"Operation of DVR and D-STATCOM for Load Voltage Control in Distribution Side"

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Abstract: *Nowadays, the rapid developments in power electronics increases use of critical and nonlinear load in power system, due to this it results in nonstandard voltage, current and frequency and reduce quality of power. This nonstandard power results failure of the load connected to the distribution system. Voltage disturbances challenging the industry are Voltage sag and Swell, among them voltage sags are considered the most significant problem to electronic loads. To solve this type of short duration voltage variation problem, various power electronics controller based custom power devices are used. In this paper utilization of including DVR and D-STATCOM in distribution side for purpose of voltage sag and swell compensation by using PI Controller with SVPWM pulse generation technique is described. Simulation results are presented to assess the performance of each device as a custom power solution. To prove the performance of the proposed method simulation results are considered by MATLAB with its Simulink and Sim Power System toolboxes.*

Key Words: *DVR, D-STATCOM, Power quality, SVPWM, SRF, Voltage sag, Voltage swell*

1. INTRODUCTION:

Nowadays, Power quality is identified as one of the very serious issues in electric power transmission and distribution, because of its bad impact on electricity suppliers, manufacturers and users. Generally we can define power quality as any power problem manifested in voltage, current or frequency deviations that results in failure or disoperation of customer equipment [1]. Presently, most of the industries use power electronics conversion and switching for manufacturing and processing. Sensitive loads such as digital computers, programmable logic controllers (PLC), consumer electronics and variable frequency motor drives need high quality power supplies. Good quality of electric power is necessary for right functioning of industrial processes as well as protection to the industrial machines and its long usage. The frequently occurring power quality issues are voltage unbalance, voltage sag and swell, transients, flickers and harmonic distortions.

Among various power quality problem voltage sag and swell are most significant short duration variation problem. Voltage sag and swell [1] can cause sensitive equipment to fail, shutdown and create a large current unbalance. A Voltage sag is a decrease to between 0.1 and 0.9pu in rms value of voltage at the power frequency for durations from 0.5 cycle to 1 min [2]. Faults on electrical power system like short circuit due to insulation breakdown at heavy load conditions can cause voltage sag. Voltage swell, as compared to sag can be defined an increase to between 1.1 and 1.8pu in rms voltage or current at the power frequency for durations from 0.5 cycle to 1 min [2]. Switching off of large loads, supplying capacitor banks etc. can be considered as the basic causes of voltage swell. Generally, Two types of VSC-based CPDs have been commonly used for compensation of the voltage sags and swells and regulating the load voltage [3]. The first one is a shunt device, which is commonly called D-STATCOM and the second one is a series device, which is commonly called DVR [3].

In this paper, the operation of the DSTATCOM and the DVR used for the load bus voltage control have been considered, when Voltage sag & swell occur in the distribution system across the load bus. In this paper, Synchronous reference frame theory is used for generating reference voltages and Space Vector Pulse Width Modulation technique is used to produce the gate pulses for Voltage source Inverter. A generalized converter Configuration is considered for inverter and it has been proposed for medium-voltage distribution system applications. Simulation studies have been performed to check the results in a three-phase distribution system.

2. Configuration of DVR and D-STATCOM:

A). Dynamic Voltage Restorer

DVR is a series connected solid state device that injects voltage into the system to maintain the load side voltage as near to 1pu. It is normally installed in a distribution system between the supply and sensitive load feeder as shown in

Figure-2.1. Usually the connection is made via a transformer, but configuration but configurations like DVR with no storage and supply-side-connected shunt converter also available. The resultant voltage at the load bus bar equals to the sum of the system voltage and the injected voltage from the DVR.

