Role of DVR and DSTATOM FACTS devices in voltage SAG and swell mitigation

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Abstract: Power Quality problem in a system leads to various disturbances such as voltage fluctuations, transients and waveform distortions those results in a mis operation or a failure of end user equipment. There are different types of custom power devices like Distribution Static Compensator (D-STATCOM) and Dynamic Voltage Restorer (DVR) which can effectively use for mitigation of different type of power quality problems. This paper describes the technique of correcting the supply voltage sag distributed system and also describes performance comparison are presented between DVR and DSTATCOM to know how both the devices successfully been applied to power system for regulating system voltage effectively. DSTATCOM and DVR both of them based on VSI principle. A DVR is a series compensation device which injects a voltage in series with system and a DSTATCOM is a shunt compensation device which injects a current into the system to correct the power quality problems. This paper presents a power system operation with PI controller with abc to dq0 convertor approach. In this paper we represent the voltage sag and swell problem simulation results.

I. INTRODUCTION

Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the ideal magnitude level and frequency but in practical power systems especially the distribution systems have numerous nonlinear loads which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing many power quality problems like voltage sag, voltage swell, distortion in waveform, harmonics, etc. Power quality phenomenon or power quality disturbance can be defined as the deviation of the voltage and the current from its ideal waveform. Faults at either the transmission or distribution level may cause voltage sag or swell in the entire system or a large part of it. Also under heavy load conditions, a significant voltage drop may occur in the system. Voltage sag and swell can cause sensitive equipment to fail, shutdown and create a large current unbalance. Two types of VSI-based compensators have been commonly used for mitigation of the voltage sags and swells and regulating the load voltage. The power provided by generating station must be improved for delivering pure and clean power to the end users. For delivering a good quality of power Flexible AC Transmission System (FACTS) devices like static synchronous series compensator (SSSC), static synchronous compensator (STATCOM), interline power flow controller (IPFC), unified power flow controller (UPFC) etc. were used. Generally FACTS devices are modified to be used in electrical distribution system known as Custom Power Devices. Some of the widely used custom power devices are Distribution Static Synchronous Compensator (DSTATCOM), Dynamic Voltage Restorer (DVR), Active filter (AF), Unified power quality conditioner (UPQC). These devices are used to reduce power quality problems. DVR is one of the most efficient and effective custom power devices due to its fast response, lower cost and smaller size. Control Unit is the main part of the DVR and D-STATCOM. The function of the control unit is to detect the voltage differences (sag or swell) in the electrical distribution system and generate gate signal to operate the Voltage Source Converter (VSC) for supplying required amount of compensating voltage. Proportional Integral (PI) Controller is used to generate control signal and a PWM Generator is used for generating switching signal, which control the output of DSTATCOM & DVR. PI controller is used as feedback controller operates with a weighted sum of error signal and generates the desired signal for the PWM generator. The first one is a shunt device, which is commonly called DSTATCOM and the second one is a series device, which is commonly called DVR. These compensators can address other PQ issues, such as load voltage harmonics, source current harmonics, unbalancing, etc., under steady state to obtain more benefits out of their continuous operation. There have been a variety of control strategies proposed for load voltage control using the aforementioned two devices. For DSTATCOM this includes reactive power compensation and voltage control mode operation of DSTATCOM. For DVR, it includes open-loop and closed-loop load voltage-control methods.

II. DYNAMIC VOLTAGE RESTORER (DVR)

DVR is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and critical load feeder as shown in Figure-2. Usually the connection is made via a transformer, but configurations with direct connection via power electronics also exist. The resulting voltage at the load bus bar equals to the sum of the grid voltage and the injected voltage from the DVR. The converter generates the reactive power needed while the active power is taken from the energy storage. The energy storage can be different depending on the needs of compensating. The DVR often has limitations on the depth and duration of the voltage dip that can compensate.

