCOM), MATLAB/SIMULINK, Power quality problems, Sinusoidal Pulse Width Modulation (SPWM), Voltage sag and swell, Voltage Source Converter (VSC)**

I. Introduction

Electrical energy is the simple and well regulated form of energy, can be easily transformed to other forms. Along with its quality, continuity also has to be maintained for good economy. Power quality has become major concern for today's power industries and consumers. Power quality issues are caused by increasing demand of electronic equipments and non-linear loads. Many disturbances associated with electrical power are voltage sag, voltage swell, voltage flicker and harmonic contents. This degrades the efficiency and shortens the life time of end user equipment. It also causes data and memory loss of electronic equipment like computer. The electronic contrivances are very sensitive to perturbances and become less tolerant to power quality quandaries such as voltage sags, swells and harmonics [3]. Voltage dips are considered to be one of the major perturbances to the industrial equipments [2].

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D-STATCOM is a voltage source converter (VSC) predicated contrivance that injects a current into the system to regulate voltage during voltage sag and swell. These power quality contrivances are power electronic converters connected in parallel or series with the lines and the operation is controlled by a digital controllers. The voltage regulation of such systems that contains both power circuits and control systems can have different solutions. One among these solutions is the utilization of a Distribution STATCOM. D-STATCOM is a class of custom power compensating contrivances for providing reliable distribution power quality.

II. Power quality problems

Power Quality concerns about the utility ability to provide uninterrupted power supply. The quality of electric power is characterized by parameters such as "continuity of supply, voltage magnitude variation, transients and harmonic contents in electrical signals". Synchronization of electrical quantities allows electrical systems to function properly. Electric Power quality is a term which has captured a plethora of attention in power engineering in the recent years. The term power quality refers to maintaining a sinusoidal waveform of bus voltages at rated voltage and frequency. Power quality areas may be made according to the source of the quandary such as converters, magnetic circuit non linearity by the wave shape of the signal such as harmonics, flicker or by the frequency spectrum (radio frequency interference). Power quality is simply the interaction of electrical power with electrical equipment.

2.1 Sources of Power Quality Problems

The puissance unsettling influences transpire on every electrical framework, the affectability of today's refined electronic contrivances make them more vulnerably susceptible to the nature of energy supply. For some delicate contrivances, a flitting unsettling influence can establish commixed information, interfered with interchanges, a solidified mouse, framework accidents and hardware disappointment and so forth. A potency voltage spike can harm paramount components. Control quality issues envelop an extensive variety of aggravations, for example, voltage sag, swell, harmonics distortion, and interruptions.

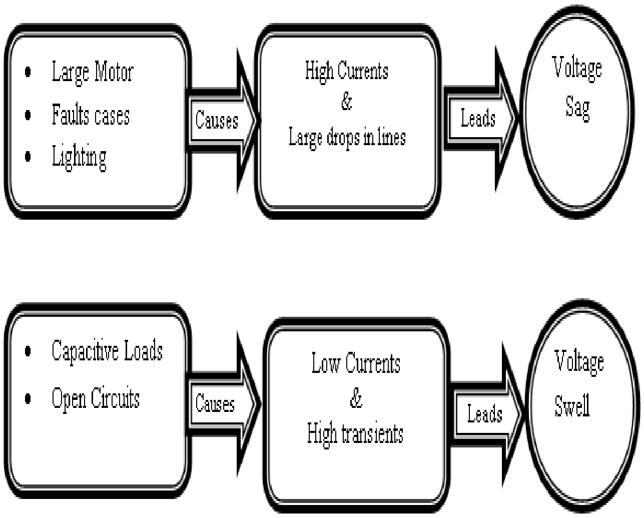

Figure 1: Power Quality problem Sources

2.2 Voltage Sags and Swells causes

- Remote power sources
- Unbalanced load
- Turn-on and turn-off of heavy loads
- Interposed loads connected from a distribution transformer for long distances
- Unreliable grid
- Equipments unsuitable for local supply.

