Power Quality Enhancement using DVR and DSTATCOM

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Abstract— This paper addresses the voltage sag of the power quality issue and Dynamic Voltage Restorer (DVR), Distribution Static Compensator (D-STATCOM) are used for mitigation. These devices are Voltage Source Converter (VSC) based equipment aimed at enhancement voltage and quality of power during voltage disturbances. They are controlled by sinusoidal PWM technique. The modeling of DVR, D-STATCOM are presented, simulations and analysis are carried out in SIMULINK . The results shows both the devices are capable of mitigating voltage sag effectively. The durability and accuracy of chosen control scheme in system response to the voltage sag due to load variations has been proved in mitigation.

Index Terms— DVR,D-STATCOM, PWM technique, VSC, voltage sag.

I. INTRODUCTION

At present scenario, power quality disturbances become wide platform which makes many researchers interested to find the best solutions to solve it. Power quality plays an important role in power system for industrial, commercial and residential applications today. Basically there are two techniques for power quality improvement .The first one is load conditioning approach, and the second approach is to connect the compensation devices in series or shunt for low or medium voltage distribution system .There are many issues which affects the quality of power such as power surges ,high voltage spikes, transients frequency variation, brownouts, blackouts. The voltage problem is mainly considered from voltage sag condition over current caused by short circuit or fault somewhere in the system. Preventing voltage sag condition, many research works have been implemented. Voltage sag is widely recognized as one of the most important power quality disturbances [1]. The voltage sag (dip) is defined as a temporary reduction of the voltage at a point of the electrical system below a threshold [2]. According to IEEE, defines voltage sags as an rms variation with a magnitude between 10% and 90% of nominal voltage or current and duration between 0.5cycles and one minute [3].

In recent years, a wide range of very flexible controllers are emerging for power system applications. Among these, the Dynamic Voltage Restorer (DVR), and the distribution Static Compensator (D-STATCOM), both of them based on the VSC principle has been used in this paper to perform the modeling and analysis of such controllers for a wide range of operating conditions [4]. Implementing the PWM control scheme reported in this paper for the D-STATCOM and DVR. It depends only on voltage measurements for its operation, i.e., it never consider reactive power measurements. Effects of load variation and system faults on the sensitive loads are investigated and the control of voltage disturbances are analysed and simulated.

II. VSC -BASED DEVICES

This description presents an overview of the VSC-based devices addressed in this paper.

The name voltage source converter explains those network connections whereas they are used to convert or transfer one type of voltage source to another. Voltage source converter means which device converts AC voltage source into DC voltage source and vice versa. Ultimately there are two categories of voltage converter, namely they are voltage inverter and voltage rectifier. As the name suggests, a voltage inverter is used to convert DC voltage source into AC voltage source. And voltage rectifier is used to convert DC voltage source into AC voltage source. Whereas coming to the rectifiers there are two types of rectifier circuit, one is half wave rectifier and another is full wave rectifier.

A. DVR

1) BASIC CONFIGURATION

DVR is a series connected FACTS device or it is voltage

Stability device which is able to protect a susceptible load against the abnormal and transient disturbances in power system. Basically the DVR consists of two types of parts, one is power circuit and another one is control scheme. Control part is used to derive the parameters as like magnitude, frequency, phase shift, etc. of the control signal that has to be injected by the DVR [5]. Due to control signal, the injected voltage is generated using switching in power circuit. As shown in Fig. 1, the power circuit of DVR consists of

a) An injection transformer,

b) AC harmonic filter,

c) VSC

d) DC energy storage unit

The main function of a DVR is the protection of sensitive

Load from voltage sags coming from the system surroundings.

Therefore as shown in Fig 1, the DVR is positioned near to the sensitive loads. If any fault occurs on other lines, DVR inserts series voltage VDVR and compensates load voltage to normal value as existed before.