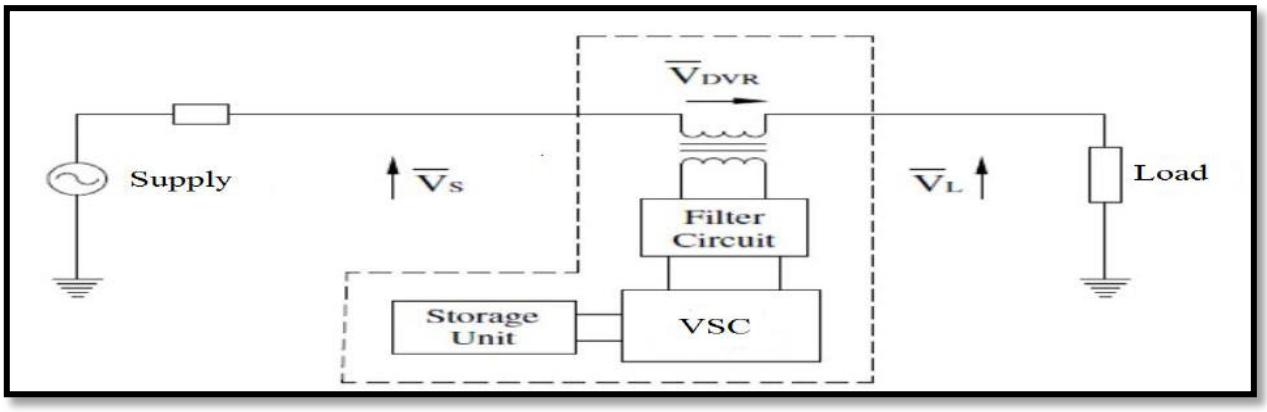

Figure-2.1 DVR Block Diagram

The voltage source converter generates the reactive power required while the active power is taken from the energy storage device. The mitigation for voltage sags and Swells using a DVR can be performed by injecting/absorbing reactive power or real power. When the injected voltage is in quadrature with the current at the power frequency, mitigation is achieved by injecting reactive power and the DVR itself is able to generate the reactive power because DVR is self-supported with dc bus. But, DVR voltage can be kept in quadrature with the current merely up to a certain depth of voltage sag and beyond which the quadrature relationship cannot be sustained to correct the voltage sag i.e. if the injected voltage is in phase with the current, DVR injects real power and hence an energy storage device is required at the dc side of VSI.

B) Fundamental Components of DVR

The Fundamental Components of DVR are:

1) Series Injection Transformer
2) Harmonic Filter
3) Voltage Source Inverter(VSI)
4) Dc energy Storage Devices and Charging Circuit
5) Control System

C) DVR control Strategy

The sag and swell in terminal voltages can be mitigated by controlling the DVR and the proposed algorithm [4] inherently provides a self-supporting dc bus for the DVR. In Figure-2.2 shows the control diagram of the DVR in which the Synchronous Reference Frame theory is used for the control of self-supported DVR [4]. The voltages at Point of Common Coupling (Vt) are converted to the rotating reference frame using the abc-dqo conversion.

