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Power Quality Improvement Using DVR (Dynamic Voltage Restorer) of Power Distribution Network

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Abstract

A Power quality problematic is an occurrence established as a modified voltage, current or frequency that results in a failure or a mis-operation of end handler equipments. Utility distribution networks, sensitive industrial loads and critical commercial maneuvers suffer from various types of outages and service disruptions which can cost important fiscal losses. With the reformation of power systems and with shifting trend towards distributed and discrete generation, the issue of power quality is going to take container dimensions. In emergent countries like India, where the variation of power frequency and many such other causes of power quality are themselves a serious question, it is very energetic to take positive steps in this way. The present work is to identify the protuberant concerns in this area and hence the measures that can improve the quality of the power are suggested. This work describes the techniques of modifying the supply voltage sag, swell and interruption in a distributed system. At present, a wide range of very elastic controllers, which capitalize on anew available power electronics machineries, are developing for custom control applications. Among these, the distribution static compensator and the dynamic voltage restore infrequent most actual devices, both of them based on the VSC principle. A DVR injects a voltage in series with the system voltage and a D-STATCOM vaccinates current into the system to correct the voltage sag, swell and disruption. Inclusive results are presented to assess the performance of each device as a probable tradition power Solution.

Keywords: Superiority, Voltage Sag, DSTATCOM, DVR, MATLAB, Interruption, Voltage swell

1. Introduction

The electrical power system is deliberated to be covering three functional blocks like generation, transmission and distribution. For unswerving power system, the generation unit must harvest satisfactory power to meet customer's demand, transmission systems should transport majority power over long distance without overloading or preserve system stability and distribution system must transport electric power to each customer's confirmations from bulk power systems. Distribution system locates the end of power system and is connected to the customer straight, so the power excellence mainly be contingent on distribution connotation.[1-4]

One of the greatest common power superiority problems currently is voltage sag and swells. Voltage sag is a short time quantity throughout which a decrease in r.m.s voltage magnitude arises likewise swell is event during which rise in r.m.s voltage degree. A voltage dip is unnatural by a fault in the helpfulness system, which affects both the phase to ground and phase to phase voltages. Typical faults are single-phase or multiple-phase short circuits, which indications to high currents. The great current results in a voltage drop terminated the linkage impedance. At the fault site the voltage in the criticized phases drops close to zero, while in the non-faulted phases it residues more or less unaffected [2-3]. Initially for the enhancement of power quality or consistency of the system FACTS devices, like static synchronous compensator (STATCOM), static synchronous series compensator (SSSC), interline power flow organizer (IPFC) and unified power flow controller (UPFC) etc are introduce. These FACTS campaigns are intended for the transmission system. But now a day more courtesy is on the circulation system for the enhancement of power quality, these devices are adapted and known as convention power devices. The main custom power devices which used in distribution prearrangement for power superiority improvement are distribution static synchronous compensator (D-STATCOM), dynamic voltage Restorer (DVR), active filter (AF), unified power quality conditioner (UPQC) etc. [2-4] In this thesis from the beyond convention power devices, D-STATCOM and DVR are used With PI controller for the power quality improvement in the distribution system. Here, different loads are measured with dissimilar fault condition and investigate the operation of DSTATCOM and DVR in dispersion structure [4-10] Some research papers and reports addressed the subject of improving power quality in distribution system by the use of convention power devices. The followings present a brief review of the work undertaken so far. N.G.Hingorani, [11] the concept of custom power is now attractive familiar. The book pronounces the value- added power that electric efficacies and other service providers will offer their customers in the future. The superior level of reliability of the power in terms of problem of which a protuberant feature will be the application of power electronics controllers to utility delivery system and at the supply end of many industrial and commercial patron and industrial parks. Olimpo Anaya-Lara and E. Acha, et al [12] this paper presents the modeling and analysis of custom power superintendents, Graphics-based models apposite for electromagnetic transient educations exist for the following three custom power organizers: the distribution static compensator (D-STATCOM), the dynamic voltage restorer (DVR), and the solid-state transfer switch (SSTS). Inclusive results are presented to assess the performance of each expedient as a potential custom power resolution. M.H.J.Bollen, et al. [12] presents the inspiration of sags that leads to an interruption of plant action. The possibility that voltage sag is not correct in a power system with large loads, after fault- clearing, they will accelerate again, drawing a high reactive current from the supply, causing protracted post fault of some voltage sags in an instance power system is shown and conferred. The inspiration of quicker guard and of reduced transformer impedance on the table is accessible. A simple model is appreciated in a method for counting stoppages due to voltage sag in the honesty of power organisms. H.P.Tiwari, et al [13] presents dynamic voltage restorer against voltage sag. A dynamic voltage restorer (DVR) is a convention power device used to correct the voltage sag by injecting voltage as well power into the system. The moderation capability of these devices is generally guidance by the maximum load; power factor and all-out voltage dip to be compensated. Voltage dip on a feeder is a main task for DVR system operation and suitable desired voltage sag compensation. This paper is proposed to conform the amount of DC energy storage be provisional on voltage dip. It is accessible in a convenient manner for DVR power circuit. Arindam Ghosh, et al [14] presents the presentation of voltage-source converter based shunt and series compensators cast-off for load voltage controller in electrical power distribution system has been observed and likened, A distribution static compensator (DSTATCOM) as shunt device and a dynamic voltage restorer (DVR) as a series device are deliberated in the voltage control mode for the judgment. The effect of various system strictures on the control performance of the compensator studied using the proposed analysis. The experimental substantiation of the analytical result derived has been achieved using a laboratory model of the single-phase D-STATCOM and DVR. Arindam Ghosh, et al. [15] presents the Dynamic Voltage Restorer (DVR) with ESS based PI Controller method to reward balanced voltage sag. Voltage sag is one of the main power eminence problems which result in a disenchantment of end use equipments. Sensitive industrial load and utility distribution networks all agonize from various types of outages and service breaks which can cost significant financial loss per event. The aim therefore is to mention measures that can recover voltage sag. C.S.Chang, et al [16] presents presentation of voltage sag validation devices such as the Dynamic voltage restorer(DVR) has been evaluated in highly basic electrical environment involving of simple line and load models. The negative stimulus of dynamic load on the existing voltage commotion, such as post- fault sags, further during fault phase angle eccentricities, during- fault and post-fault voltage variability have often been unobserved. First, the influence of load operation on the during-fault and post-fault waveforms will be debated.

2. Power Quality Issue

Power quality in electric networks is the biggest ad major problem I today world it is very serious in modern area ,it affect the quality of power like voltage sag ,voltage swell and steady state stability and also transient stability of the power system. The Manufactures innovation and automation of trade and increasing use of computers, microprocessor and power electronics system such as modifiable speed drive. Integration of non-conventional generation machineries such as fuel cells, wind turbines and photo-voltaic with utility grids often requires power electronic interfaces. The power electronic system also donates to power quality problem. Under the decontrolled environment, in which electric utilities are expected to participate with each other, the customer satisfaction becomes very significant. The influence of power quality snags is gradually felt by customers- industrial, marketable and even uptown [1] [5].