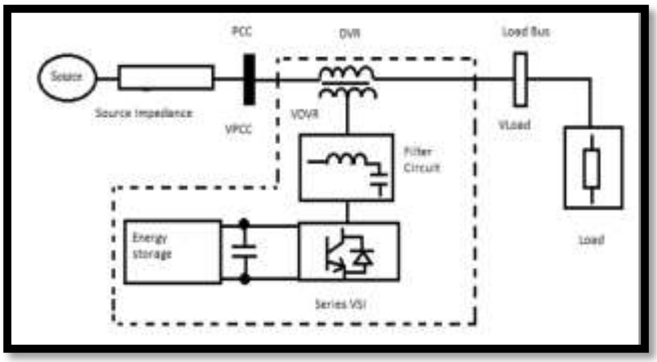

Figure 1 DVR series connected topology

The compensation for voltage sags 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 fundamental frequency, compensation is achieved by injecting reactive power and the DVR itself is capable of generating the reactive power because DVR is self-supported with dc bus. But, DVR voltage can be kept in quadrature with the current only up to a certain value of voltage sag and beyond which the quadrature relationship cannot be maintained 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. The control technique adopted should consider the limitations such as the voltage injection capability (inverter and transformer rating) and optimization of the size of energy storage.

III. DISTRIBUTION STATIC COMPENSATOR (D-STATCOM)

A Distribution-STATCOM consists of a two-level VSI, a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer as shown in Figure-2. The VSI converts the dc voltage across the storage device into a set of three-phase ac output voltages. 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 DSTATCOM output voltages allows effective control of active and reactive power exchanges between the DSTATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power.

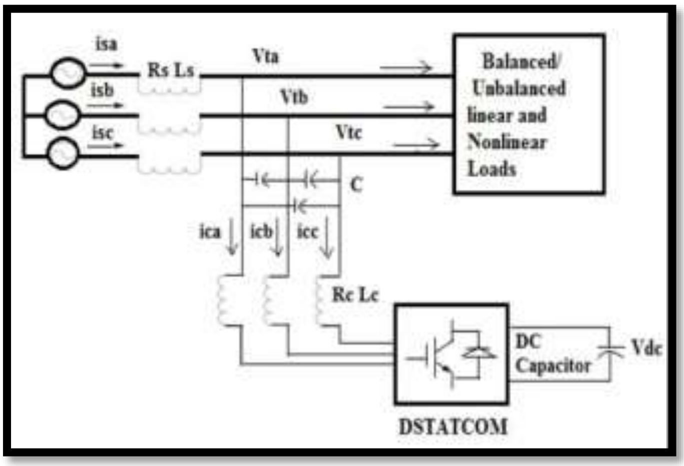

Fig-2: Schematic Diagram of DSTATCOM

The system scheme of DSTATCOM is shown in Figure 3. These are briefly described as follows:

A. *Isolation transformer*: It connects the DSTATCOM to the distribution network and its main purpose is to maintain isolation between the DSTATCOM circuit and the distribution network.

B. *Voltage source converter*: A voltage source converter consists of a storage device and devices of switching, generating a sinusoidal voltage at any required frequency, magnitude and phase angle. In the DSTATCOM application, this temporarily replaces the supply voltage or generates the part of the supply voltage which is absent and injects the compensating current into the distribution network depending upon the amount of unbalance or distortion. In this work, an IGBT is used as the switching device.

C. *DC charging unit*: This unit charges the energy source after a compensation event and also maintains the dc link voltage at the nominal value.

D. *Harmonic filters*: The main function of harmonic filter is to filter out the unwanted harmonics generated by the VSC and hence, keep the harmonic level within the permissible limit. Energy storage unit: Energy storage units like flywheels, batteries, superconducting magnetic energy Storage (SMES) and super capacitors store energy. It serves as the real power requirements of the system when DSTATCOM is used for compensation [3]. In case, no energy source is connected to the DC bus, then the average power exchanged by the DSTATCOM is zero assuming the switches, reactors, and capacitors to be ideal. Figure 3 represents the schematic scheme of DSTATCOM in which the shunt injected current Ish corrects the voltage sag by adjusting the voltage drop across the system impedance Zth and value of Ish can be controlled by altering the output voltage of the converter.