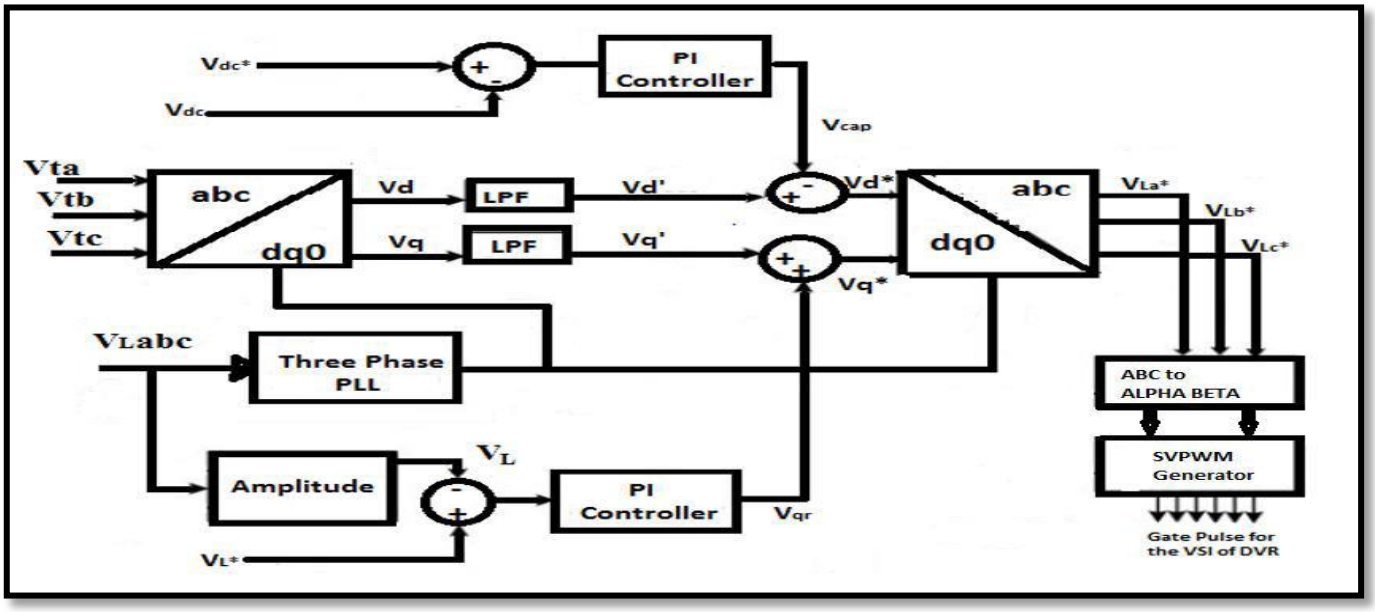

Figure-2.2 Block Diagram of DVR control strategy with SRF theory

The harmonics and the oscillatory components of voltages are eliminated using Low Pass Filters. Three-phase reference supply voltages (VLa*,VLb*,VLc*) are obtained using the sensed load voltages, terminal voltages and dc bus voltage of the DVR as feedback signals. The SRF theory based method is used to get the direct axis (Vd) and quadrature axis (Vq) components of the load voltage. The load voltages are converted into the d-q-0 frame using the abc-dq0 transformation [4]. The resultant voltages (Vd*, Vq*, Vo) are again converted into the reference supply Voltages using the reverse dq0 to abc transformation. Reference supply voltages (VLa*,VLb*,VLc*) are then transformed into alpha beta component with the help of alpha beta conversion. Then the SVPWM generator generates required gating pulses for switches of VSI.