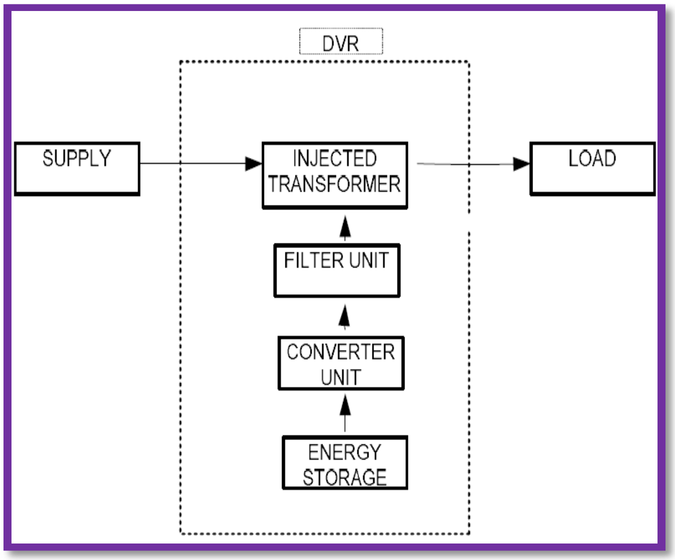

Figure 1 Block Diagram of DVR

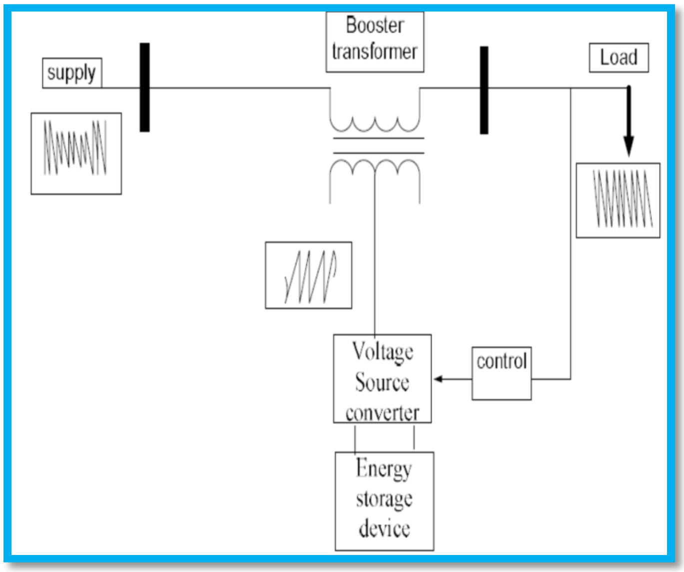

Figure 2 Circuit Block Diagram of DVR

The reactive power swapped between the DVR and distribution system is within generated by the DVR deprived of any ac passive reactive components, i.e. reactors and capacitors. For large differences in the source voltage, the DVR supplies partial power to the load from a rechargeable energy source devoted to the DVR dc terminal. The DVR, with its three single phase self-governing control and inverter design is able to restore line voltage to critical loads during sags caused by unsymmetrical as well as regular three phase faults on adjacent feeders or disturbances that may originate many much away on the higher voltage unified transmission system. Connection to the delivery network is via three single-phase series transformers there by allowing the DVR to be applied to all classes of distribution voltages. At the point of joining the DVR will, within the limits of its inverter, provide a highly structured clean output voltage [7-9][15][19][23].

3. Methodology

3.1 Basic Arrangement of DVR

The broad-spectrum prearrangement of the DVR involves of,

1. An Inoculation/ Promoter transformer

2. A Sung filter

3. Storage Policies

4. A Current Source Converter (VSC)

5. DC charging circuit

6. A Control and Fortification system

3.2 Distribution Static Synchronous Compensator (D-STATCOM)

This chapter focused on the operating principles of DSTATCOM. The DSTATCOM is basically one of the tradition power devices. It is nonentity but a STATCOM but used at the Spreading level. The key constituent of the DSTATCOM is a power VSC that is based on high power electronics technologies. The block diagram of D-STATCOM is shown in figure-

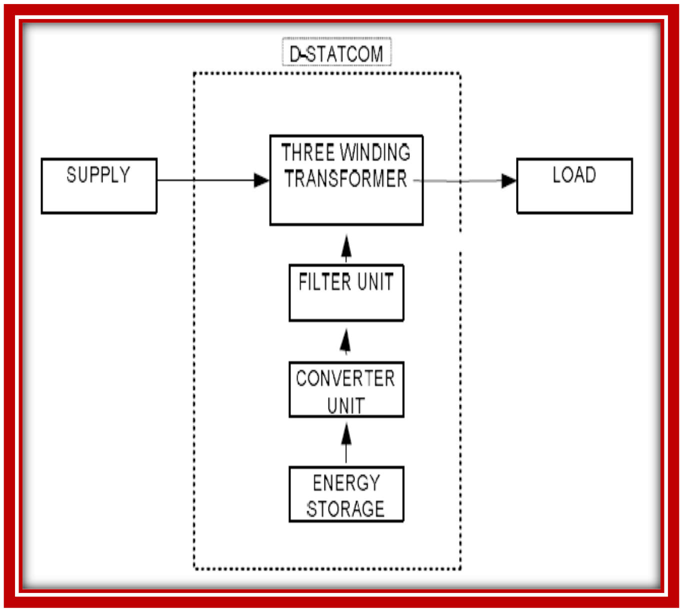

Figure 3 Block Diagram of D-STATCOM

3.2.1 Principle of DSTATCOM

Fundamentally, the DSTATCOM system is included of three main parts: a VSC, a set of connection reactors and a controller. The basic principle of a DSTATCOM connected 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 circuit block digram of D-STATCOMis shown in figure 5.2, the ac voltage source, in general, appears after a transformer leakage reactance. The active and reactive power transmission between the power system and the DSTATCOM is initiated by the voltage metamorphosis across this reactance. The DSTATCOM is connected in shunt with the power networks at purchaser side, where the voltage-quality problem is a concern. All required voltages and currents are measured and are fed into the controller to be associated with the commands. The controller then makes feedback control and outputs a set of switching signals to drive the main semiconductor switches (IGBT's, which are used at the distribution level) of the power converter accordingly [5].

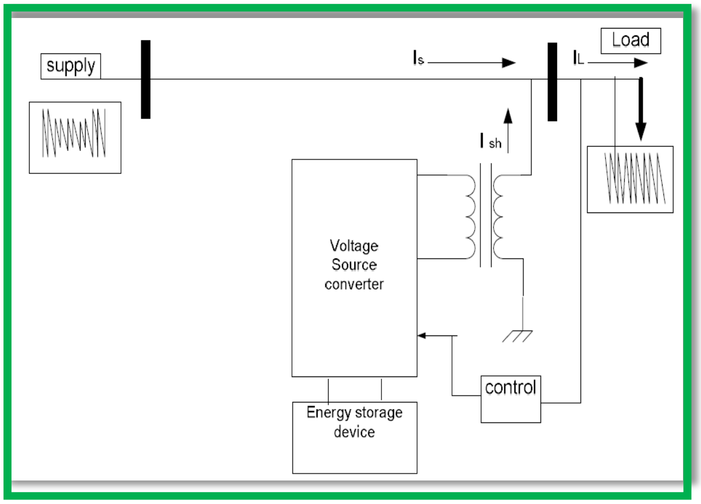

Figure 4 Circuit Block Diagram of DVR

3.2.2 Principle of voltage regulation

The schematic diagram of a D-Statcom is shown in figure 5 [5].