2.3 Solution to power quality problem

There are two strategies to mitigate the power quality problems. The solution to the power quality can be done from customer side or from utility side.

Local Solutions Provide 'ride through' capability to the equipment so that they can protected against certain amount of voltage sag and swell. Disadvantage of this approach is that it cannot take care of existing polluting installations and further it is not always economical to provide the above arrangement for every equipment.

Global Solutions Here independent compensating devices are installed at PCC so that overall PQ improves at PCC. Advantages of this approach is Individual equipment need not be designed according to PQ standards.

III. METHODOLOGY

3.1 Distributed Static Compensator (DSTATCOM)

D-STATCOM is the most consequential controller for distribution networks. It has widely used to regulate system voltage, amend voltage profile, reduce voltage harmonics, reduce transient voltage perturbances and load emolument. The DSTATCOM utilizes a power–electronics converter is controlled utilizing pulse width modulation (PWM).

Schematically single line diagram is depicted in Figure 2 consists of a two level self-commutated Voltage source converter (VSC), a dc energy storage contrivance, a coupling transformer connected in shunt to the distribution network through a coupling transformer. Such configuration sanctions the contrivance to absorb or engender controllable active and reactive potency. The D-STATCOM has been utilized mainly for regulation of voltage, rectification of puissance factor and elimination of current harmonics. Such a contrivance is employed to provide perpetual voltage regulation utilizing an indirectly controlled converter. In this paper, the D-STATCOM is utilized to regulate the voltage at the point of connection. The control is predicated on sinusoidal PWM and only requires the quantification of the r.m.s voltage at the load point. The Distribution Static Compensator (D- STATCOM) is a voltage source inverter predicated static compensator that is utilized for the rectification of bus voltage sags.

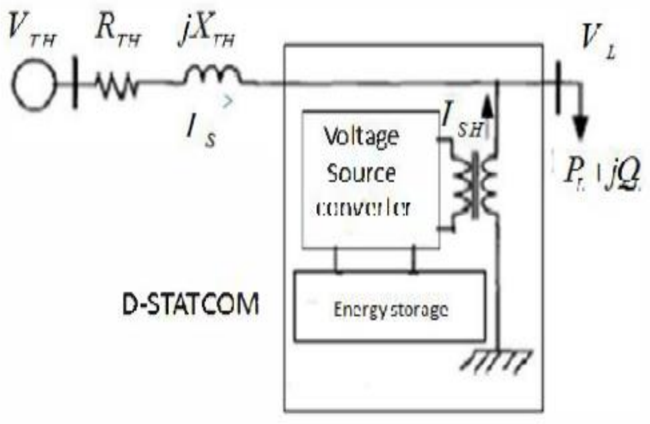

Figure 2: Structure of D-STATCOM

3.2 Equations Related to D-STATCOM

The shunt injected current Ish rectifies the voltage sag by adjusting the voltage drop across the system impedance Zth. The value of Ish can be controlled by adjusting the output voltage of the converter. The shunt injected current Ish can be indited as,

$$I_{sh} = I_L - I_S$$

Here source current is

$$I_s = \frac{V_{th} - V_L}{Z_{th}}$$

Therefore the injected shunt current is given by

$$I_{sh} = I_L - \frac{V_{th} - V_L}{Z_{th}}$$

$$I_{sh} = I_L - \frac{V_{th}}{Z_{th}} - \frac{V_L}{Z_{th}}$$

In Polar form

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

The complex power injection of the D-STATCOM can be expressed as,

$$S_{sh} = V_L I_{sh}^*$$

Where,

Iout = Output current,
I_L = Load current,
Is = Source current,
V_L = Load voltage,
V_{th} = Thevenin voltage,
Z_{th} = Impedance (Z_{th} = R + jX)

3.3 Three Phase Voltage Source Converter (VSC)

A voltage source converter (VSC) is a potency electronic contrivance, which can engender a three-phase ac output voltage is controllable in phase and magnitude [1]. These voltages are injected into the ac distribution system in order to maintain the load voltage at the desired voltage reference. VSCs are widely utilized in adjustable speed drives, but can withal be habituated to mitigate the voltage sags and swells. The VSC is utilized to either thoroughly superseding the voltage or to inject the 'missing voltage'. The 'missing voltage' is the distinction between the nominal voltage and the authentic voltage.