D) D-STATCOM

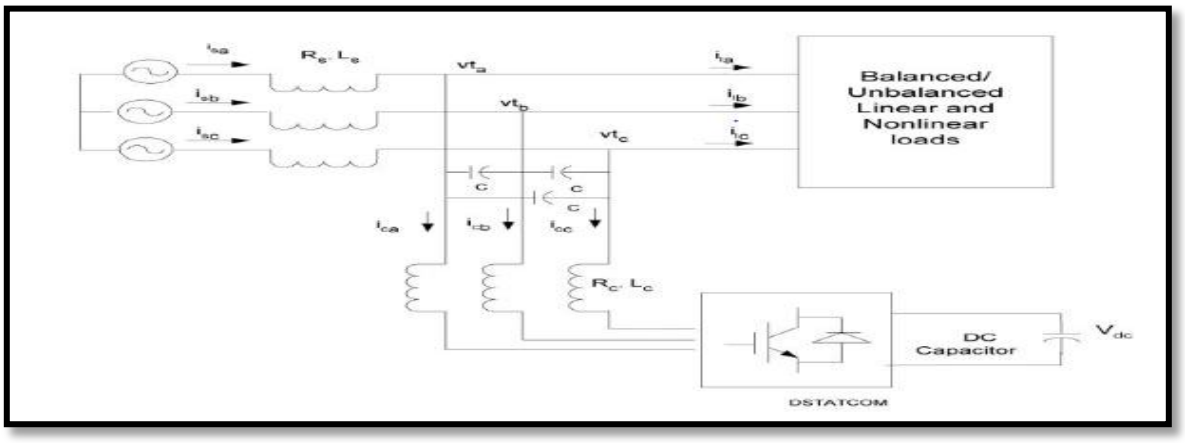

Figure-2.3 D-STATCOM block Diagram

Block diagram of shunt connected D-STATCOM is shown in Figure-2.3. The model is developed for a three-phase, three-wire system configuration. D-STATCOM consists of three-phase Insulated Gate Bipolar transistor (IGBT) based voltage source inverter (VSI) with small ripple filter and DC bus capacitor. The VSI converts the dc voltage across the storage device into a set of three-phase ac output voltages. 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. This type of configuration allows the device to absorb or generate controllable active and reactive power.

E) Control Strategy for D-STATCOM

The control block diagram of D-STATCOM with SRF theory which is used to control D-STATCOM is shown in Figure-2.4. Measurement system measuring the d and q components of AC positive sequence voltage and current to be controlled as well as Dc link voltage Vdc. Phase Locked Loop, which synchronizes on the positive sequence component of the three phase primary voltage V1. The output of the Phase Lock Loop is used to compute the direct-axis and quadrature-axis components of the AC three phase voltages (Vd, Vq) and currents (Id, Iq) as shown in Figure-4. dq0 rotating reference frame is employed because it offers higher accuracy compared to the stationary frame based method.

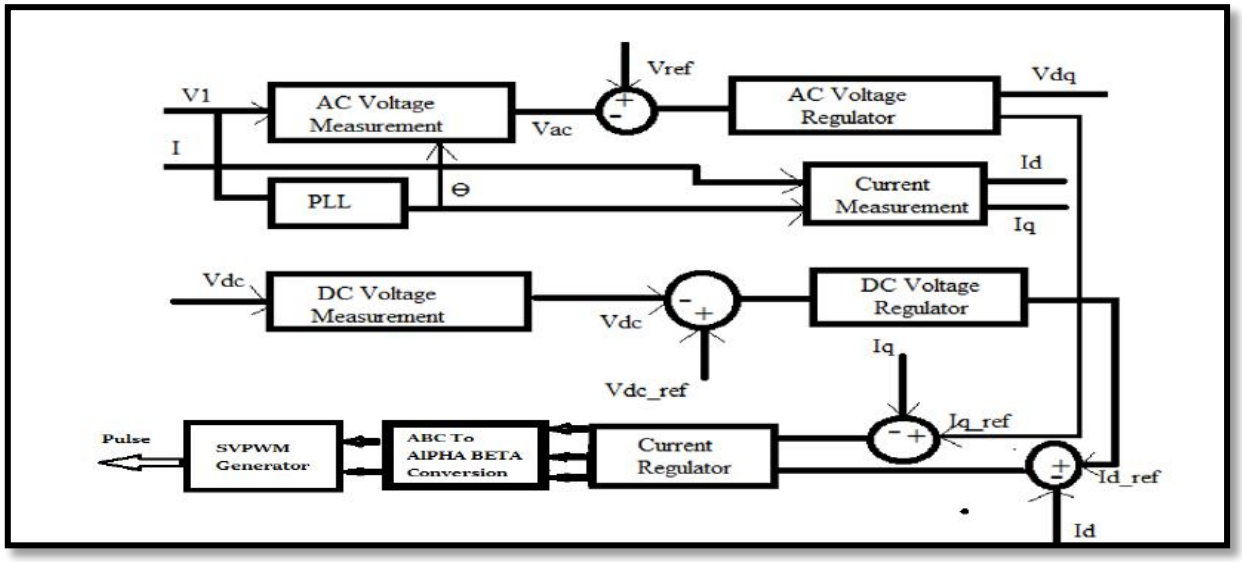

Figure-2.4 Block diagram of D-STATCOM control strategy with SRF theory

The output of the AC voltage regulator is the reference current Iq_ref and the output of the DC voltage regulator is the reference current Id_ref for the current regulator. The first PI controller is responsible for controlling the terminal voltage through the reactive power exchange with the AC network. This PI regulator provides the reactive current Iq_ref. and second PI controller is responsible to maintain DC voltage constant through a small active power exchange with the AC system compensating the active power losses in the transformer and inverter. The current PI controller controls the magnitude and phase of the voltages generated by the Voltage source inverters from the reference currents (Id_ref, Iq_ref) produced respectively by the DC voltage regulator and AC voltage regulator (in voltage control mode). The Iq reference comes from the outer voltage regulation loop and Id reference comes from the DC-link voltage regulator. Output of current regulator is then converted into alpha beta component through alpha beta conversion. Then with the help of SVPWM generator gate pulses are generated for switching devices of VSI.

