International Journal of Power System Operation and Energy Management

Volume 2 | Issue 3 Article 5

July 2013

DESIGN AND SIMULATION STUDIES OF D-STATCOM FOR VOLTAGE SAG, SWELL MITIGATION

D.R. PATIL
Walchand college of Engg., dadasorpatil@gmail.com

KOMAL K. MADHALE
Walchand college of Engg., madhale_k@yahoo.com

Recommended Citation
PATIL, D.R. and MADHALE, KOMAL K. (2013) "DESIGN AND SIMULATION STUDIES OF D-STATCOM FOR VOLTAGE SAG, SWELL MITIGATION," *International Journal of Power System Operation and Energy Management*: Vol. 2 : Iss. 3 , Article 5.
DOI: 10.47893/IJPSOEM.2013.1083
Available at: https://www.interscience.in/ijpsoem/vol2/iss3/5

DESIGN AND SIMULATION STUDIES OF D-STATCOM FOR VOLTAGE SAG, SWELL MITIGATION

D.R.PATIL[1] & KOMAL K.MADHALE[2]

[1,2]Walchand college of Engg.
E-mail : dadasorpatil@gmail.com, madhale_k@yahoo.com

Abstract - This paper presents the design of a prototype distribution static compensator (D-STATCOM) for voltage sag mitigation in an unbalanced distribution system. The D-STATCOM is intended to replace the widely used static Var compensator (SVC). The model is based on the Voltage Source Converter (VSC) principle. A new PWM based control scheme has been implemented to control the electronic valves in two level of VSC. The D-STATCOM injects a current into the system to mitigate the voltage sags. In this work, the 6-pulse D-STATCOM configuration with IGBT has been designed using MATLAB SIMULINK. Accordingly, simulations are first carried out to illustrate the use of D-STATCOM in mitigating voltage sag in a distribution system. Simulation results prove that the D-STATCOM is capable of mitigating voltage sag as well as improving power quality of a system.

Keywords: *D-STATCOM, voltage Sag, VSC, Controller.*

I. INTRODUCTION

Power quality is certainly a major concern in the present era. It becomes especially important with the insertion of sophisticated devices, whose performance is very sensitive to the quality of power supply. A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or a mis-operation of end user equipments. Modern industrial processes are mainly based on electronic devices such as PLC's, power electronic devices, drives etc., and since their controls are sensitive to disturbances such as voltage sag , swell and harmonics , voltage sag is most important power quality problems It contributes more than 80% of power quality (PQ) problems that exist in power systems, and more concern problems faced by many industries and utilities. [1]. By definition, a voltage sag is an rms (root mean square) reduction in the AC voltage at the power frequency, for duration from a half-cycle to a few seconds.

Voltage sag is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing. Typical faults are single-phase or multiple-phase short circuits, which leads to high currents. The high current results in a voltage drop over the network impedance. Voltage sags are not tolerated by sensitive equipments used in modern industrial plants such as process controllers, programmable logic controllers (PLC), adjustable speed drive (ASD) and robotics. Various methods have been applied to reduce or mitigate voltage sags. The conventional methods are by using capacitor banks, introduction of new parallel feeders and by installing uninterruptible power supplies (UPS). However, the PQ problems are not solved completely due to uncontrollable reactive power compensation and high costs of new feeders and UPS. The D-STATCOM has emerged as a promising device to provide not only for voltage sags mitigation but a host of other power quality solutions such as voltage stabilization, flicker suppression, power factor correction and harmonic control.

II. CONFIGURATION OF D-STATCOM

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. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable 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 shows the schematic of D-STATCOM. The D-STACOM employs an inverter to convert the DC link voltage *Vdc* on the capacitor to a voltage source of adjustable magnitude and phase. Therefore the DSTATCOM can be treated as a voltage-controlled source. Figure 1 shows a single phase equivalent of the Statcom.

A voltage source inverter produces a set of three phase voltages, Vi, that are in phase with the system voltage, Vs. small reactance, Xc, is used to link the compensator voltage to the power system. When Vi>Vs, a reactive current, ic, is produced that leads Vs and when Vi<Vs, the current lags Vs.