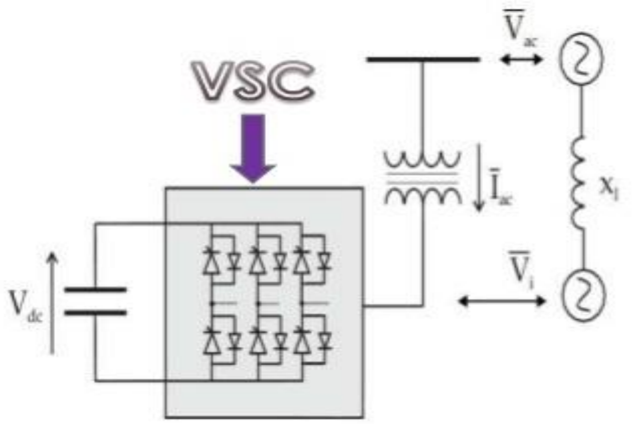

Figure 3: Basic Voltage Source Converter

IV. SINUSOIDAL PWM BASED CONTROL

The point of the control plan is to keep up steady voltage extent at the point where a touchy load is associated, under framework unsettling influence. The control framework just measures the r.m.s voltage at the load point i.e., no responsive power estimations are required [10]. The VSC exchanging [4] system depends on sinusoidal PWM procedure which offers effortlessness and great reaction. The PI controller handle recognizes the mistake flag and produces the required edge (α) to drive the blunder to zero, i.e., the load r.m.s voltage is taken back to the reference voltage. In the PWM generator, the sinusoidal flag Vcontrol is looked at against a triangular flag (transporter) with a specific end goal to produce the exchanging signals for the VSC valves [9]. The principle parameters of the sinusoidal PWM plan are the sufficiency adjustment list Ma of flag Vcontrol and the recurrence tweak file Mf of the triangular flag. The adequacy record Ma is kept settled at 1 p.u.

$$M_a = \frac{V_{control}}{V_{in}}$$

Where

$V_{control}$ is the Peak amplitude of the signal.

V_{in} is the peak amplitude of the Triangular signal.

V. DSTATCOM MODELING FOR DIFFERENT FAULT CONDITIONS

Simulink model of the test system is given in Figure-4. The system consists of two parallel feeders with similar loads of same rating. We have define modeling the D-STATCOM using the simulink power system block set

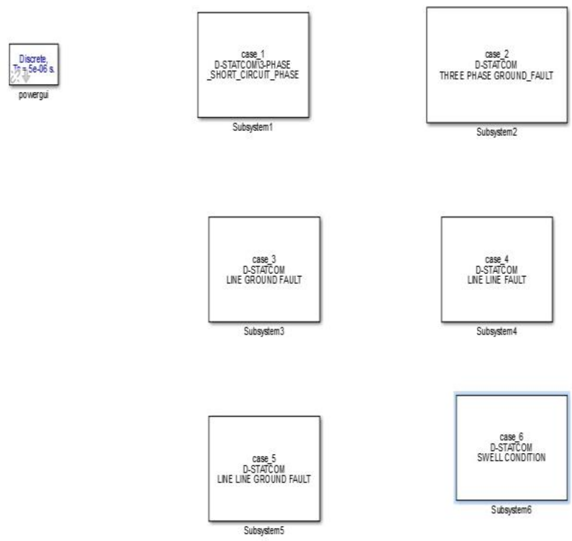

Figure 4: Control scheme and test system implemented in MATLAB/SIMULINK to carry out the D-ST ATCOM simulations.