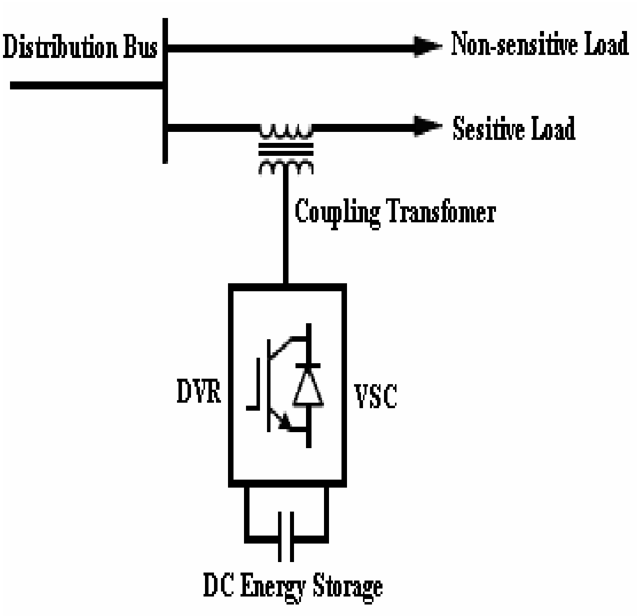


Fig. 1 Schematic diagram of DVR

2) OPERATION and CONTROL

The momentary peaks of the three injected phase voltages are controlled such as to eliminate any adverse effects of a bus fault to the load voltage VL. This means that any differential voltages caused by disturbances in the ac feeder will be compensated by a suitable equivalent voltage generated by the converter and injected on the medium voltage level through the coupling transformer.

There are two modes of operation in case of DVR which are: and boost mode and standby mode. In standby mode (VDVR=0), the coupling transformer's low voltage winding is shorted through the converter. No switching of semiconductors occurs in this mode of operation, because the individual converter legs are triggered to establish a short circuit path for the transformer connection. Therefore, only the comparatively low conduction losses. The DVR will be most of the time in this mode.

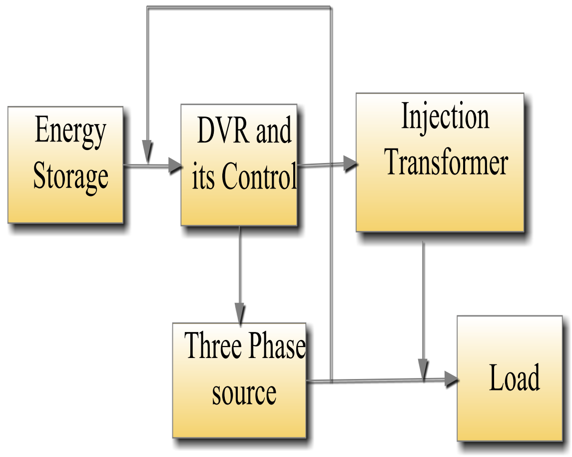


Fig. 2 Block model of simulation for DVR

In boost mode (VDVR>0), the DVR is injecting a compensation voltage through the booster transformer due to a detection of a supply voltage disturbance [4]. The series injected voltage of the DVR can be written as

$$Vinj = Vload + Vs \qquad (1)$$

In the control scheme the actual voltage and the desired value are measured. These voltages are then converted in dq0 with relating to Parks transformation [6]. Initially, convert the voltage from a-b-c reference frame to d-q-o reference. To avoid complexity zero phase sequence components are ignored. . The control is completely based on the comparison of a voltage reference and the measured terminal voltage (V_a, V_b, V_c).

$$\begin{bmatrix} V_d \\ V_q \\ V_0 \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \cos(\theta - \frac{2\pi}{3}) & 1 \\ -\sin(\theta) & -\sin(\theta - \frac{2\pi}{3}) & 1 \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \qquad (2)$$

The above equation defines the transformation from three phase system a, b, c to dq_0 stationary frame. In this transformation, phase A is taken along the d-axis that is in drops below 90% of the reference value whereas voltage swells is detected when supply voltage increases up to 25% of the reference value. The error signal is used as a modulation signal that allows generating a commutation process pattern for the power switches (IGBT's) based on which the voltage source converter works. The commutation process pattern is generated by means of the Sinusoidal Pulse Width Modulation technique (SPWM) .voltages are controlled through the modulation. The PLL circuit is used to generate a unit sinusoidal wave in phase with mains voltage.