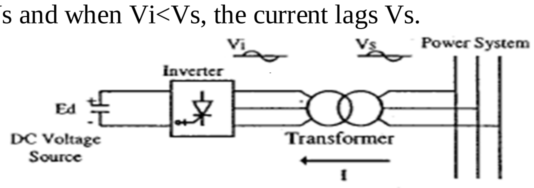
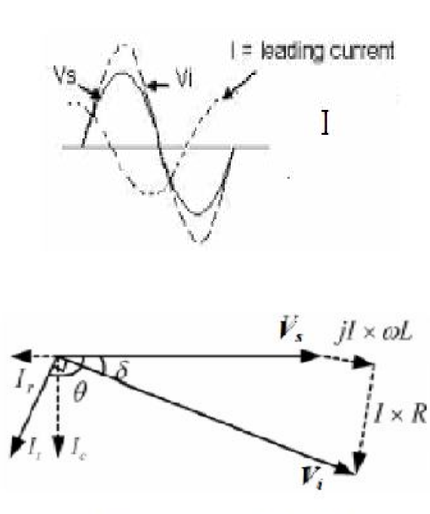


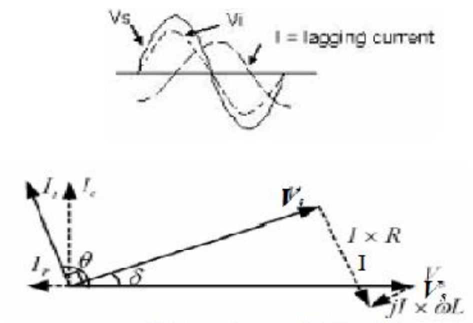
Figure 1. Single line equivalent model of dstatcom.

Figure 1 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. The voltage *Vi* is the effective output voltage of the D-STATCOM and δ is the power angle. The reactive power output of the D-STATCOM inductive or capacitive depending can be either on the operation mode of the D-STATCOM. Referring to figure 1, the controller of the D-STATCOM is used to operate the inverter in such a way that the phase angle between the inverter voltage and the line voltage is dynamically adjusted so that the D-STATCOM generates or absorbs the desired VAR at the point of connection. The phase of the output voltage of the thyristor-based inverter, Vi, is controlled in the same way as the distribution system voltage, Vs. Figure 2 shows the three basic operation modes of the DSTATCOM output current, I, which varies depending upon Vi. If Vi is equal to Vs, the reactive power is zero and the D-STATCOM does not generate or absorb reactive power. When Vi is greater than Vs, the DSTATCOM shows an inductive reactance connected at its terminal. The current, I, flows through the transformer reactance from the D-STATCOM to the ac system, and the device generates capacitive reactive power. If Vs is greater than Vi, the D-STATCOM shows the system as a capacitive reactance. Then the current flows from the ac system to the D-STATCOM, resulting in the device absorbing inductive reactive power.

a) No-load mode ($V_s = V_i$)



b) Capacitive mode ($V_i > V_s$)



c) Inductive mode ($V_i < V_s$)

Figure 2: Operation modes of D-STATCOM

III. VOLTAGE SOURCE CONVERTER (VSC)

A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. Voltage source converters are widely used in adjustable-speed drives, but can also be used to mitigate voltage dips. The VSC is 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. The converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage. The solid-state electronics in the converter is then switched to get the desired output voltage. Normally the VSC is not only used for voltage sag/swell mitigation, but also for other power quality issues, e.g. flicker and harmonics.