3. SIMULATION AND RESULT:

A) DVR

The main objective of the control is to maintain the PCC voltage at a nominal value by reacting fast to the fluctuation of the voltage. The Simulink model for the system is shown in Figure-3.1, while the parameter values used for simulation are given in Table 3.1. For checking the performance of the DVR with its controller in mitigating sag and swell which produces at a 415V distribution Feeder, the following approach is selected.

In the initial Stage, the system is simulated without connecting the DVR. The Voltage Sag and Swell are produced in the programmable Voltage source. Figure-3.2 shows the performance of the system under voltage sag and voltage swell conditions. At 0.2 s, a Voltage sag in supply voltage is produced for five cycles or 0.1 s time interval and at 0.4 s, a swell in the supply voltages is produced for o.1 s time interval or five cycles.

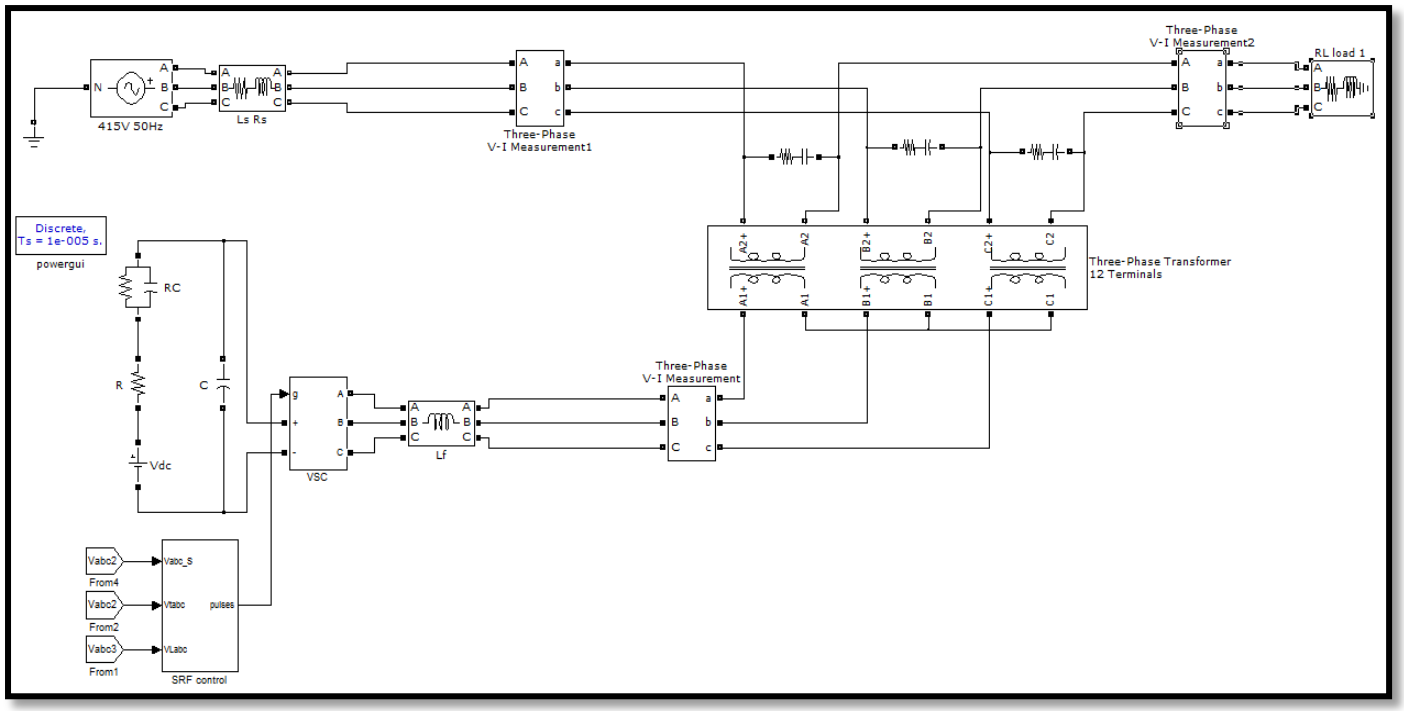

Figure-3.1 Simulink model of DVR

PCC voltages Vs, load voltages Vl, DVR voltages Vdvr, magnitude of load voltage VL and PCC voltage Vs are shown in Figure-3.2. At 0.2 s, the supply voltage is distorted, sagged and continued for five cycles. The load voltage is maintained sinusoidal and near to 1pu by injecting appropriate compensation voltage by the DVR. At 0.4 s, the