B. D-STATCOM

Commonly a STATCOM is connected to support electricity networks which are suffering with poor power factor and poor voltage regulation. But there are other uses; the most common use is for stabilizing the system voltage. A STATCOM is formed by a voltage source converter (VSC), along with the voltage source followed by a reactor. The voltage source is created from a DC capacitor as nothing but a storage device and therefore a STATCOM has very little active power flexibility. But its active power flexibility can be increased if a suitable energy storage device is connected across the DC capacitor. The reactive power at the ends of the STATCOM depends on the voltage source amplitude. For example, if the terminal voltage of the VSC is higher than the AC voltage at the point of connection, the STATCOM produces reactive current; on the other hand, when the voltage source amplitude is lower than the that of AC voltage, it absorbs reactive power.

1) BASIC CONFIGURATION

The D-STATCOM configuration mainly consists of a VSC, a dc energy storage device, a coupling transformer connected in shunt with the ac system, and associated control circuits. Fig. 3 shows the basic configuration of D-STATCOM. The D-STATCOM is a powerful controller that is commonly used for voltage sags mitigation at the point of connection. The D-STATCOM employs the same blocks as DVR, but in this

Application, the coupling transformer is connected in shunt with the ac system.

The VSC 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 D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the system.

The VSC connected in shunt with the ac system provides

Three quite distinct purposes:

- Voltage regulation and compensation of reactive power.
- Power factor correction.
- Elimination of current harmonics.

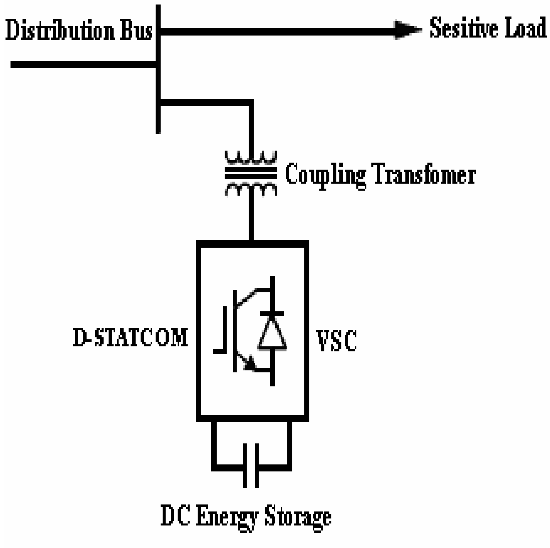


Fig. 3 Basic configuration of D-STATCOM

2) OPERATION and CONTROL

The D-STATCOM function is to regulate the bus voltage by absorbing or generating reactive power to the network, like a thyristor static compensator.

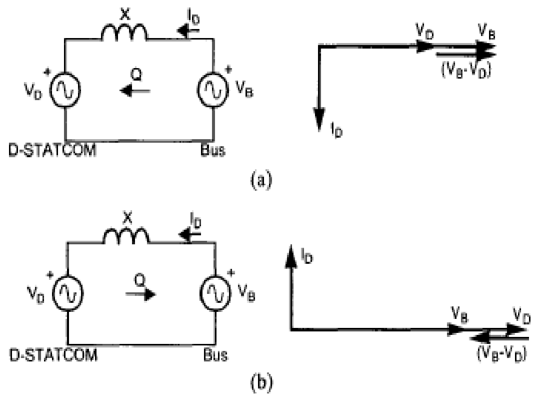


Fig. 4 a) Inductive Operation b) Capacitive Operation

The reactive power transfer is done through the leakage reactance of the coupling transformer by using a secondary voltage in phase with the primary voltage.This voltage is provided by a voltage-source PWM inverter. The D-STATCOM operation is illustrated by the Phasor diagrams shown in Figure 5. When the secondary voltage (VD) is lower than the bus voltage (VB), the D-

STATCOM acts like an inductance absorbing reactive power from the bus.

When the secondary voltage (VD) is higher than the bus voltage (VB), the D-STATCOM acts like a capacitor generating reactive power to the bus. In steady state, due to inverter losses the bus voltage always leads the inverter voltage by a small angle to supply a small active power. The error signal is obtained by comparing the per unit value of the voltage with a constant 1. The reference sinusoidal signals required for the generation of PWM pulses is obtained by using a PI controller in conjunction with the error signal obtained. The PWM techniques have several advantages compared to other techniques.