IV. CONTROLLER

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

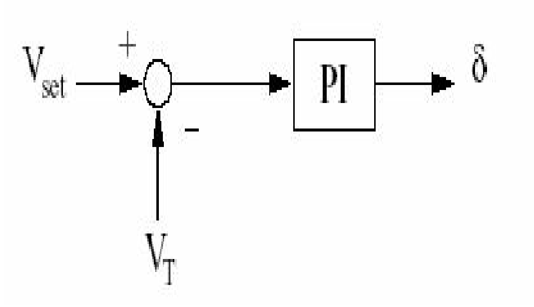


Fig.3 PI controller

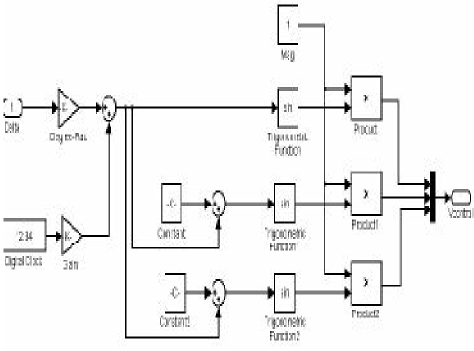


Fig4 Phase-Modulation of the control angle δ

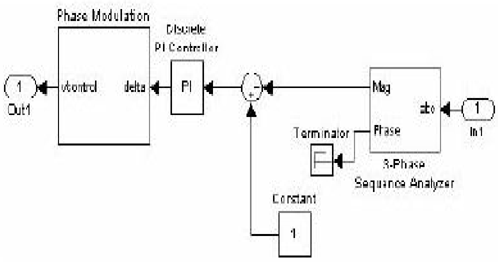
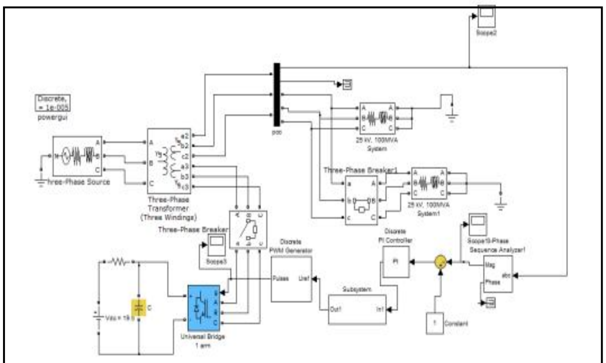


Fig.5 Simulink Diagram of Controller.

V. METHODOLOGY

To enhance the performance of distribution system, D-STATCOM was connected to the distribution system. D-STATCOM was designed using MATLAB simulink version R2008b. The test system shown in figure 4 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. A 75 µF capacitor on the dc side provides the DSTATCOM energy storage capabilities. Circuit Breaker is used to control the period of operation of the D-STATCOM.

VI. SIMULINK MODEL FOR THE TEST SYSTEM



Fig(6)

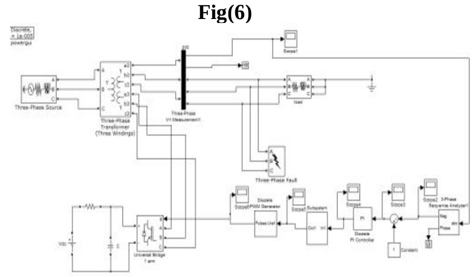


Fig.(7)

VII.RESULTS

1. Simulation results for inductive load (3 phase balanced sag):

In figure (6) the system for immediate occurrence of inductive load is shown for 500ms to 900ms duration during this the balanced sag will occur.

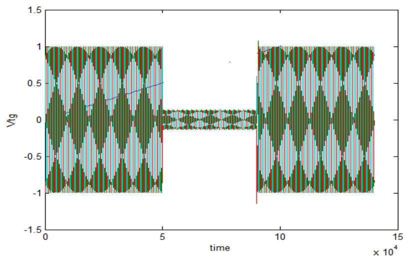


Fig.(6.1) Three phase vtg profile at load point

Simulation results of Vrms at load point:

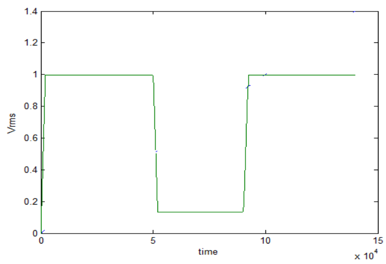


Fig.(6.2)

Simulation results after compensation at load side :