5.1 Simulation Model for Voltage Sag

Figure 5.1 shows the test system model to measure r.m.s value of voltage at load point during three phase short circuit fault condition i.e case 1. The model measures the voltage in per unit with and without DSTATCOM connected to the system.

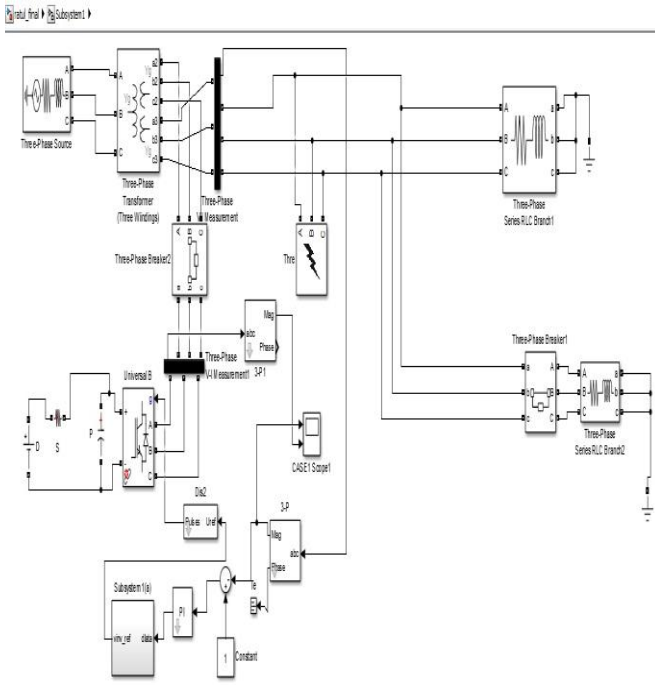

Figure 5.1: Model for Three Phase short circuit fault condition

Figure 5.2 shows the test system model to measure r.m.s value of voltage at load point during three phase to ground fault condition i.e case 2. The model measures the voltage in per unit with and without DSTATCOM connected to the system.

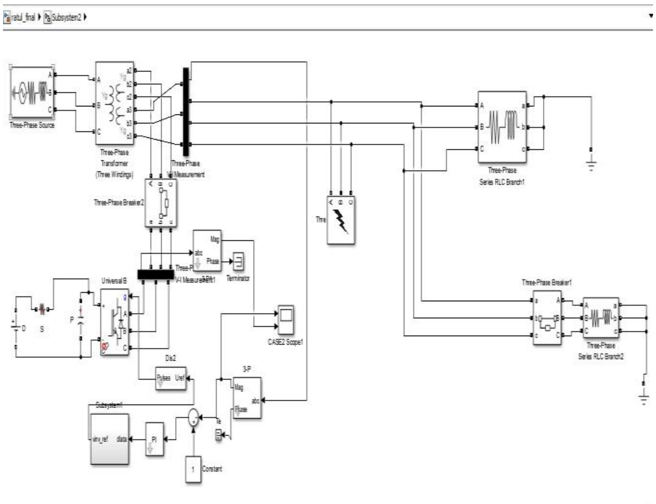

Figure 5.2: Model for Three Phase to Ground Fault condition

Figure 5.3 shows the test system model to measure r.m.s value of voltage at load point during line-ground fault condition i.e case 3. The model measures the voltage in per unit with and without DSTATCOM connected to the system.