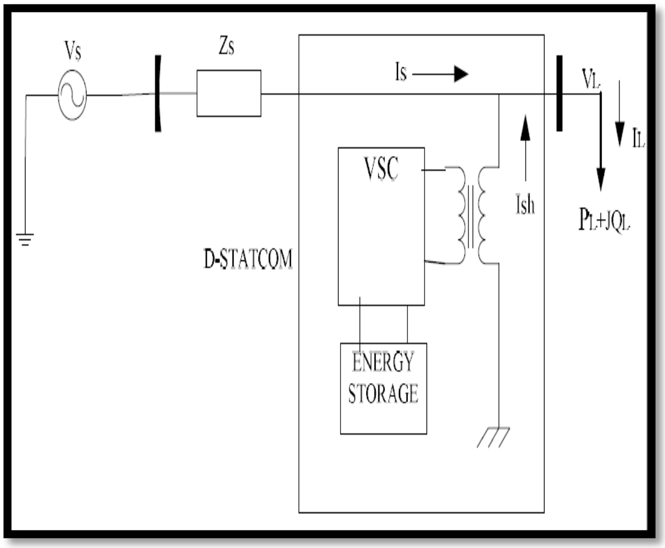

Figure 5 Schematic Diagram of a D-STATCOM

3.2.2.1 Voltage regulation deprived of D-STATCOM

A simple phasor as shown in figure 5, it consists of a source voltage Vs, VL is the load voltage and load current IL. Without a voltage compensator the load voltage drop, produced by the load current IL. The change in load voltage is ΔV.

$$\Delta V = V_s - V_L = Z_S * I_L$$

$$I_L = \frac{(PL - jQL)}{VL}$$

$$\Delta V = (R_s + jX_s) * \left(\frac{(PL - jQL)}{VL}\right)$$

$$\Delta V = \Delta V_r + \Delta V_x$$

So, the voltage change has a essential ΔVr in phase with Vth and element ΔVx having lagging phase alteration [5].

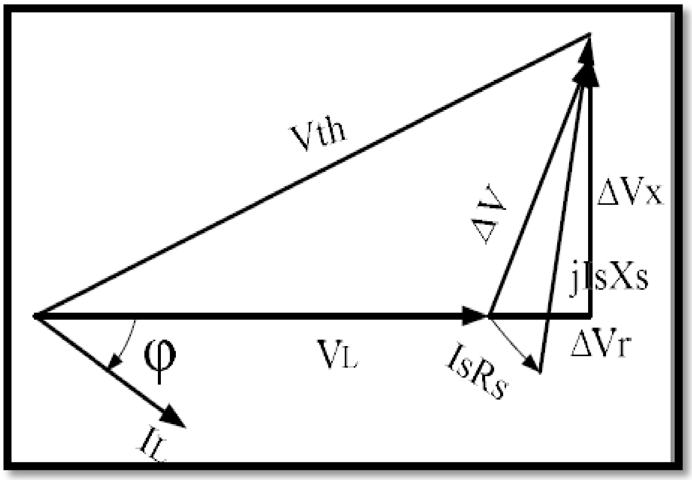

Figure 6 Phasor Figure for Uncompensated

Voltage Regulation with DSTATCOM

Now cogitate, a compensator connected to the system, Figure 7 shows and the vector diagram with voltage recompense. By adding a compensator in parallel with the load, it is possible to supply energy equal to load voltage by correcting the present-day of the compensator [5].

$I_s = I_{sh} + I_L$

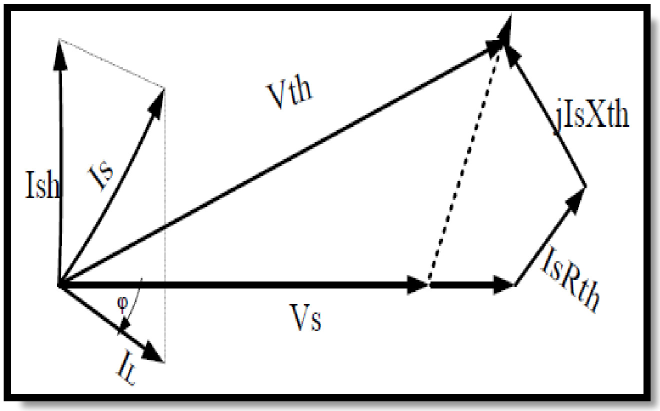

Figure 7 Phasor Diagram for Compensated

3.3 Recreation of D-STATCOM and DVR

A controller is obligatory to control or to operate both D-STATCOM and DVR during the fault disorder only. Load voltage is detected and passed through a sequence analyzer. The magnitude of the actual voltage is likened with reference voltage i.e Vref. Pulse width modified (PWM) control system is every day for inverter transporting so as to engender a three phase 50Hz sinusoidal power at the load terminals.

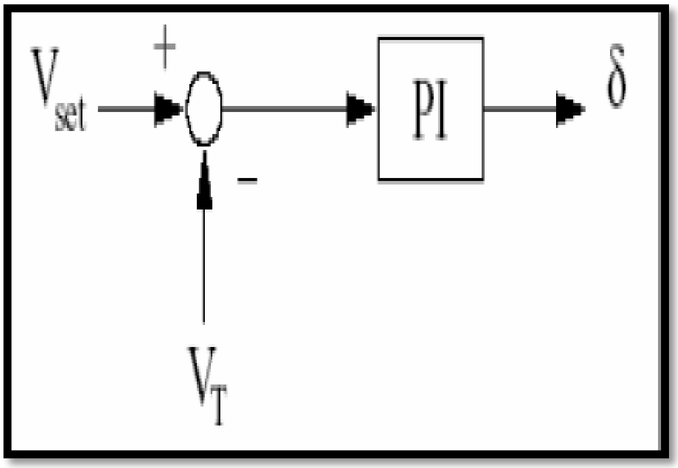

Figure 8 Schematic of Controller

3.3.1 Phase Modulation

The Phase Modulation of the Control Angle is shown in figure 6.2. The sinusoidal signal V control phase moderated by incomes of the angle δ is,

V_A= Sin (ωt + δ) V_B= sin (ωt + δ -2π/3) V_C = sin (ωt + δ+2π/3)