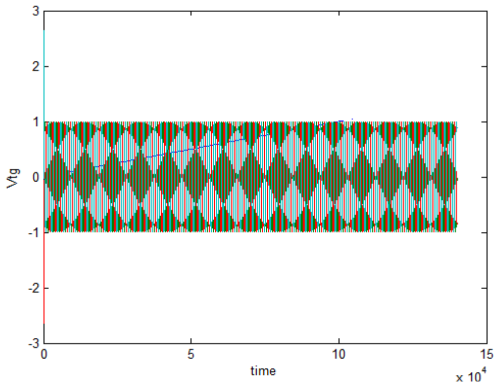
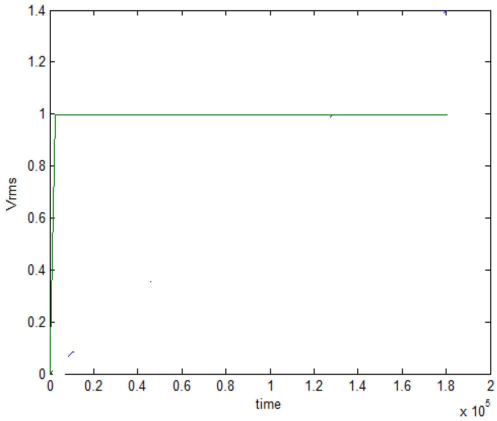


Fig.(6.3)

Simulation results of Vrms after compensation at load point:



Fig(6.4)

2. Case1Simulation results of voltage sag (unbalanced) during single line to ground fault.

In this case, D-STATCOM is not connected and a single line to ground fault is applied at a point pcc with a fault resistance of 0.2 Ω. The voltage sag is shown in fig.(7)

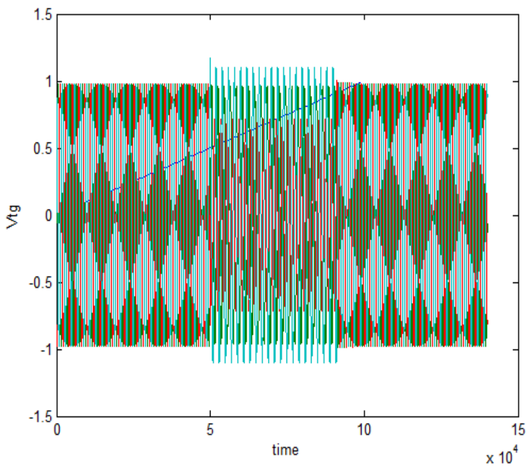
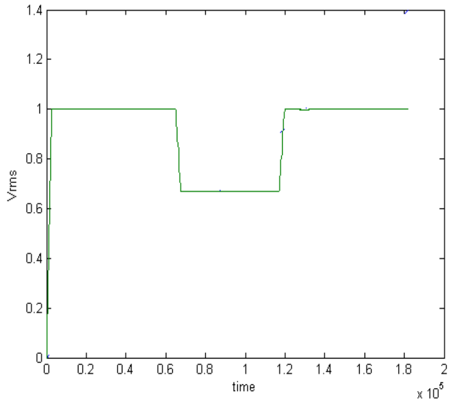


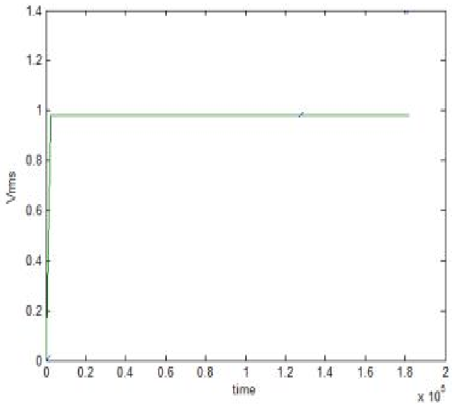
Fig (7.1) Three phase vtg profile at load point

Simulation results of Vrms before compensation at load point:



Fig(7.2) Voltage Vrms at load point without D-STATCOM.

Simulation result of Vrms after compensation at load point :

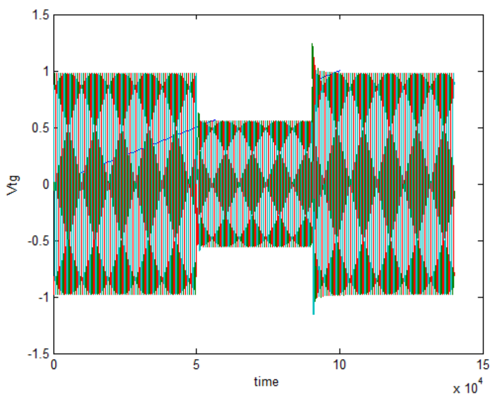


Fig(7.3) Voltage Vrms at load point D-STATCOM.