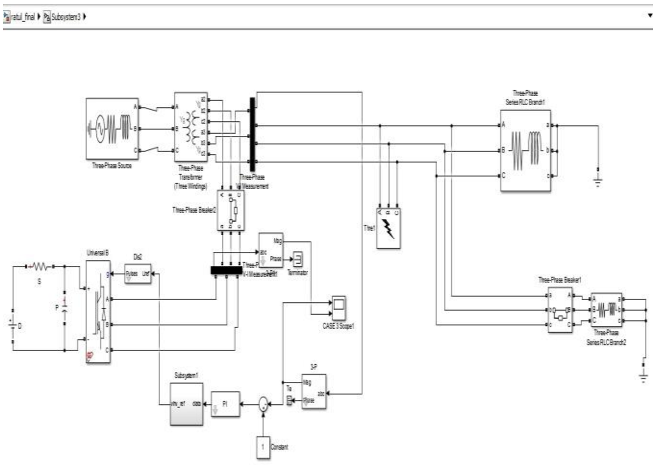

Figure 5.3: Model for Line-Ground Fault condition

Figure 5.4 shows the test system model to measure r.m.s value of voltage at load point during line-line fault condition i.e case 4. The model measures the voltage in per unit with and without DSTATCOM connected to the system.

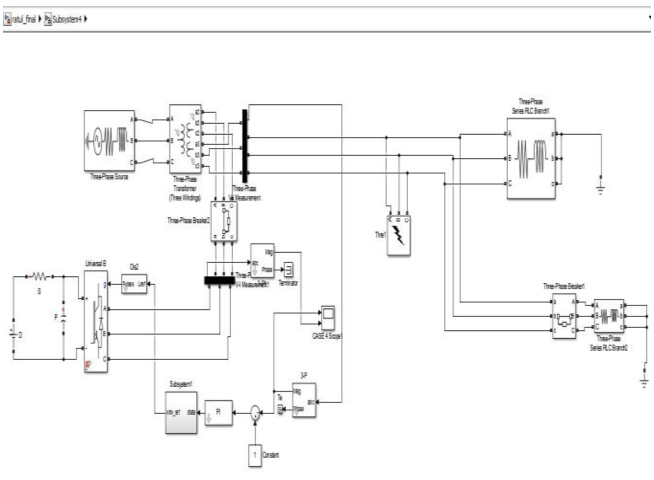

Figure 5.4: Model for Line-Line Fault condition

Figure 5.5 shows the test system model to measure r.m.s value of voltage at load point during line-line-ground fault condition i.e case 5. The model measures the voltage in per unit with and without DSTATCOM connected to the system.

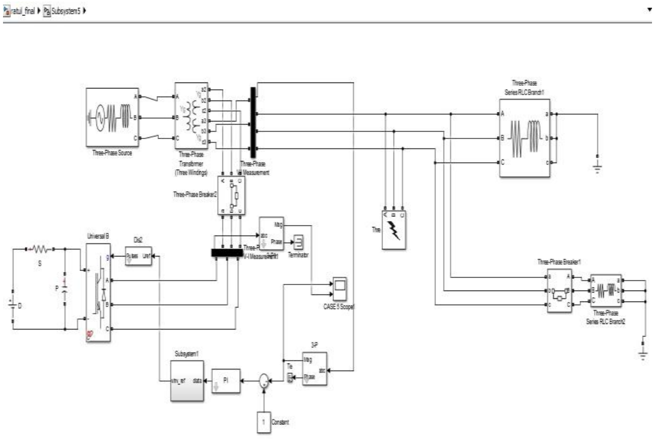

Figure 5.5: Model for Line-Line-Ground fault condition

5.2 Simulation Model for Voltage Swell

Figure 5.6 shows the test system model to measure r.m.s value of voltage at load point during voltage swell condition i.e case 6. The model measures the voltage in per unit with and without DSTATCOM connected to the system.

