IMPLEMATATION OF D-STATCOM FOR IMPROVEMENT OF POWER QUALITY AND POWER FACTOR CORRECTION IN THREE PHASE FOUR WIRE SYSTEM : MODELLING AND SIMULATION

Sumit Sharma[1], Pragati[2], Lalit Singh[3], Mohit Pant[4]

[1,2,3,4] *Assistant Professor, SRMS CET, Bareilly (India)*

ABSTRACT

In recent years, Power engineers are increasingly concerned over the quality of the electrical power. In standard industries, load equipment utilizes electronic controllers which are sensitive to poor voltage quality and will shut down if the supply voltage is depressed and may mal-operate in other ways if harmonic Distortion of the supply voltage is excessive. An increasing demand for high power quality, reliability of electrical power and increasing number of distorting loads may leads to an increased awareness of power quality both by customers and utilities. The most usual power quality problems are voltage sags, low power factor and harmonic distortion. This paper presents the compensation of voltage sags, using Distribution Static Compensator (D-STATCOM) with LCL Passive Filter in Distribution system. This model is based on the Voltage Source Converter (VSC) principle. D-STATCOM can use with different types of controllers. The D-STATCOM injects a current into the system to compensate the voltage sags. LCL Passive Filter was then introduced to D-STATCOM to improve low power factor and harmonic distortion. The simulations were performed using MATLAB SIMULINK.

Keywords: DSTATCOM, Power Quality, PWM Technique, Voltage Sag, Voltage Source Converter

I. INTRODUCTION

In recent years, Power engineers are increasingly concerned over the quality of the electrical power. Load equipment uses electronic controllers which are sensitive to poor voltage quality and will shut down if the supply voltage is depressed and may mal-operate in other ways if harmonic Distortion of the supply voltage is excessive in modern industries. Much of this modern load equipment itself uses electronic switching devices which then can contribute to poor network voltage value. The introduction of competition into electrical energy supply has created greater commercial awareness of the issues of power quality while equipment is now readily available to measure the quality of the voltage waveform and so quantify the problem.

Many efforts have been taken by utilities to fulfill consumer requirement, some consumers require a level of PQ higher than the level provided by modern electric networks. This indicates that some measures must be taken in order to achieve higher levels of Power Quality.

The FACTS devices and Custom power devices are introduced to electrical system to improve the power quality of the electrical power. DVR, STATCOM/DSTATCOM, ACTIVE FILTERs, UPFC, UPQC etc are some of the devices used to improve the power quality of the current and voltage. With the help of these strategies we are skillful to reduce the problems related to power quality.

This work presents the design of a prototype distribution static compensator (D-STATCOM) for voltage sag mitigation in a balanced distribution system. The D-STATCOM is proposed to replace the widely used static Var compensator (SVC). The model is based on the principle of Voltage Source Converter (VSC). A new PWM based control scheme has been implemented to control the D-STATCOM. The D-STATCOM injects a current into the system to mitigate the voltage sags and to improve the power factor.

II. IMPROVEMENT OF POWER QUALITY BY USING DSTATCOM

When the STATCOM is applied in distribution system is called DSTACOM (Distribution-STACOM) and its configuration is similar, or with small modifications, oriented to a possible future amplification of its possibilities in the distribution network at low and medium voltage, applying the function so that we can describe as harmonic filtering, flicker damping and short interruption compensation. Distribution STATCOM (DSTATCOM) exhibits high speed control of reactive power to provide flicker suppression, voltage stabilization, and other types of control on system. The DSTATCOM employs a design consisting of a GTO- or IGBT-based voltage sourced converter connected to the power system via a multi-stage converter transformer. The DSTATCOM can also be applied to industrial facilities to compensate for voltage sag and flicker caused by non-linear dynamic loads, supporting such problem loads to co-exist on the same feeder as more thoughtful loads. The DSTATCOM instantaneously exchanges reactive power with the distribution scheme without the use of bulky capacitors or reactors.

The basic electronic block of the D-STATCOM is the voltage source inverter that converts an input dc voltage into a three-phase output voltage at fundamental frequency. The voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Appropriate adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the DSTATCOM and the ac system. (Fig.1) illustrations the schematic of D-STATCOM. The D-STACOM works an inverter to convert the DC link voltage V_{dc} on the capacitor to a voltage source of adjustable phase and magnitude. Therefore the DSTATCOM can be treated as a voltage-controlled source. (Fig.1)displays a single phase equivalent of the STATCOM. A voltage source inverter yields a set of three phase voltages, V(i), that are in phase with the scheme voltage, V(s). Small reactance, Xc, is used to associate the compensator voltage to the power system. A reactive current, ic, is created that leads V(s)When V(i)>V(s) and the current lags Vs, when V (i)<V(s).