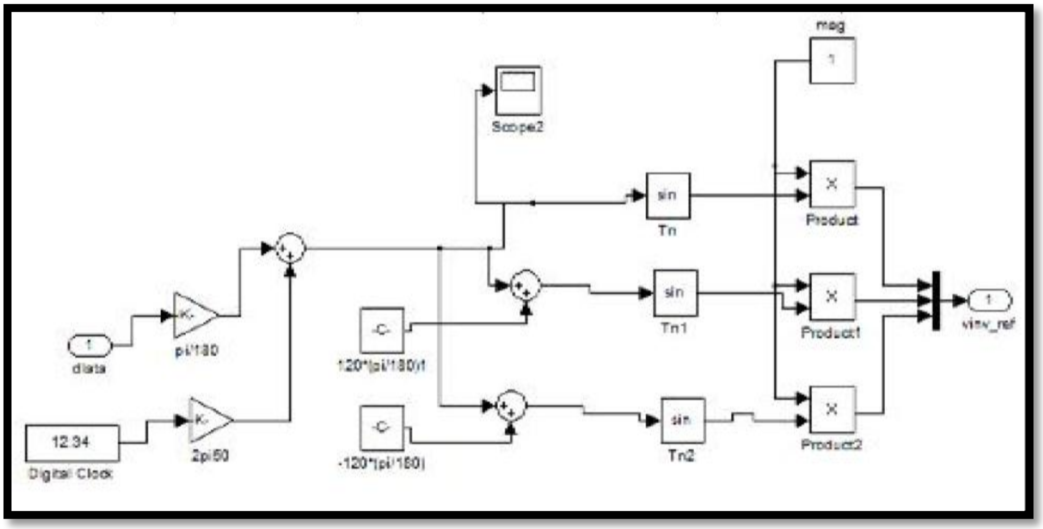

Figure 9 Phase Modulation of the Control Angle

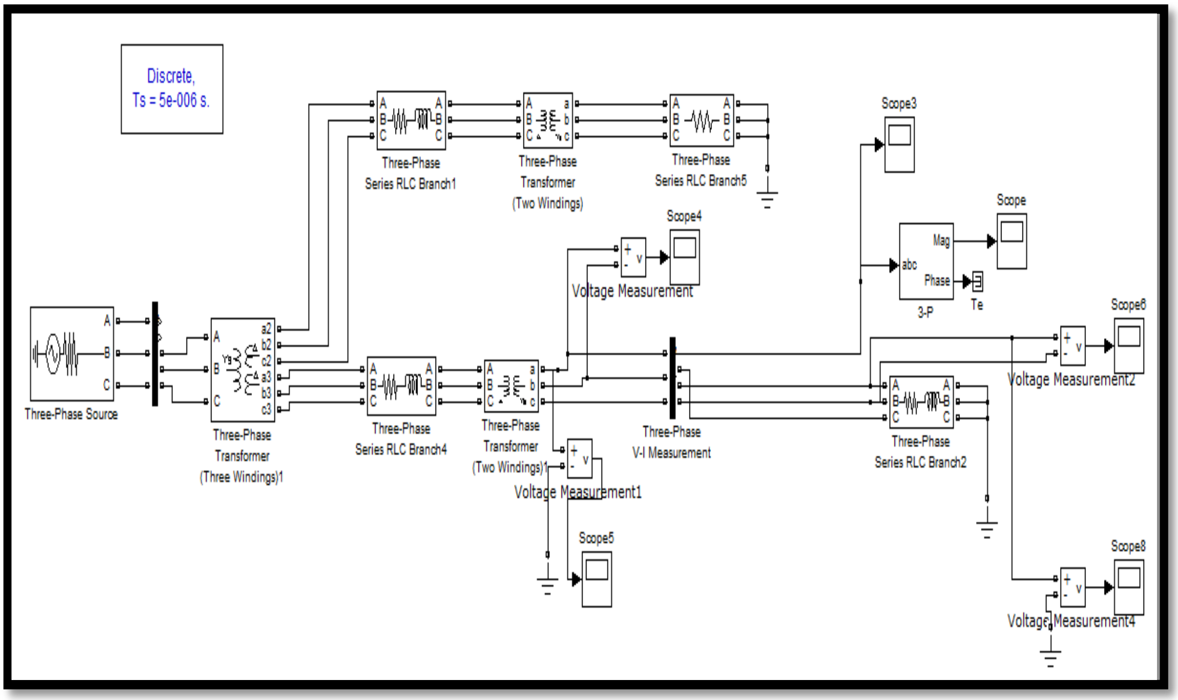

Figure 10 Simulink Model of Test System without Fault and Without DV

3.4 Simulation Fallouts without Fault and deprived of DVR

The RMS value of Voltage in p.u, instantaneous voltages, line to line voltage and phase voltage of the simulation result shown in the figure 11, 12,13 and 14 respectively, when the system considering no fault and no connection of DVR. The line to line voltage is 11KV and phase voltage is 6.3508V is measured.

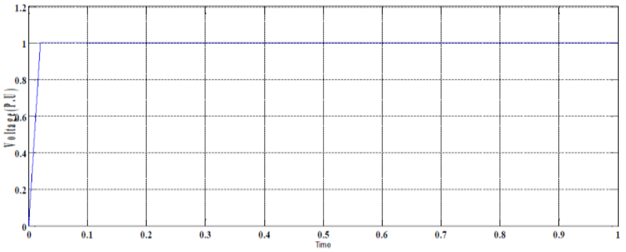

Figure 11 Voltage Vrms (p.u) at Load Side.

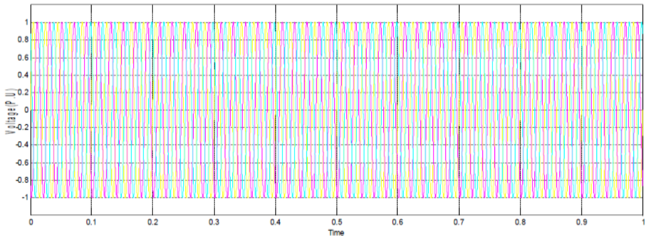

Figure 12 Instantaneous Values in p.u at Load Side.

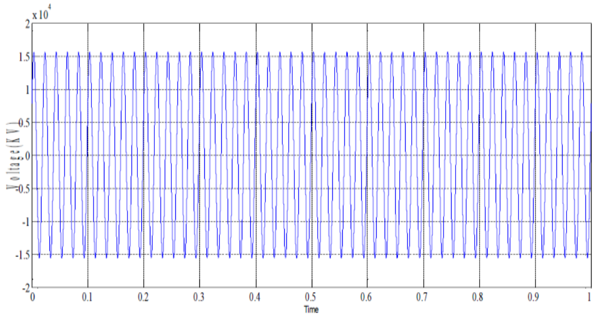

Figure 13 Line to Line Voltages (KV) at Load Side

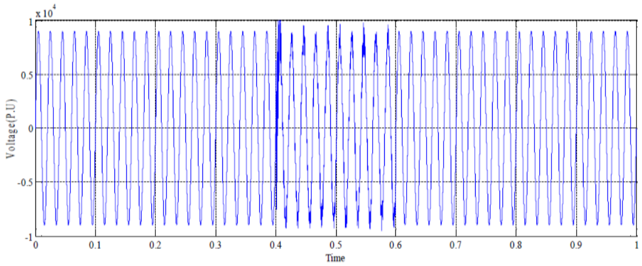

Figure 14 Phase Voltage (KV) at Load Side.

3.4.1 Simulink typical of test system with fault but deprived of DVR

The Simulink model with fault deprived of DVR is shown in figure 15. In this Simulink model we have system which fed the two buses or feeders over two winding transformer as shown. On the upper bus we are smearing the 3phase Line to ground fault(3LG) , here we are not considering the presence of DVR and have to observe the result on currents on the minor bus (another bus or second feeder).

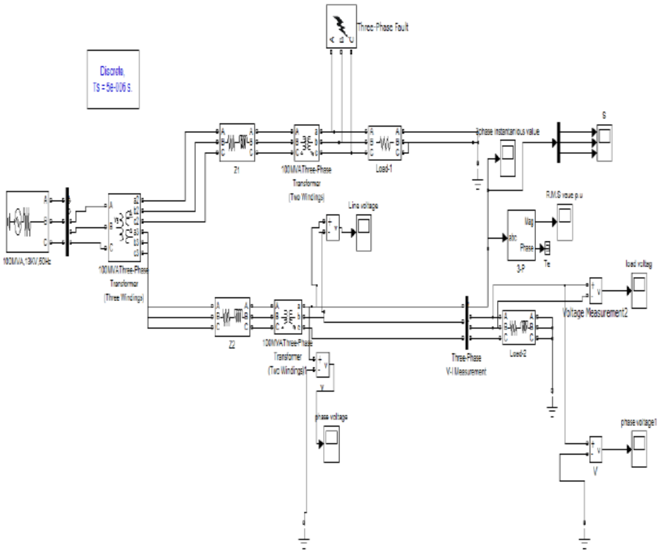

Figure 15 Simulink Model With fault Deprived of DVR

3.4.2 Simulation Result of Test System with Fault and Deprived of DVR

The simulation result showed in the figure 16,17, 18 and 19 respectively. From the next results it is experiential that during the fault time i.e 0.4-0.6 sec, the voltage sags to some finite value. Since the fault is on higher bus, hence sag may be 70-80 %. The sag on the lower bus at the load side is nearly 10-15%, and unhurried the line to line voltage value and phase voltage value during fault time is 10.1KV and 6.01KV, respectively.