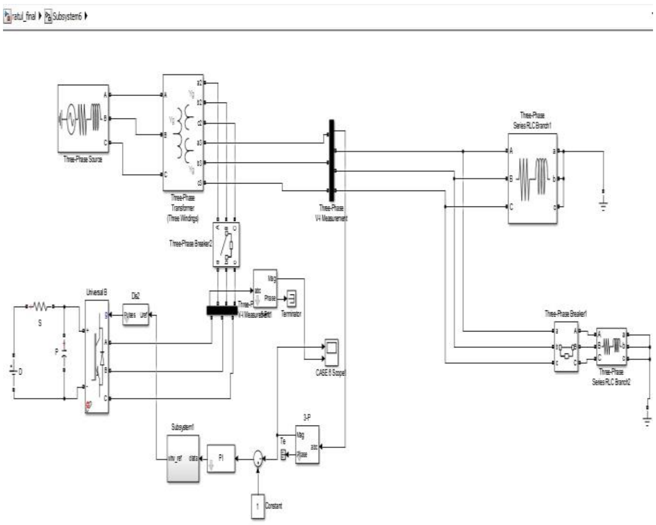

Figure 5.6: Model for voltage Swell Condition during three phase Fault

VI. RESULTS

6.1 Results for Voltage Sag Cases

The first simulation is done without D-STATCOM when a three-phase short-circuit fault is applied with a fault resistance of 0.2 Ω during the period of 0.3-0.6 seconds. The second simulation is done utilizing an indistinguishable situation from above, however now D-STATCOM is associated with the system, then the voltage sag is mitigated totally, appeared in figure 6.1

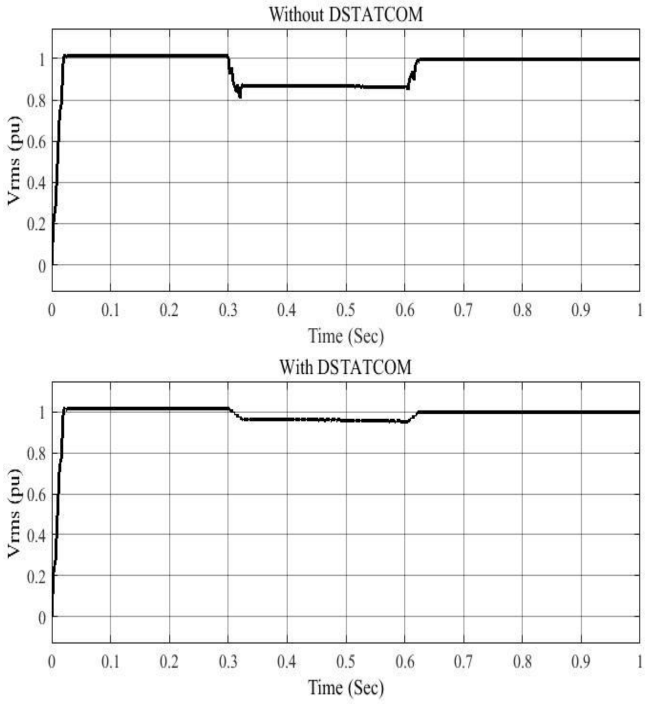

Figure 6.1: Voltage at load point during three phase short circuit fault without DSTATCOM and with DSTATCOM

The first simulation has no D-STATCOM when a three-phase to ground fault appears with a fault resistance of 0.2 Ω during the period of 0.3-0.6 seconds. The second simulation is done utilizing an indistinguishable situation from above, however now D-STATCOM is associated with the system, then the voltage sag is mitigated totally, appeared in figure 6.2