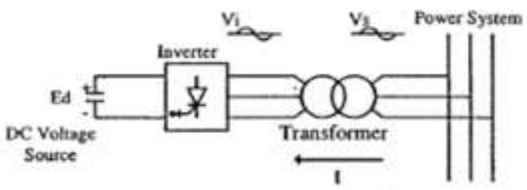


Fig 1: Single line equivalent model of DSTATCOM

Figure shows the inductance *L* and resistance *R* which represent the equivalent circuit elements of the step-down transformer and the inverter will is the main component of the D-STATCOM. Output voltage of the D-STATCOM *Vi* is the effective voltage and δ is the effective power angle. The output reactive power of the D-STATCOM inductive or capacitive depending can be either on the operation mode of the D-STATCOM.

III. CONTROL SCHEMES FOR DSTATCOM

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is linked, under system disturbances. The control system only measures the r.m.s voltage at the load terminal i.e. - no reactive power measurements are requisite. The VSC switching approach is based on a sinusoidal PWM technique which offers simplicity and good result. 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. Moreover, without incurring significant switching losses, high switching frequencies can be used to improve on the efficiency of the converter. The controller input is an error signal obtained from the reference voltage and the value rms of the terminal voltage. Such error is deal with a PI controller the output is δ angle, which is providing to the PWM signal generator. It is vital to note that here, indirectly controlled converter, there is reactive and active power exchange with the network simultaneously: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load terminal. The PI controller processing the error signal generates the required angle to drive the error to zero, i.e., the rms value of load voltage is took back to the reference voltage.

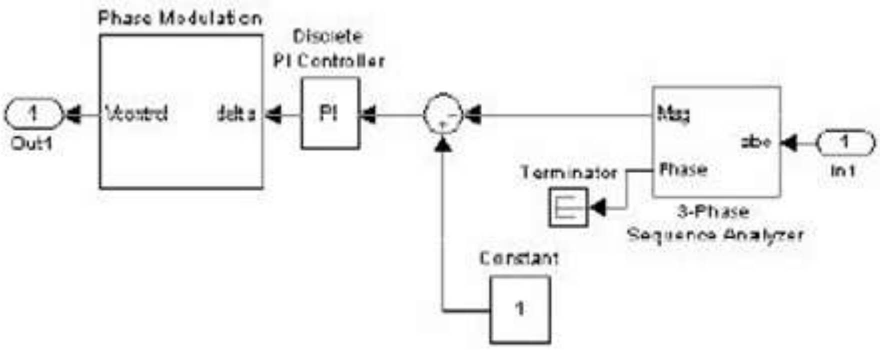


Fig2: Simulink Diagram of Controller

IV. PARAMETERS OF THE TEST SYSTEM

The modeled system has been tested a different fault conditions with linear as well nonlinear load. The system is working with three phase generation source with configuration of 11 KV, 50 Hz. The source is feeding two transmission lines through a three phase, three winding transformer with power rating 250 MVA at 50 Hz.

Winding 1: V1rms (ph-ph) = 11 KV, R1 = .0021 (pu), L1 = .080012 (pu).

Winding 2: V2rms (ph-ph) = 11 KV, R2 = .0022 (pu), L2 = .080022 (pu).

Winding 3: V3rms (ph-ph) = 11 KV, R3 = .0021 (pu), L3 = .080012 (pu).

V. RESULTS UNDER DIFFERENT FAULT CONDITIONS

Three different fault conditions are considered for the test system as shown in Figure the three different fault conditions are single line to ground, double line to ground and three phase line to ground fault. The outcomes for each fault condition are given one by one.

In this system Fault is created between 0.3 to 0.5 seconds with Static linear load. DSTATCOM is not connected in that system. Simulink model of the test system is given in Figure. The system consists of two parallel feeders with similar loads of same rating. This system is analyzed under different fault conditions. The simulation result for Voltage sag, voltage swell, flickers and other power quality problems can be obtained.