supply voltage is distorted, swelled and continued for five cycles. The load voltage is maintained sinusoidal and near to 1pu by injecting proper compensation voltage by the DVR. So we can see that DVR mitigate voltage sag and swell very effectively from the system during 0.2 to 0.3 s and 0.4 to 0.5 s respectively.

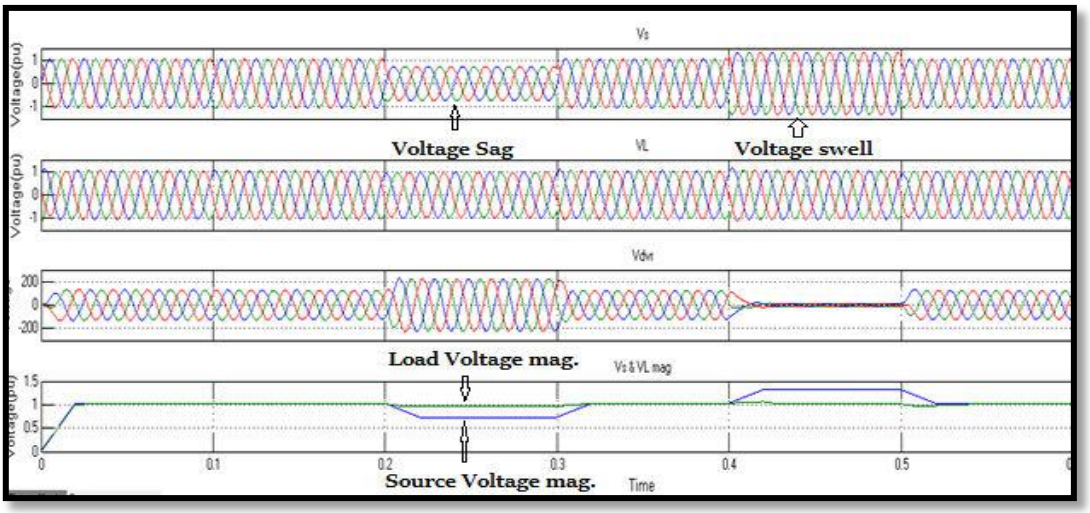

Figure-3.2 PCC or Source Voltage, compensated Load Voltage with DVR, injected voltage by DVR, Source voltage mag. and compensated Load Voltage mag.

B) Parameter Value used in Simulation for DVR

AC Line Voltage	415v,50Hz
Line Impedance	Ls = 3 mH, Rs = 0.01 Ω
Linear Load	10 kva, 0.80 pf, lag
DC Voltage of DVR	300 V
AC Inductor	2.0 mH
DC Bus volt. PI controller	Kp = 0.5, Ki = 0.35
AC Bus volt. PI controller	Kp = 0.1 , Ki = 0.5
Series Transformer	10 kva, 200V/300V

Table-3.1 System parameter

C) D-STATCOM

The main aim of the control is to maintain the PCC voltage at a nominal value by reacting fast to the fluctuation of the voltage. The Simulink model for the system with D-STATCOM is shown in Figure-3.3, while the parameter values used for simulation are given in Table-3.2. For testing the viability of the D-STATCOM with its controller in mitigating sag and swell which occurs at a 415V distribution Feeder, the following approach was adopted.