From above fig.the voltage sag is mitigated with an energy storage of 20.9 kv, when the DSTATCOM is connected to the system.

Case2. Simulation results of Voltage Interruption during Three-Phase fault.

In this case, D-STATCOM is not connected and a three-phase fault is applied at pcc with a fault resistance of 0.001 Ω. The voltage sag is shown in fig.



.

Fig.(7.4)

As the simulation is carried out with a DSTATCOM connection as shown in the fig.(d). The voltage sag is mitigated with energy storage of 50 kv

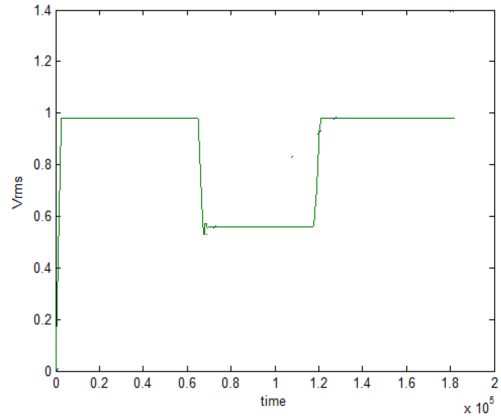


Fig.(7.5) Voltage Vrms at load point without D-STATCOM.

Voltage Vrms at load point without D-STATCOM

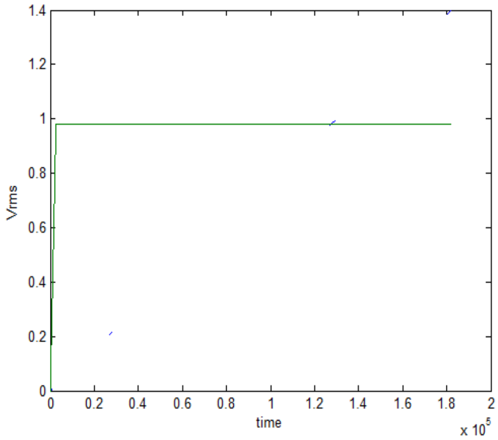
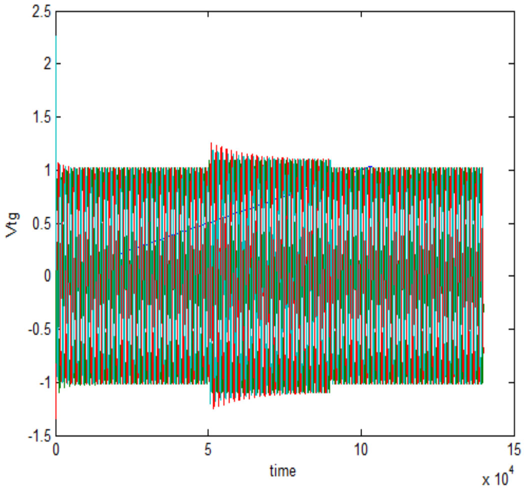


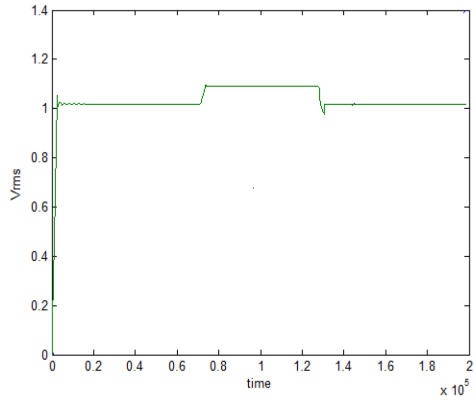
Fig.(7.6) Voltage Vrms at load point D-STATCOM. Voltage Vrms with DSTATCOM and energy storage of 50 kV.

3. Simulation results of Voltage swell

In this case, D-STATCOM is not connected and a capacitive load is applied at a pcc. The voltage swell is shown in fig.6. with a time period of 500ms-900ms.