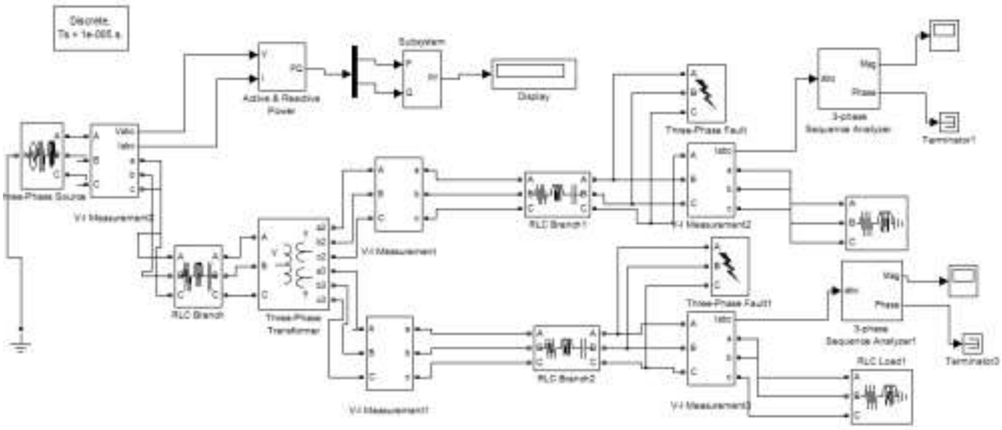


Figure 3: Simulink model for test system without DSTATCOM

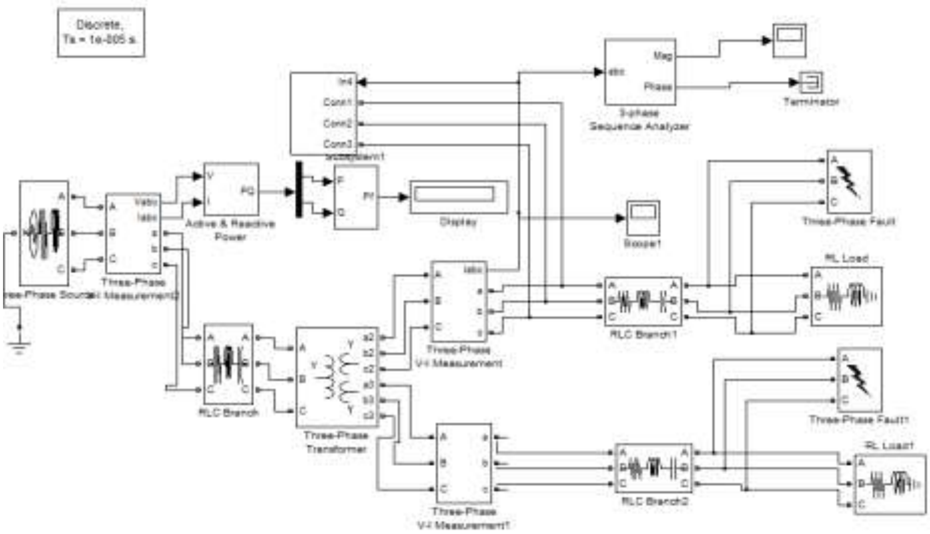
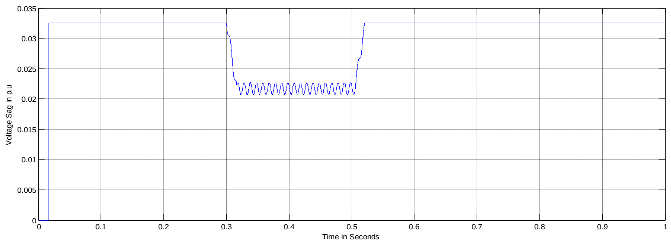


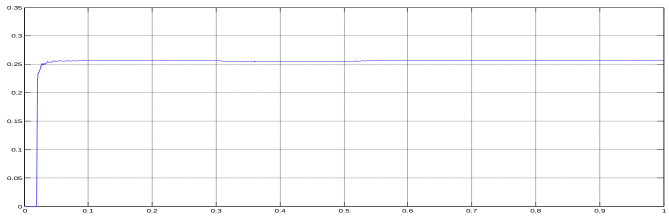
Fig 4. Simulink model for Test system with DSTATCOM