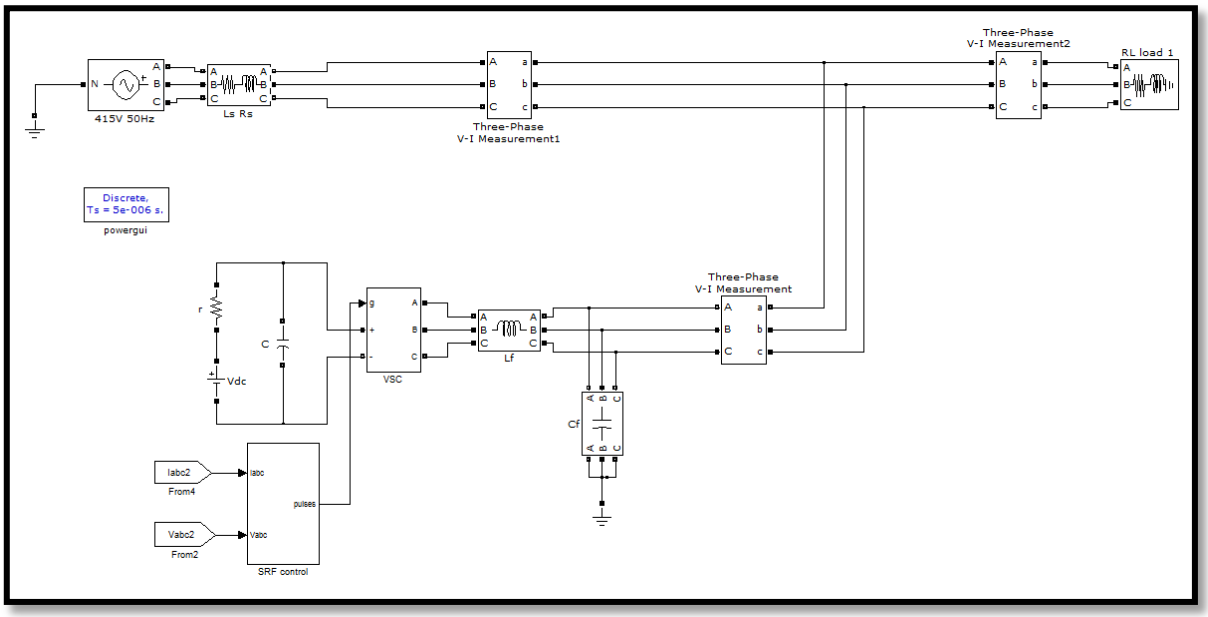

Figure 3.3 Simulink model of D-STATCOM

Same as for DVR to check the performance of D-STATCOM the Voltage Sag and Swell are produced in the programmable Voltage source. Figure-3.4 shows the operation of the system under voltage sag and voltage swell conditions. At 0.2 s, a voltage sag in supply voltage is created for five cycles or 0.1 s time interval, and at 0.4 s, a voltage swell in the supply voltages is created for five cycles.

Load Voltage without D-STATCOM, load voltages with D-STATCOM, injected current by D-STATCOM, amplitude of load voltage VL with and without D-STATCOM are depicted in Fig. 8. At 0.2 s, the supply voltage is distorted, sagged and continued for five cycles. The load voltage is maintained sinusoidal by injecting suitable compensated current by the D-STATCOM. At 0.4 s, the Load voltage without D-STATCOM is distorted, swelled and continued for o.1 s time duration. The load voltage is maintained sinusoidal and near to 1pu by injecting suitable compensated current by the D-STATCOM. Also D-STATCOM maintain Load Voltage near 1pu. so we can see that D-STATCOM compensate voltage sag and swell very effectively from the system during 0.2 to 0.3 s and 0.4 to 0.5 s respectively.