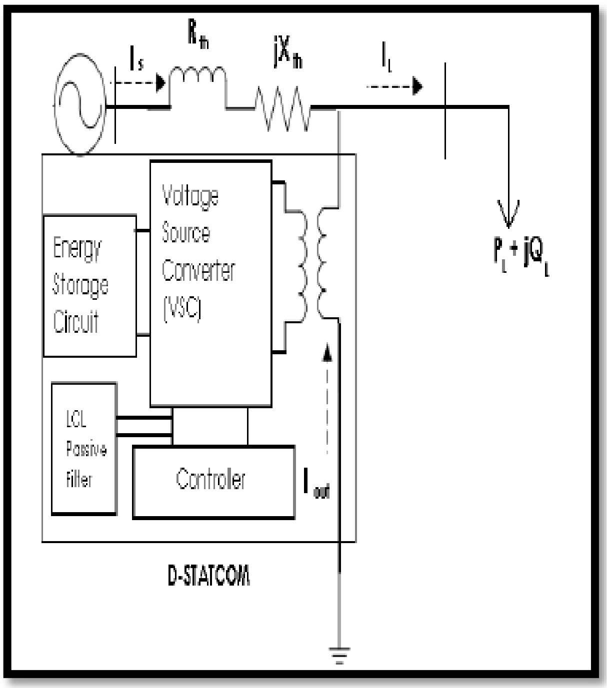

Fig 3: System scheme for d-statcom

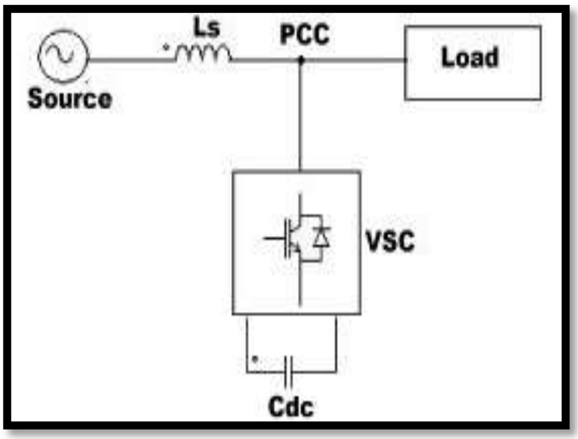

Fig 4: Basic structure of d-statcom

The effectiveness of the DSTATCOM in correcting the fault depends on the value of Zth or fault level of the load bus. When the shunt supplied current Ish is set in quadrature with VL, the desired correction of voltage can be achieved without injecting any active power into the system. Alternatively, when the value of Ish is decreased, the same correction of voltage can be achieved with minimum apparent power injection into the system.

The contribution of the DSTATCOM to the load bus voltage equals the injected current times the impedance seen from the device also, that is the source impedance in parallel with the load impedance. The ability of the STATCOM to compensate the voltage dip is limited by this available parallel impedance. It helps to reduce the voltage fluctuations at the PCC (point of common coupling). Voltage dips can be mitigated by DSTATCOM, which is based on a shunt connected voltage source converter. VSC with pulse-width modulation (PWM) offers fast and reliable control for voltage dips mitigation.

IV. CONTROLLER ALGORITHM

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 VSI switching strategy is based on a PWM technique which offers simplicity and good response also PWM is used to vary the amplitude and the phase angle of the injected voltage. Since custom power is a relatively low-power application, PWM methods offer a more flexible option than the Fundamental Frequency Switching (FFS) methods favoured in FACTS applications. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses.

There are several ways to control the DVR. Different parts of the controls include.

- identify the occurrence of sag / swell in the system.
- Calculate the offset voltage.
- Pulse output of the PWM inverter fire and stop it when the problem is resolved.