CASE 1. Single Line to Ground Fault Condition

In first case a single line to ground fault is considered for both the feeders. Here the fault resistance is 0.001 Ω and the ground resistance is approx. 0.001Ω. The fault is created for the duration of 0.3s to 0.5s. The outcome wave for the load current with compensation and without compensation is shown in Figure respectively

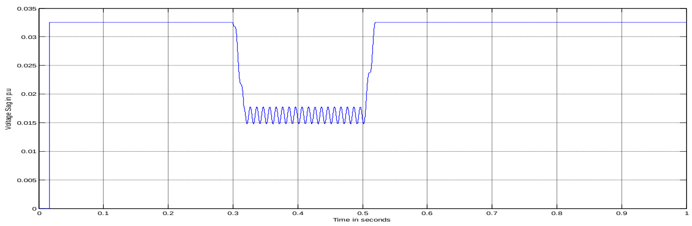


(Without Compensation)



(With Compensation)

CASE 2. Single Line to Line Fault Condition



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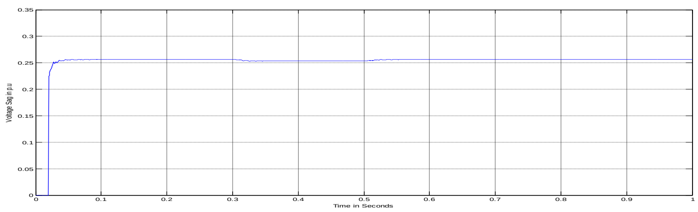
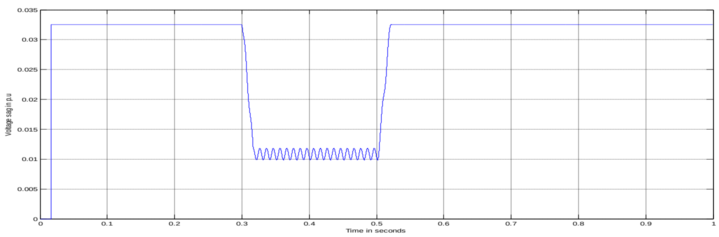


(With Compensation)

Case 3. Double Line to Ground Fault Condition

In second case considered fault for both the feeders is double line to ground fault. For this fault resistance and ground resistance is approx. 0.001Ω and 0.001Ω respectively. Moreover, time duration for this fault is 0.3sec to 0.5sec.



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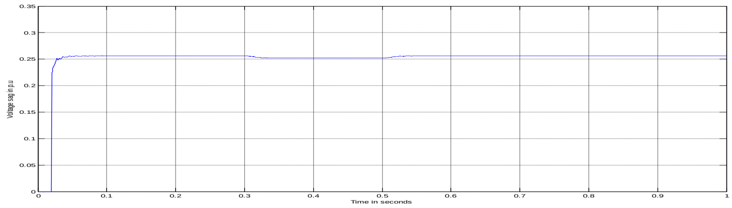
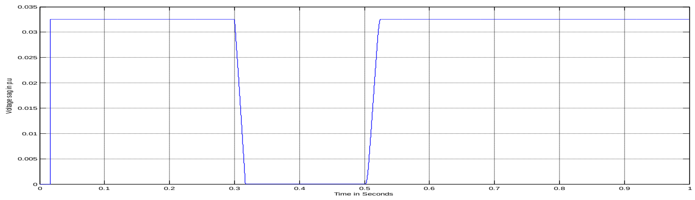


(With Compensation)

The output wave shapes clear that the current in the phase where fault is created is increasing during the fault duration in the uncompensated feeder, but in system where the DSTATCOM is connected unbalancing is reduced clearly

Case 4. Three Phase Fault Condition

In third case a considered fault for both the feeders is three phase to line fault. The fault is created for the duration of 0.3sec to 0.5sec. And fault resistance and ground resistance is approx. 0.001Ω and 0.0 01Ω respectively



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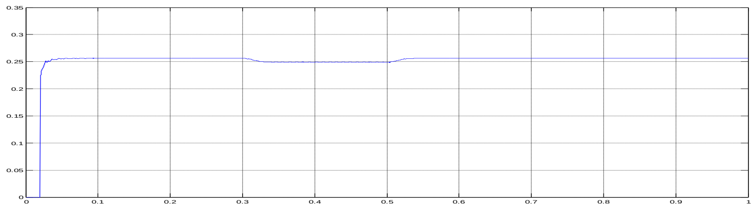