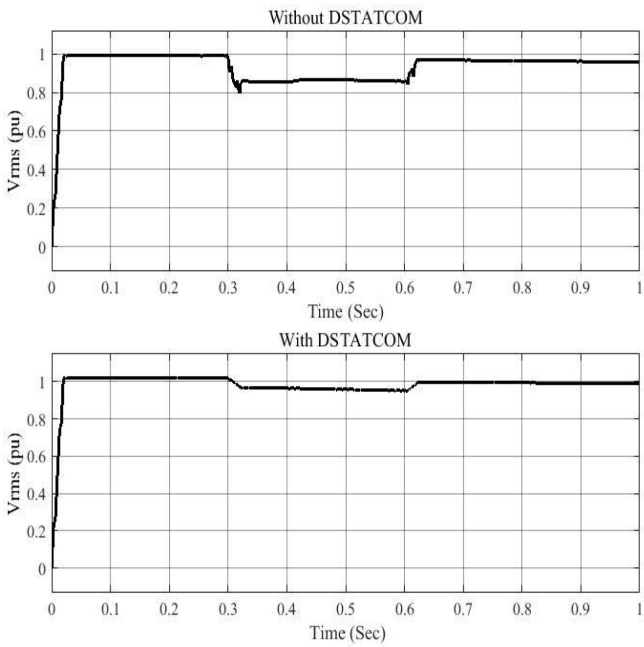

Figure 6.2: Voltage at load point during three phase ground fault without DSTATCOM and with DSTATCOM

The first simulation has no D-STATCOM when a line to ground fault appears with a fault resistance of 0.2 Ω during the period of 0.3-0.6 seconds. The second simulation is done utilizing an indistinguishable situation from above, however now D-STATCOM is associated with the system, then the voltage sag is mitigated totally, appeared in figure 6.3

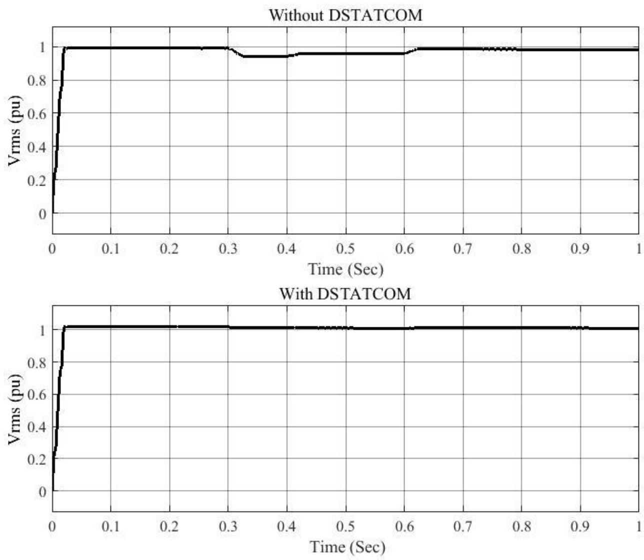

Figure 6.3: Voltage at load point during line-ground fault without DSTATCOM and with DSTATCOM

The first simulation has no D-STATCOM when a line-line fault appears with a fault resistance of 0.2 Ω during the period of 0.3-0.6 seconds. The second simulation is done utilizing an indistinguishable situation from above, however now D-STATCOM is associated with the system, then the voltage sag is mitigated totally, appeared in figure 6.4

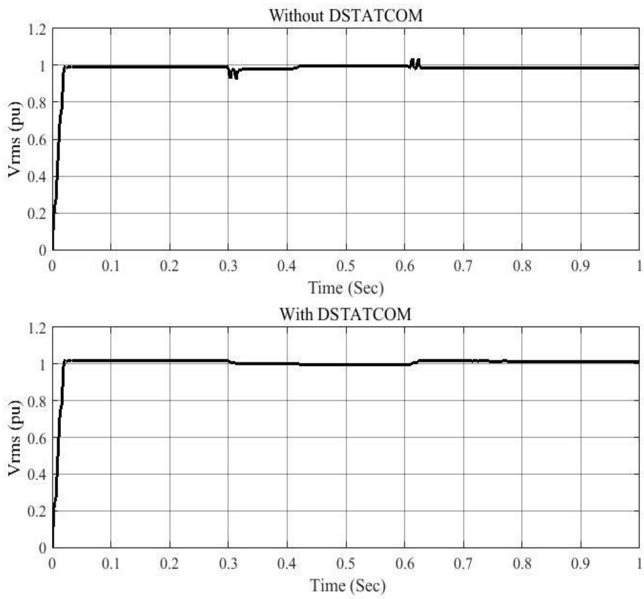

Figure 6.4: Voltage at load point during line-line fault without DSTATCOM and with DSTATCOM