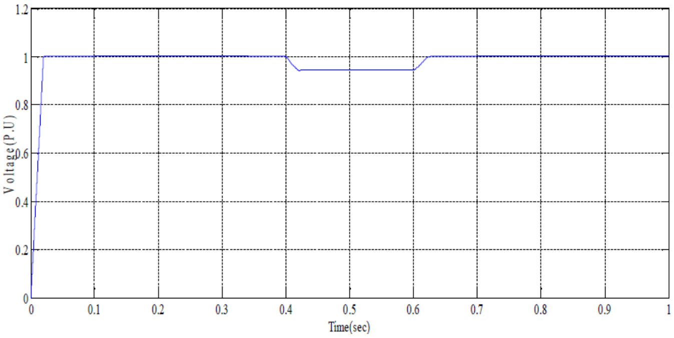

Figure 16 Voltage Vrms (p.u) at Load Side.

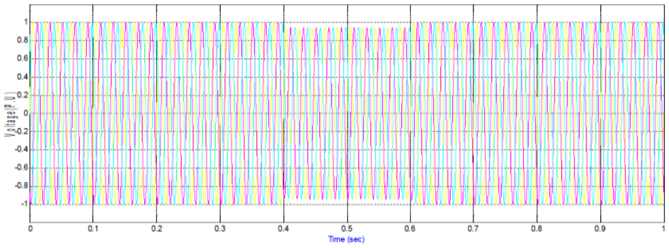

Figure 17 Instantaneous Values in p.u at Load Side.

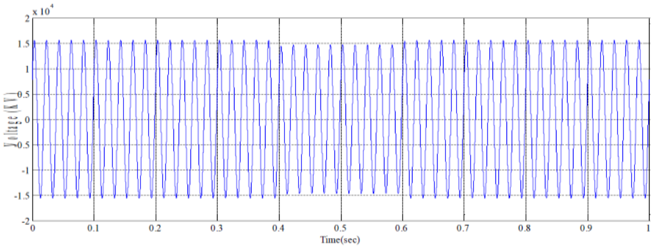

Figure 18 Line to Line Voltages (KV) at Load Side

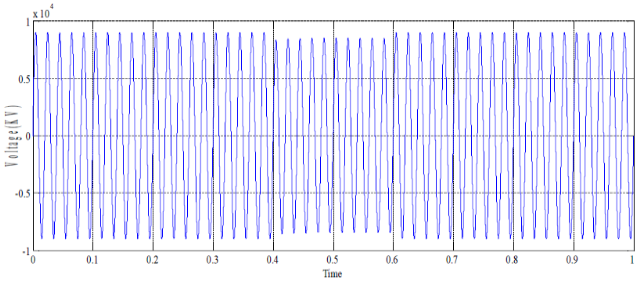

Figure 19 Phase Voltage (KV) at Load Side.

3.4.3 Simulation of Test System for Voltage Swells with DVR

The Simulation Test System for Voltage Swell with DVR is shown in figure 20. In the Simulink model we are considering the working of DVR to eliminate the swell during the capacitor switching.

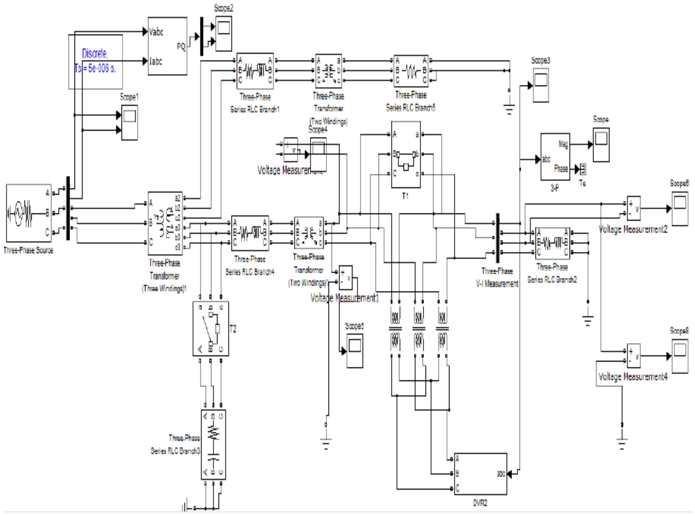

Figure 20 Simulation Test Systems for Voltage Swell with DVR.

3.4.3.1 Simulation Results for Voltage Swell with DVR

From the results shown in figure 21, 22, 23 and 24 shows the compensated results of swell with respective rms value of voltage, instantaneous value, line to line voltage and phase voltages respectively, it is clear that the DVR compensate the voltage swell during the switching time 0.4-0.6 second.

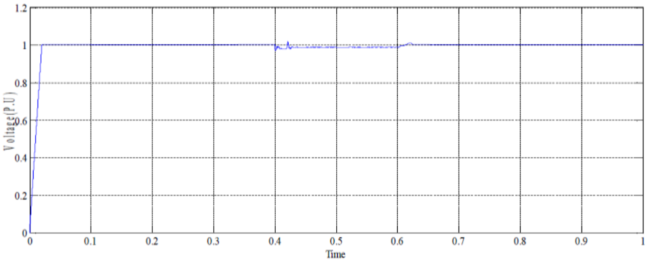

Figure 21 Voltage Vrms (p.u) at Load Side.

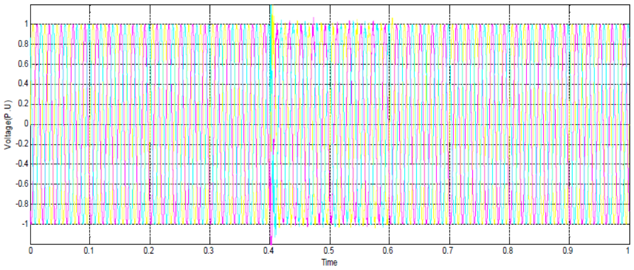

Figure 22 Instantaneous Values in p.u at Load Side.

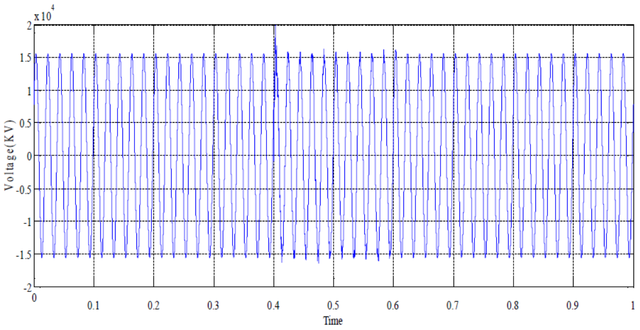

Figure 23 Line to Line Voltages (KV) at Load Side.