In normal and synchronous conditions, the voltage is a constant, d-voltage is one pu and q-voltage unit is zero pu, but in normal circumstances can be a change. The d-voltage and q-voltage with the interest that needed for best performance is compared then the d and q error is generated. Thus the d-q contents of error become abc content. Choose to provide dq0 method, give information about the size (d), phase shift (q) with start and end voltage fallen leaves. Load voltages base on the Park transformations, and according to the following equation becomes.

Vd = 2/3*[Va*sin(wt) + Vb*sin(wt-2pi/3) + Vc*sin(wt+2pi/3)]

Vq = 2/3*[Va*cos(wt) + Vb*cos(wt-2pi/3) + Vc*cos(wt+2pi/3)]

V0 = 1/3*[Va + Vb + Vc]

And according inverse Parks Transformation

Va = [Vd*(wt) + Vq*cos(wt) + Vo]

Vb = [Vd*sin(wt-2pi/3) + Vq*cos(wt-2pi/3) + Vo)

Vc = [Vd*sin(wt+2pi/3) + Vq*cos(wt+2pi/3) + Vo)

where w= rotation speed (rad/s) of the rotating frame.

Main voltages used as a Phase lock loop (PLL) to generate sine-wave single phase. The contents are used for production abc three phases PWM pulses. Control technique employed throughout this paper is shown below in Figure-5.

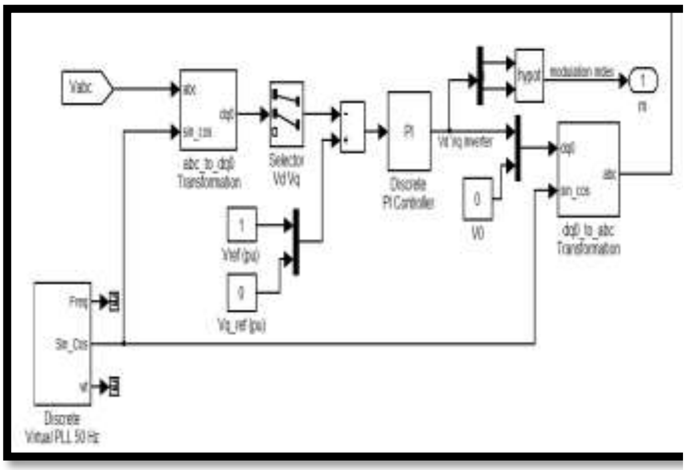

Figure 5 Schematic diagrams of control block

V. Simulation & Results

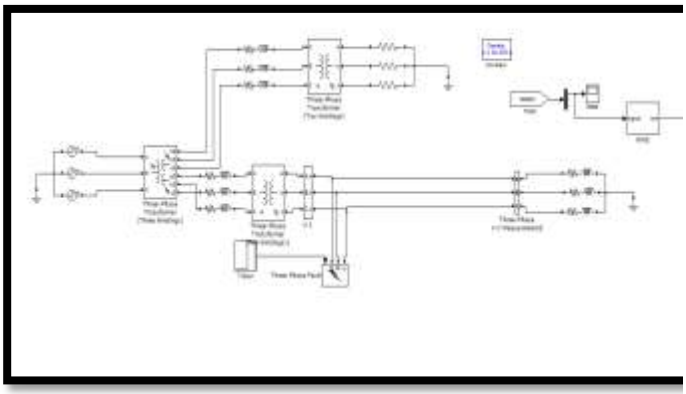

Fig-6 Voltage Sag condition in 3-phase system

As shown above in fig-6 there is 3-phase fault is created in the three phase system which creates voltage sag problem in this system. The three phase fault is operated and controlled through external timer signal which is also shown in the fig. The simulation results of voltage sag condition are shown below:-