The first simulation has no D-STATCOM when a line-line-ground fault appears with a fault resistance of 0.2 Ω during the period of 0.3-0.6 seconds. The second simulation is done utilizing an indistinguishable situation from above, however now D-STATCOM is associated with the system, then the voltage sag is mitigated totally, appeared in figure 6.5

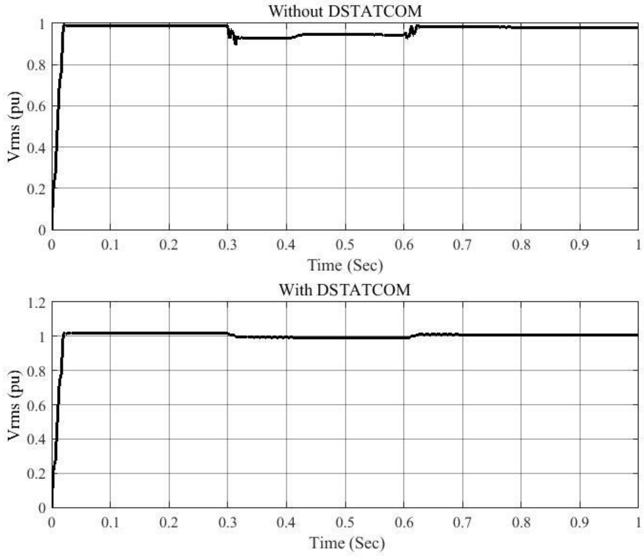

Figure 6.5: Voltage at load point during line-line-ground fault without DSTATCOM and with DSTATCOM

6.2 Result for Voltage Swell Case

The first simulation has no D-STATCOM when a three phase fault appears with a fault resistance of 0.2 Ω during the period of 0.3-0.6 seconds. The second simulation is done utilizing an indistinguishable situation from above, however now D-STATCOM is associated with the system, then the voltage swell is mitigated totally, appeared in figure 6.6

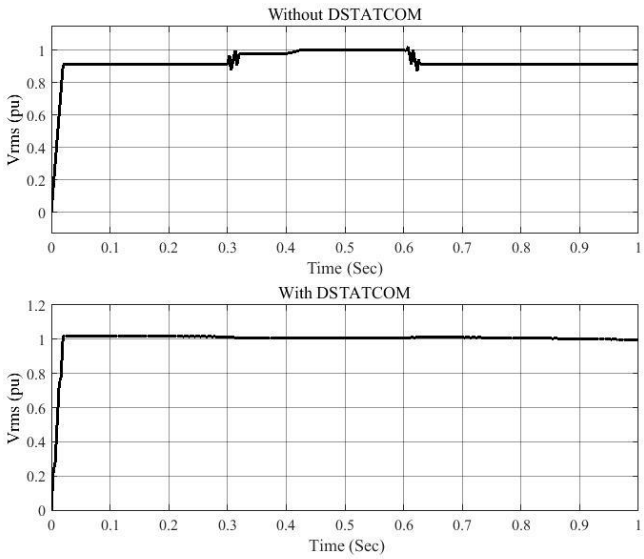

Figure 6.6: Voltage at load point during voltage swell condition without DSTATCOM and with DSTATCOM

VII. Conclusion

In this paper, the examination on the part of Distributed Static Synchronous Compensator (D-STATCOM) can repay the voltage sag and swells under faulty condition. The power quality issues, for example, voltage sag and swell compensating strategies of custom power electronic gadget D-STATCOM was introduced. The plan and utilizations of D-STATCOM for voltage sag, swells and exhaustive outcomes were displayed. The Voltage Source Change over (VSC) was actualized with the assistance of Sinusoidal Pulse Width Modulation (SPWM). The control plan was tried under an extensive variety of working conditions, and it was seen to be extremely powerful for each situation. For demonstrating and reenactment of a D-STATCOM by utilizing the much created realistic offices accessible in MATLAB/SIMULINK were utilized. The reenactments did here demonstrate that the D-STATCOM gives generally better voltage control abilities.

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