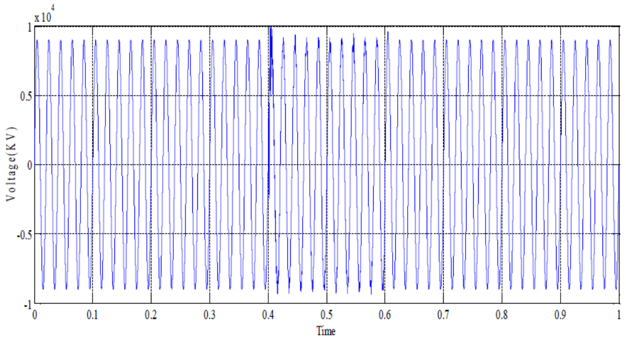

Figure 24 Phase Voltage (KV) at Load Side.

3.5 Parameters of D-STATCOM Test System

The test system comprehends of 230KV, 50Hz transmission line (measured to be source). This source, feeding two distribution network through a three winding transformer connected in Y/Δ/Δ 230/11/11 KV. The single line diagram of the test system for D-STATCOM is shown figure 25

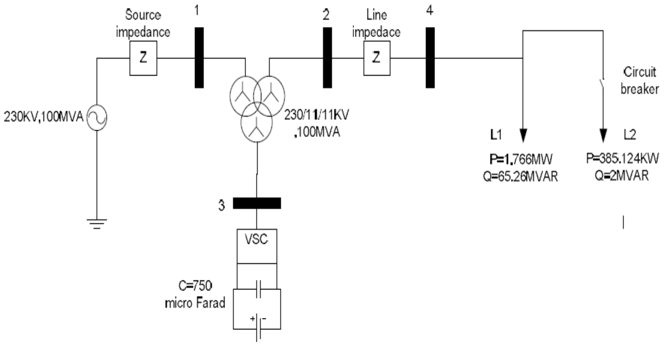

Figure 25 Sole Line Diagram of the Test System for D-STATCOM

3.5.1 Simulink Model of Test Scheme and Outcome

Simulation of test system deprived of fault and D-STATCOM the Simulink model of the test system without any fault and no connecting custom device like DVR is shown in figure 26.

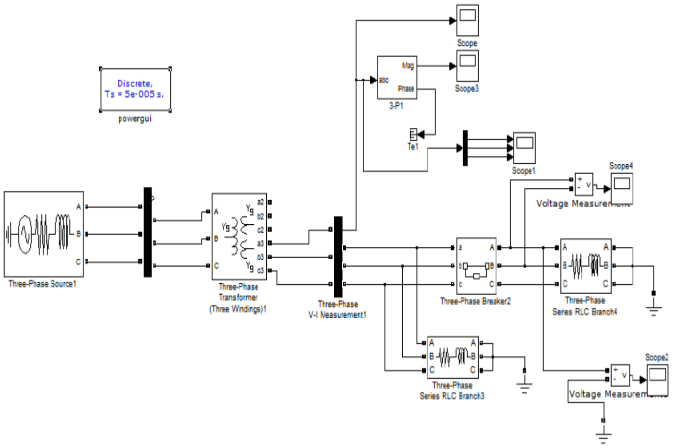

Figure 26 DVR Simulation Model

3.5.2 Simulation Results without Fault and Without D-STATCOM

The result of the system when considering no fault and no connection of D-STATCOM rms value of Voltage in p.u, instantaneous voltages, line to line voltage and phase voltage of the simulation result shown in the following figure 27, 28, 29 and 30 respectively. The line to line voltage and phase voltage are nearly11KV and 6.3508V is measured.

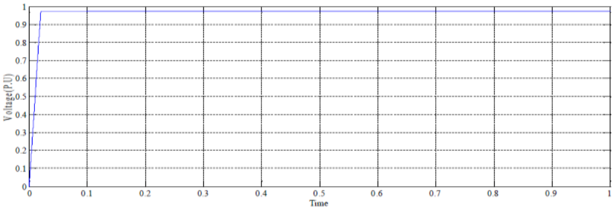

Figure 27 Voltage Vrms (p.u) at Load Side.

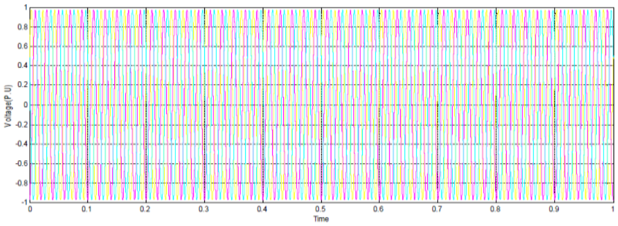

Figure 28 Instantaneous Values in p.u at Load Side.

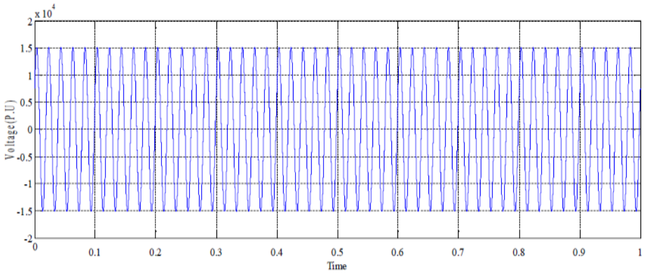

Figure 29 Line to Line Voltages (KV) at Load Side.

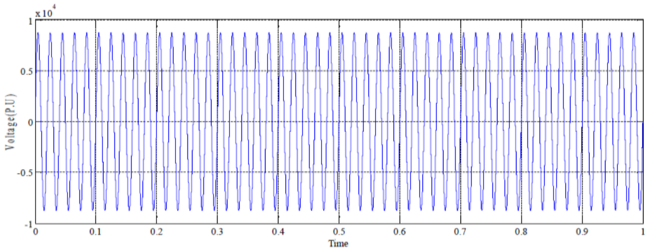

Figure 30 Phase Voltage (KV) at Load Sideways.

3.5.2 Replication Results with Fault but Deprived of D-STATCOM

After the simulation the results shown in figure 31, 32, 33 and 34, it is trial that throughout the fault time i.e. 0.4-0.6 sec, the voltage sag to some limited value. The sag during the fault at the load side is nearly 10-15%, and measured the line to line voltage value and phase voltage value through fault time is 10.25KV and 6.01KV correspondingly.

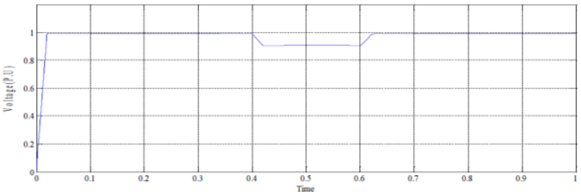

Figure 31 Voltage Vrms (p.u) at Load Side

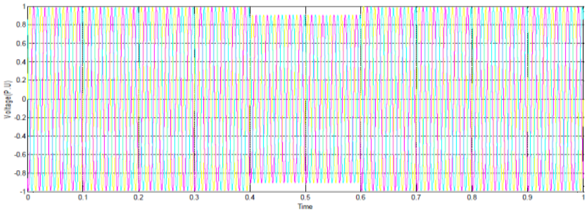

Figure 32 Instantaneous Values in p.u at Load Side

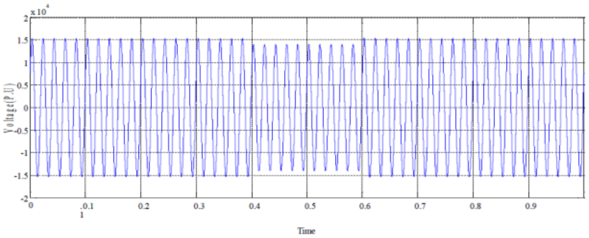

Figure 33 Routes to Line Voltages (KV) on Load Lateral

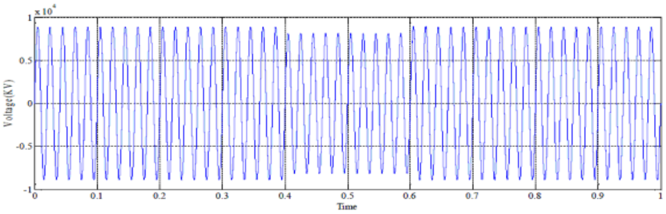

Figure 34 Phase Voltage (KV) at Load Side.