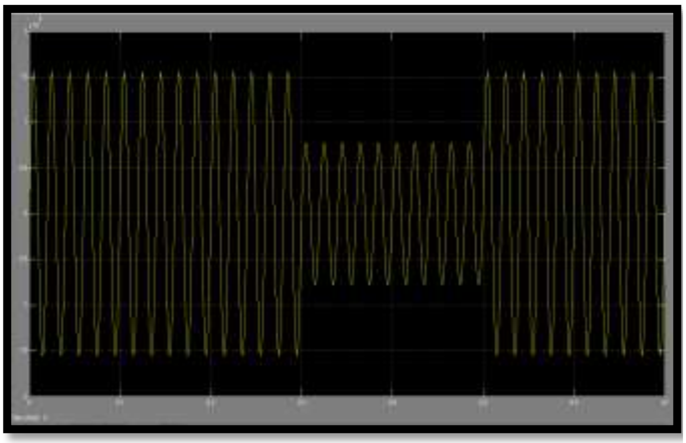

Fig-7 Voltage Sag condition

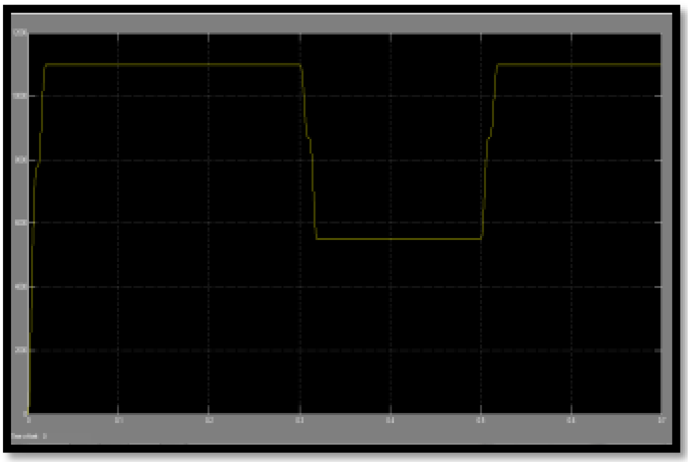

Fig-8 Voltage Sag R.M.S value

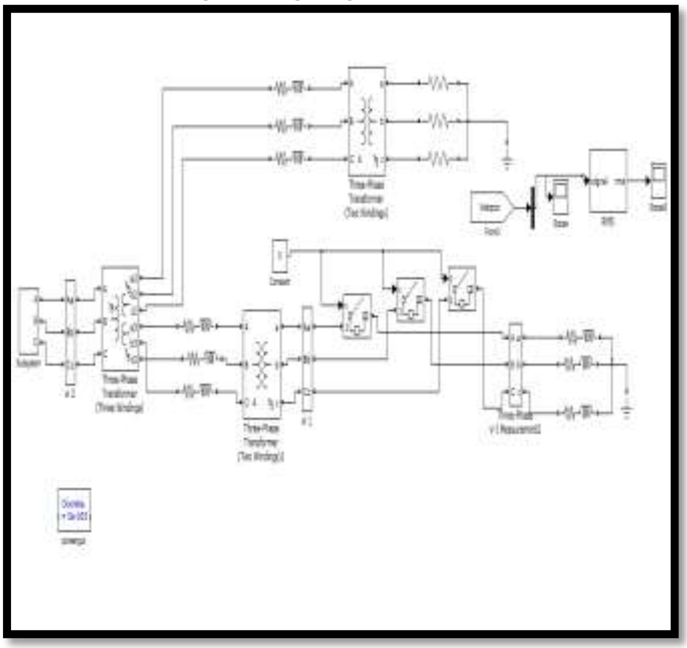

Fig 9- Voltage Sag condition in 3-phase system

Now as shown above in fig-9 there is delay will be provided using external timer signal in the three phase system which creates voltage swell problem in this system. The three phase power supply is operated and controlled through external timer signal which is also shown in the fig. The simulation results of voltage sag condition are shown below:-