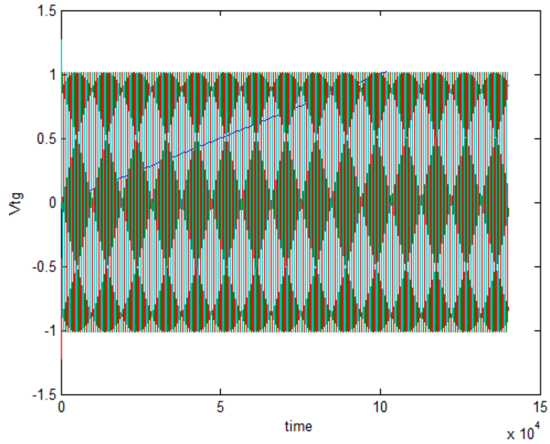


Fig(7.7)Three phase vtg profile at load point

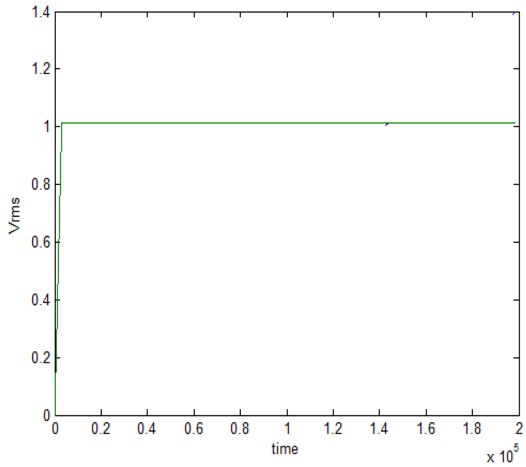


Fig(7.8)Voltage Vrms at load point without D-STATCOM.

Simulation result of after compensation at load point



Fig(7.9) Three phase vtg profile at load point



Fig(7.10) Voltage Vrms at load point with D-STATCOM.

VIII. CASE STUDY (Walchand College of Engg., Sangli.)

A typical distribution feeder from a sub-station to load centers is shown in Fig. 1(b). A three-phase 11Kv/433V, Dy11 transformer is employed in most complexes for catering to the loads locally.

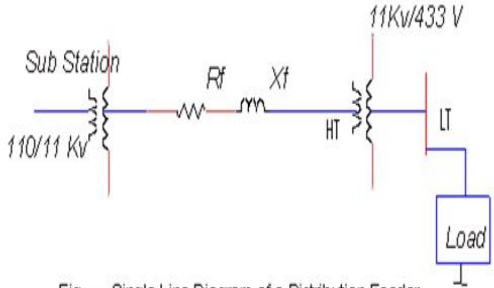


Fig.1(b) Single Line Diagram of a Distribution Feeder

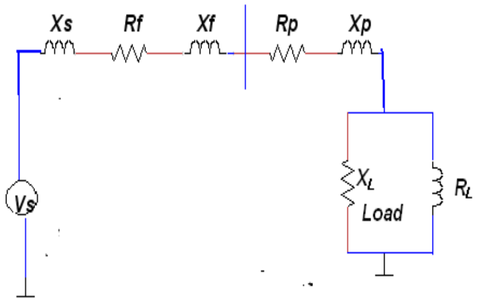


Fig.8 Electrical Equivalent Diagram for the Distribution Feeder with inductive load.

Single phase equivalent diagram representing the feeder is given in Fig. 2 with actual values as calculated below

1. Source Reactance = Xs=Short circuit level on 11kV bus-bar 20 kA'Xs = 0.3175 Ω

Transformer's parameters-The shunt path is neglected. The percentage impedance for 125 kVA transformer is 4.25%.Ip = 6.56 A Zp = = 41.1 Ω ,Copper losses in the transformer = 2000 Watts, Equivalent resistance Rp = 15.49 Ω, Xp = 38.069 Ω.