3.5.3 Simulation of Test System with D-STATCOM

The simulation exam system with D-STATCOM is exposed in figure 35. In this Simulink model we have structure which fed the load through secondary winding of tertiary transformer as shown. Out of two parallel loads, sag is created by providing the Switching on solitary of load. The D-STATCOM is related to one of the secondary twisting of tertiary transformer.

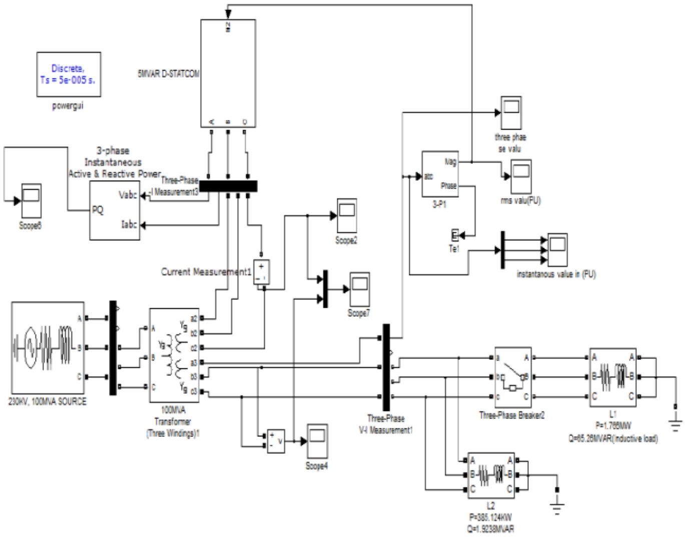

Figure 35 Simulation Test Systems with D-STATCOM

3.5.4 Simulation Results with Fault and with D-STATCOM

From the simulation results shown in figure 36, 37, 38 and 39, it is clear that the D-STATCOM compensate the voltage sag during the fault time 0.4-0.6 sec. the compensated results of sag with respective rms worth of voltage, prompt value, line to line voltage and phase voltages respectively. The battery voltage is found to be 28KV.

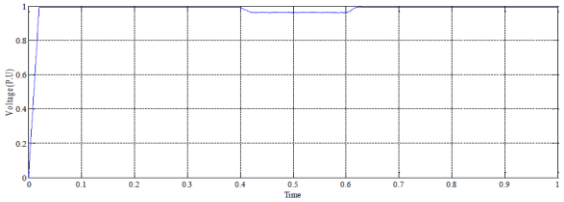

Figure 36 Voltage Vrms (p.u) at Load Side.

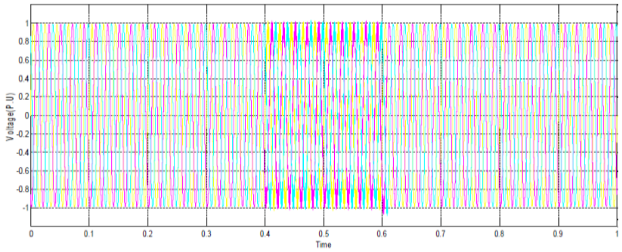

Figure 37 Instantaneous Values in p.u at Load Side with Fault but Without D-STATCOM

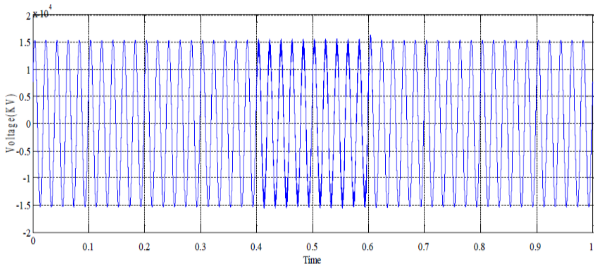

Figure 38 Line to Line Voltages (KV) at Load Side with Fault but Without D-STATCOM

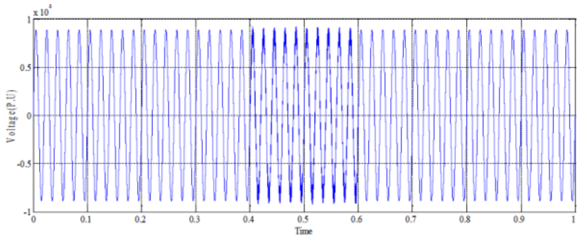

Figure 39 Phase Voltage (KV) at Load Side with Fault but Without D-STATCOM

3.5.5 Replication of Test System for Voltage Swells without D-STATCOM

The simulation of test system for voltage swell deprived of D-STATCOM is shown in figure 40. The Simulink model represents the creation of swell for the time 0.4-0.6 sec. To create the swell switch is closed for the interval of 0.4-0.6 sec.

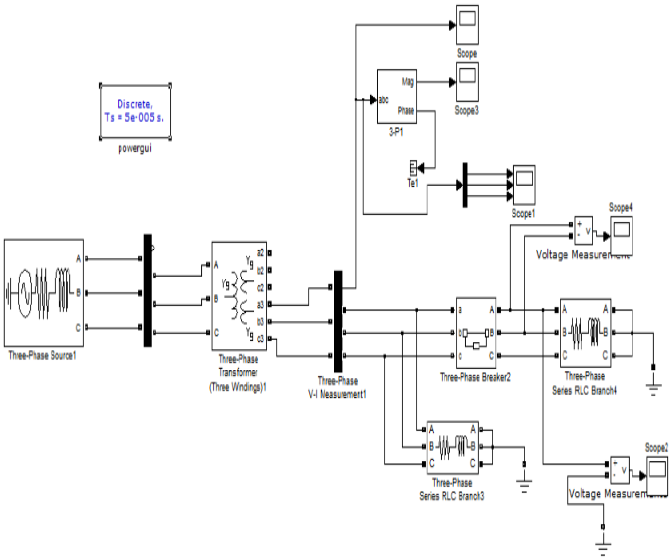

Figure 40 Replication of Test System for Voltage Swells Deprived of D-STATCOM.

3.5.6 Replication Results for Voltage Swell deprived of D-STATCOM

The voltage swell is created by closing the switch during 0.4-0.6 sec. The swell of 10-15% of its normal value is found at the interval of 0.4-0.6 sec, which is shown in the figure 41,42, and 43 representing rms charge of voltage in p.u, three stage instantaneous worth in p.u, line to line voltage and phase power in KV respectively. The line to line energy and phase voltage during the 0.4-0.6 are 0.93KV and 0.588KV respectively.

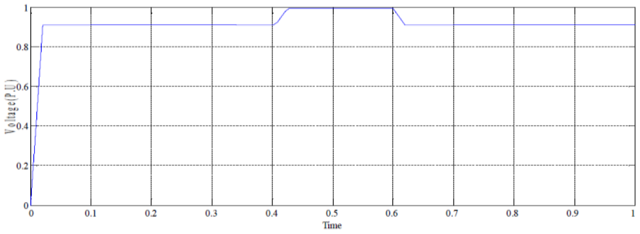

Figure 41 Voltage Vrms (p.u) at Load Side.