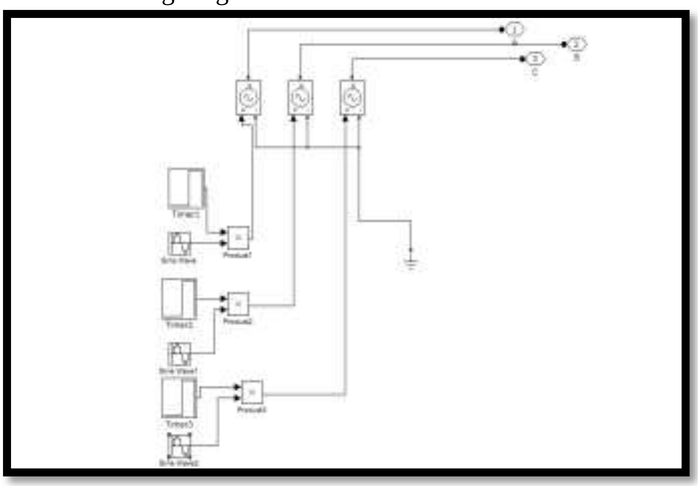

Fig 10- Three phase power supply with external timer signal control

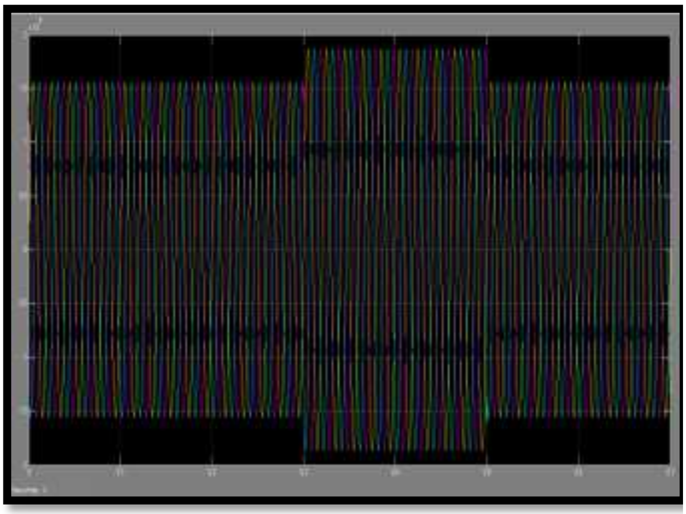

Fig-11 Voltage Swell condition

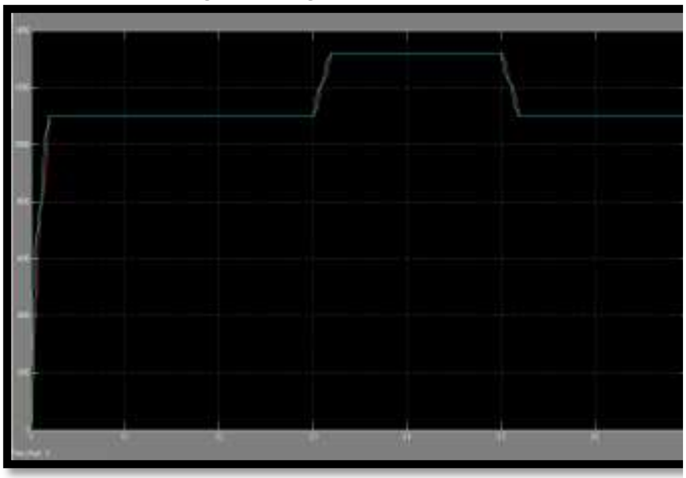

Fig-12 Voltage Sag R.M.S value

VI. CONCLUSION

This paper has presented the power quality problems such as voltage dips, swells and interruptions, and mitigation techniques of custom power electronic devices DVR, D-STATCOM. The design and applications of DVR and D-STATCOM for voltage sags, interruptions and swells, and comprehensive results are presented. A new PWM-based control scheme has been implemented to control the electronic valves in the VSI used in the DSTATCOM and DVR. As opposed to fundamental frequency switching schemes already available in the MATLAB/SIMULINK, this PWM control scheme only requires voltage measurements. This characteristic makes it ideally suitable for low-voltage custom power applications. The simulations and results shows the voltage sag and swell problems occur in the three phase system.

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