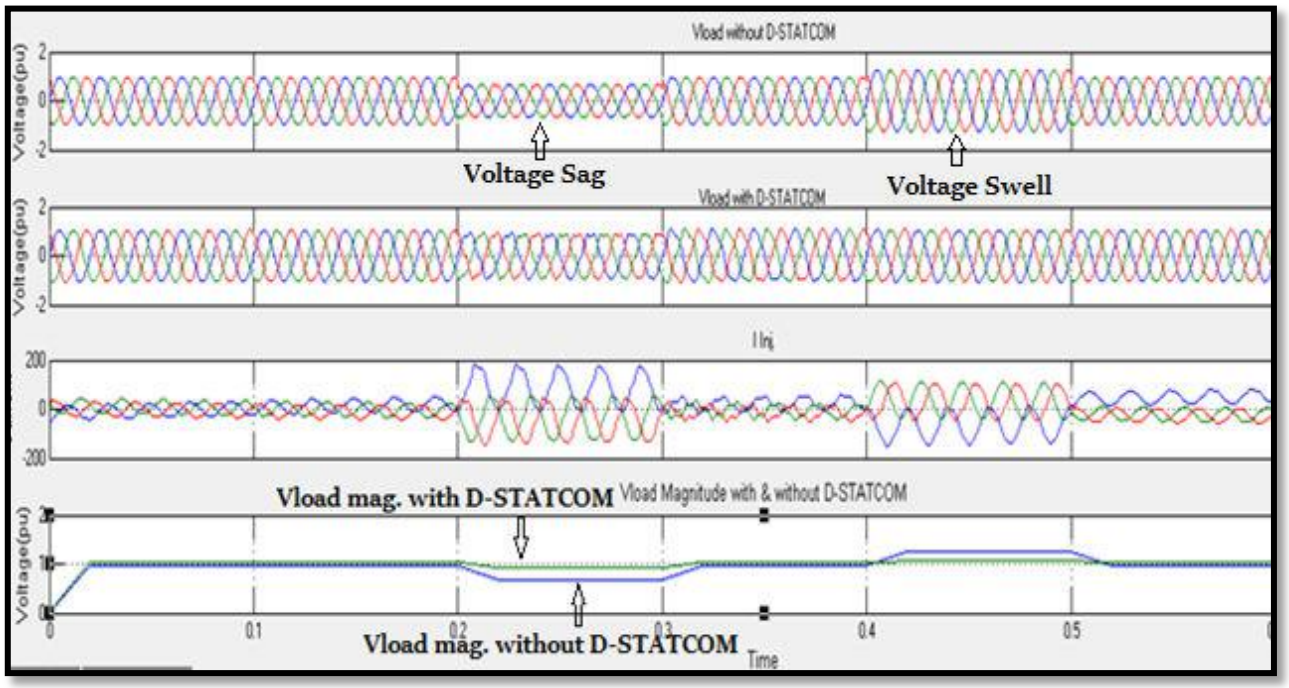

Figure-3.4 Vload without D-STATCOM, Vload with D-STATCOM, Injected current by D-STATCOM, Vload mag. with & without D-STATCOM

D) Parameter Value used in simulation for D-STATCOM

AC Line Voltage	415v,50Hz
Line Impedance	Ls = 3 mH, Rs = 0.01 Ω
Linear Load	10 kva, 0.80 pf, lag
DC Bus volt. PI controller	Kp = 10, Ki = 0.05
AC Bus volt. PI controller 1	Kp = 50 , Ki = 120

Table 3.2

4. CONCLUSION:

In this paper, Modelling and simulation of DVR and D-STATCOM with SRF Control theory and SVPWM based pulse generation technique has been developed by using matlab/simulink. The simulation result clearly shows that the DVR and D-STATCOM compensates voltage sag and swell effectively and provides excellent voltage regulation.

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