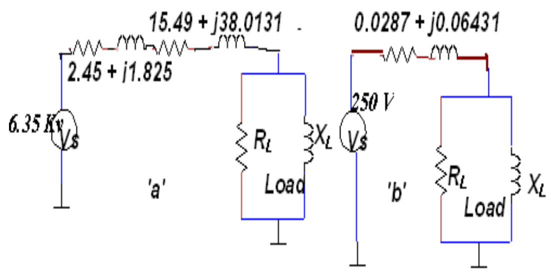


Fig.9 Parametric Diagram 'a '- H.V. Side & 'b' - L.V. Side

3. Feeder parameters -Distance = 5 Km; RF/Km = 0.49 Ω; XF/Km = 0.365 Ω,RF = 0.49 x 5 = 2.45 Ω & XF = 0.365 x 5 = 1.825 Ω Equivalent values referring to H. V. side-Total resistance = 2.45 + 15.49= 17.94 Ω Total equivalent reactance = 0.365 + 1.825 + 38.069 = 40.259 Ω The equivalent values referring to L. V. sides are = R_{LV}= 0.0287 Ω , X_{LV}=0.06431 Ω; (X_{LV}=0.2047mH) All the parameters are shown in the equivalent diagram Fig. 9. The R_L and X_L values will depend on the loading level.

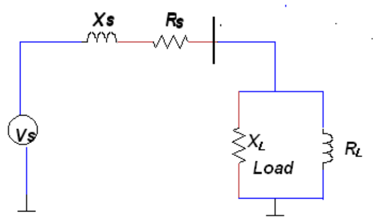


Fig.10. Equivalent diagram of test system

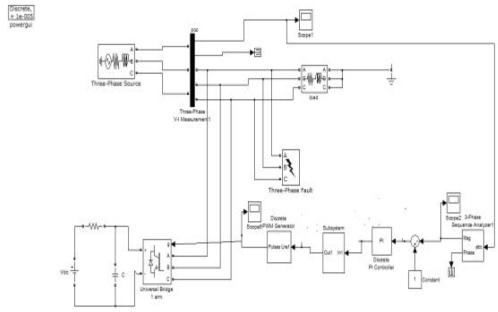
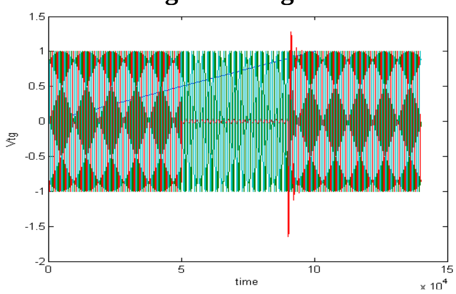


Fig.(8)Simulink model for Test System

Case 1: Single line to ground fault:



Simulation results of Vrms before compensation at load point:

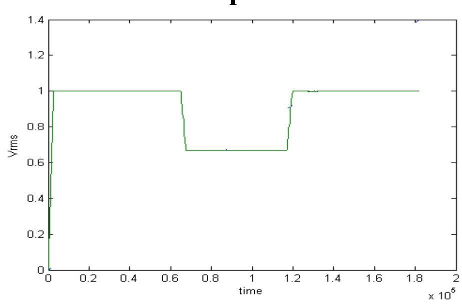
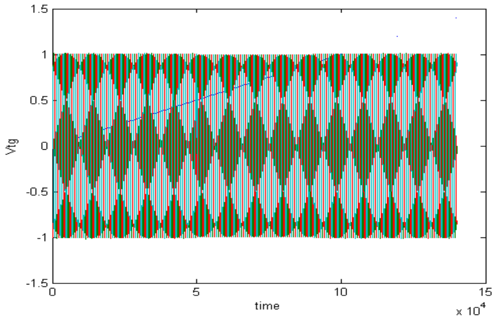


Fig.(8.1)

Simulation results of after compensation at load point:



Fig(8.2) Three phase vtg profile at load point

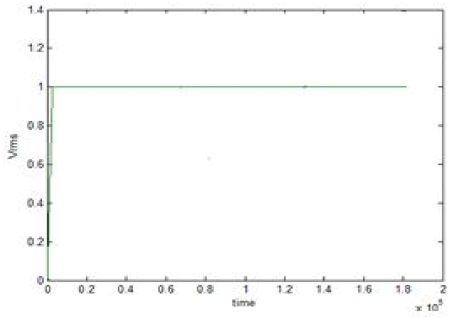


Fig.(8.3) Voltage Vrms at load point with D-STATCOM

Case 2: 3 phase to ground fault:

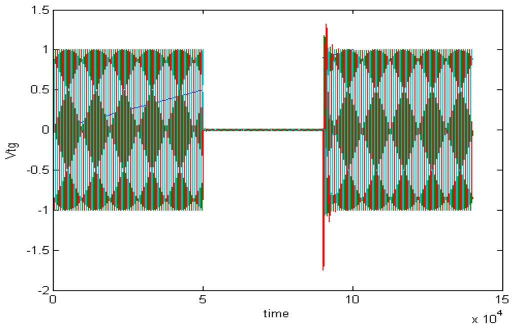
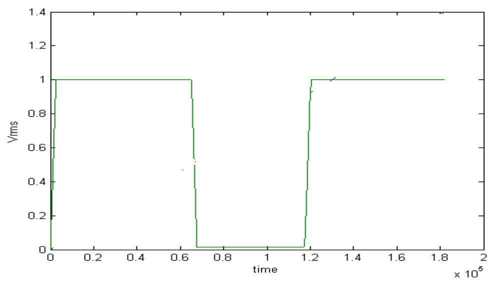


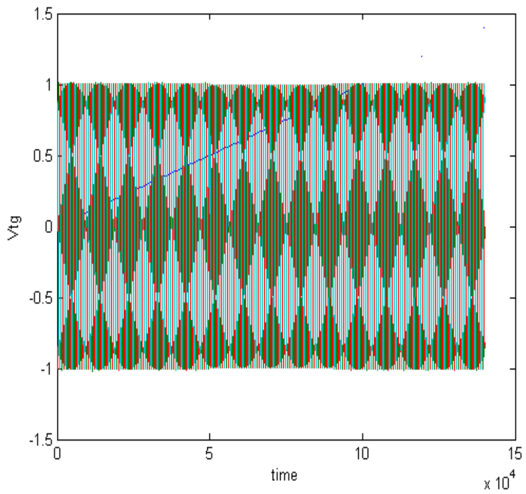
Fig.(8.3) Three phase vtg profile at load point without D-STATCOM

Simulation results of Vrms before compensation at load point:



Fig(8.4) Vrms at load point without D-STATCOM

Simulation results of Vtg after compensation at load point:



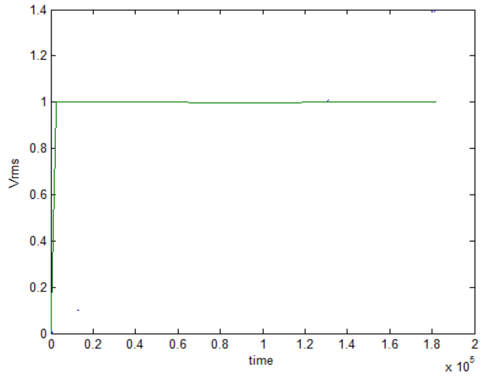


Fig.(8.5) Voltage Vrms at load point with D-STATCOM

IX. CONCLUSION

From above simulation results we conclude that D-STATCOM is promising device which is used for voltage sag,swell mitigation at distribution side.In this work only the Vrms value is required to measure instead KVAR, so that complexity is reduced.

REFERENCE:

1. Dugan, Roger C.; McGranaghan, Mark F.; Beaty, H Wayne. 1996. “Electrical Power Systems Quality”. McGraw Hill Companies, Inc.
2. Power Quality Improvement in Distribution system using DSTATCOM in transmission lines by Sai Kiran Kumar Sivakotti, Y.Naveen Kumar, D.Archana.
3. Design o a Prototype DSTATCOM or voltage sag mitigation by Hendri Masdi , Norman Mariun, S.M.Bashi,MIEEE, A.Mohamed, Sallehhuddin Yusuf MIEEE.
4. Simulation of D-STATCOM and DVR in power systems by S.V.KUMAR and SIVA NAGARAJU J.N.T.U College of Engineering , Kakinada, A.P ,India.fig(8.4) Three phase vtg profile at load point with D-STATCOM.

❖❖❖