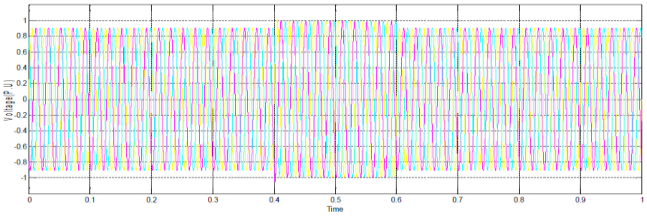

Figure 42 Instantaneous Values in p.u at Load Side.

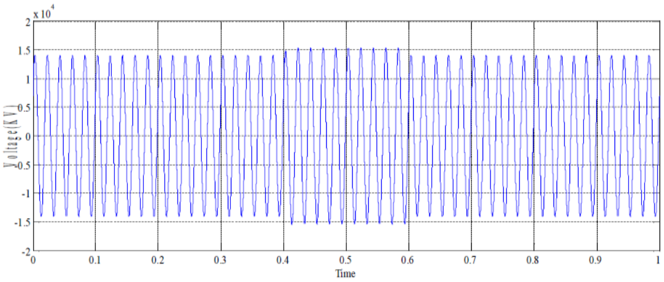

Figure 43 Line to Line voltages (KV) at Load Side.

3.5.7 Simulation of Test System for Voltage Swells With D-STATCOM

The replication test system of voltage swell with D-statcom is shown in figure 44.

In the simulink model we are considering the working of D-STATCOM to eliminate the swell during the switchin of load.

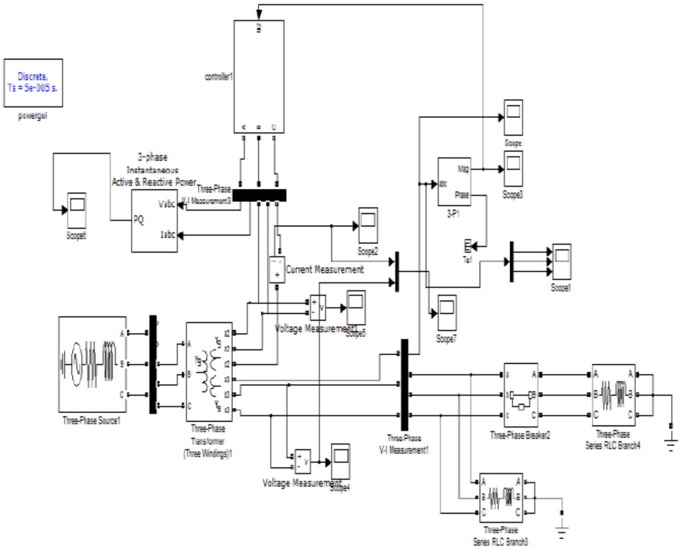

Figure 44 Simulation Test Systems for Voltage Swell with D-STATCOM

3.5.8 Simulation of test system for voltage swells with D-STATCOM

From the simulation results shown in figure, 45,46, 47 and 48, it is clear that the DVR compensate the voltage swell during the switching time 0.4-0.6 sec. the compensated results of swell with respective rms value of voltage, instantaneous value, line to line voltage and phase voltages respectively.

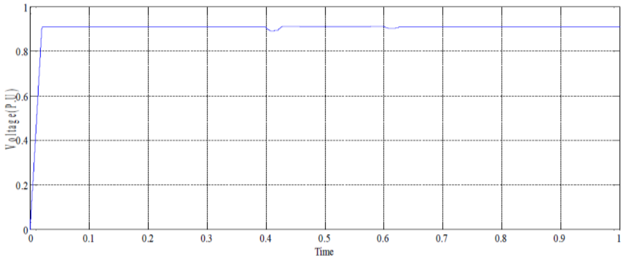

Figure 45 Voltage Vrms (p.u) at Load Side.

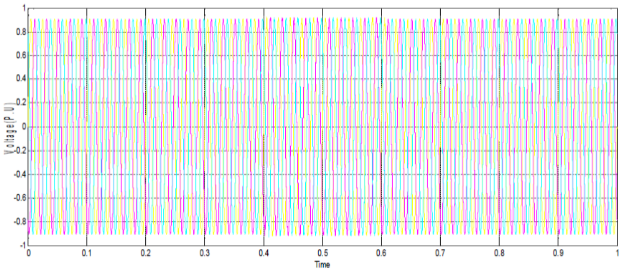

Figure 46 Instantaneous Values in p.u at Load Side.

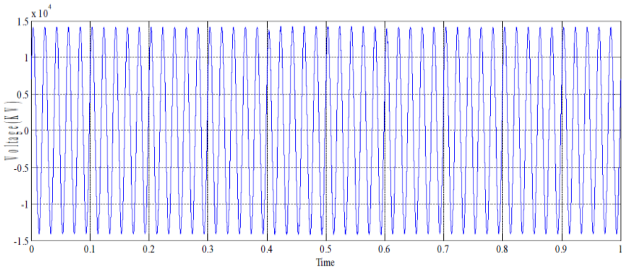

Figure 47 Line to Line voltages (KV) at load

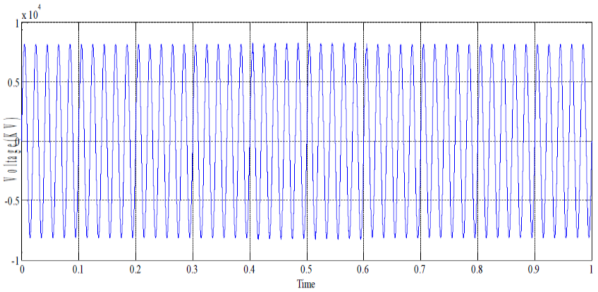

Figure 48 Phase Voltage (KV) at Load Side.

4. Result and Discussion

This project report has presented the study and simulation model of tradition power equipment, namely D-STATCOM and DVR, and applied them for power quality badly-behaved such as voltage sag and voltage swell. The highly grow graphic services available in MATLAB is used to conduct all the feature of typical implementation and to carry out general simulation educations.

A regulator which is based on closed loop method is used which generate error signals and this signals are used to trigger the switches of inverter using pulse width modulation (PWM) arrangement in the D-STATCOM and DVR, this PWM control scheme only requires voltage measurements. The simulations are passed out for both sag and swell on 11KV feeder using both D-STATCOM and DVR as custom power devices and it has been originate that DVR provide outstanding voltage regulation capabilities. It is also observed that the DVR capacity for power recompense and voltage regulation depends mainly on two influences that is, the rating of the dc storage device and the coupling transformer.

7. Conclusion

This project tale has presented the study and simulation model of tradition power equipment, namely D-STATCOM and DVR, and applied them for power superiority problem such as voltage sag and voltage swell. The highly grow graphic amenities available in MATLAB is used to conduct all the characteristic of model enactment and to transfer out wide simulation trainings.

A controller which is created on closed loop technique is used which generate error signals and this signals are used to stimulate the changes of inverter using pulse width modulation (PWM) system in the D-STATCOM and DVR, this PWM control structure only requires voltage measurements. The simulations are carried out for both sag and swell on 11KV feeder by means of both D-STATCOM and DVR as routine power devices and it has been found that DVR deliver excellent voltage regulation capabilities. It is also observed that the DVR volume for power recompense and voltage regulation depends mainly on two influences that is, the rating of the dc storage device and coupling transformer.

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