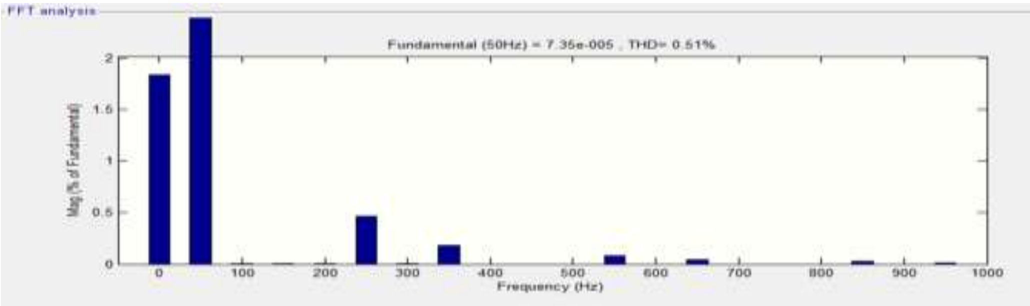
(With Compensation)

As we can see in the above different fault conditions that the voltage sag is drastically increased in the case of three phase to Ground Fault condition. The value of voltage sag is 0.02 p.u in the case of Single Line to Ground fault , 0.015 in the case of Line to Line Fault, 0.01 in the case of Double Line to Ground fault system and 0 in case of Three phase to Ground Fault.

Total Harmonic Distortion

The THD graphs with compensation and without compensation are given in Figure-15 and Figure-16. The total harmonic distortion without compensation is 21.80%, which is reduced to 0.50% where DSTATCOM is connected.

(Without Compensation)



(With Compensation)

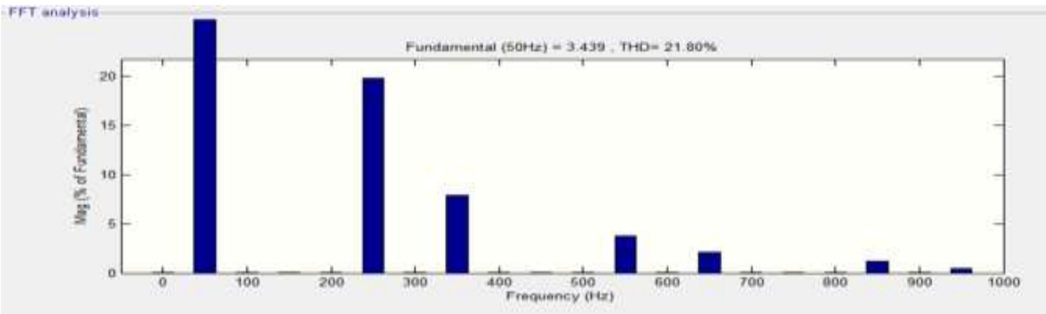


Fig 5: THD Spectrum

So to Compensate Voltage sag in these different Fault Condition, DSTATCOM Controller is used .Here it is clear from the output wave shapes that the current in the phase where fault is created is increasing during the fault duration in the uncompensated feeder. In Double Line to Ground fault case, the output wave shapes clear that the current in the phase where fault is created is increasing during the fault duration in the uncompensated feeder.

VI. CONCLUSION

Nowadays, reliability and quality of electric power is one of the most discuss topics in power industries. There are many types of power quality issues and power problems and each of them might have varying and assorted causes. The types of power quality problems that a customer may encounter classified depending on how the voltage waveform is distorted. There are transients, short duration variants (sags, swells, and interruption), long duration variations (sustained interruptions, under voltages, over voltages), voltage imbalance, waveform distortion (dc offset, inter harmonics, harmonics, noise and notching), power frequency variations and voltage fluctuations. Amongst these, two power quality problems have been identified to be of major concern to the customers are voltage sags and harmonics, but this project is focusing on voltage sags.

Sags also may be produced when large motor loads are generated or due to operation of certain types of electrical equipment such as welders, arc furnaces, smelters, etc. The distribution static compensator (DSTATCOM) offers an alternative to conventional series shunt compensation. The traditionally power transmission system, controllable devices are limited to the slow mechanisms such as transformer tap changers and switched capacitor. In the late 1980’s, the major developments in the technology of semiconductor, it became conceivable to apply power electronics in the control.

Also the power factor of the system is improved from 0.3 to 0.82 due to DSTATCOM connected.

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