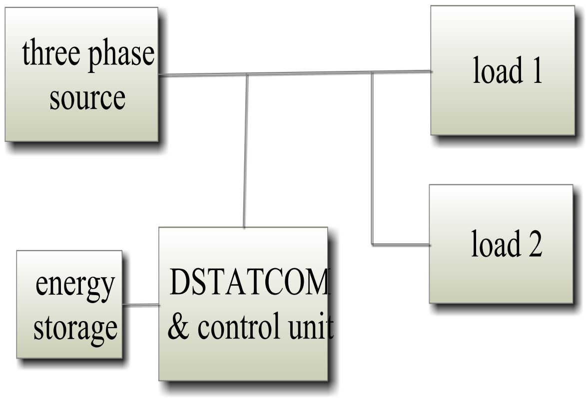


Fig. 5 Block model of simulation for D-STATCOM

III. SINUSOIDAL PWM CONTROL SCHEME

This part of description address the PWM-based control scheme with related to the DVR and D-STATCOM The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, at any disturbances. The control system only measures the rms

voltage at the load point i.e., no reactive power measurements

are required. The VSC switching pattern is based on a sinusoidal PWM technique which provides simplicity and quite good enough response. Because distribution is a relatively low-power application, PWM methods offer a more flexible option than the fundamental frequency switching 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.

IV. STUDY CASE AND SIMULATION RESULTS

This section is divided into two parts. Simulations relating to the DVR are presented first. This is followed by simulations carried out for the D-STATCOM.

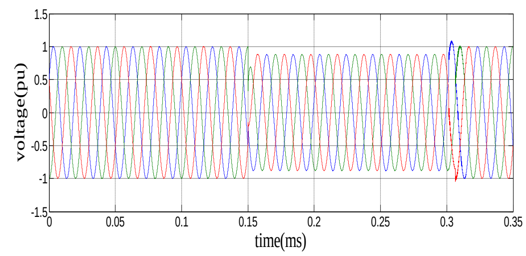
Table. 1 System parameters used for simulation

Main supply voltage	200V
Line impedance	L_S = 0.5Mh, R_S = 0.1Ω
Transformer turns ratio	1:1
DC bus voltage	100V
Line frequency	60Hz
Load active power	3000W

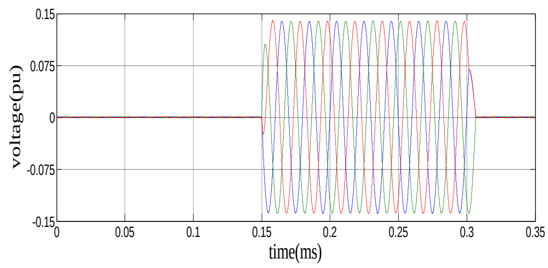
A. DVR SIMULATION RESULTS

The first simulation of three phase voltage sag is simulated and a 13% three-phase voltage sag occurring at the utility grid.

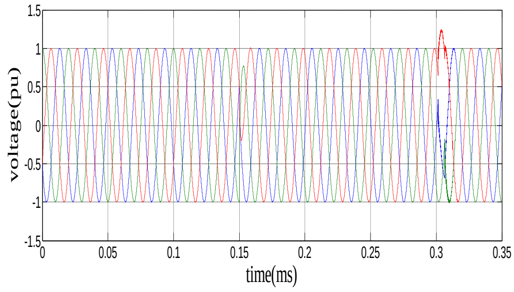
In Fig. 6(a) also shows a 13% voltage sag initiated at 0.15ms and it is kept until 0.3ms, with total voltage sag duration of 0.15s. Fig. 6(b) and fig. 6(c) show the voltage injected by the DVR and the corresponding load voltage with compensation.



(a)



(b)



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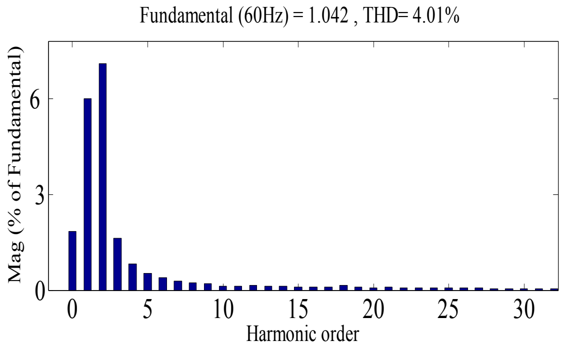


(d)

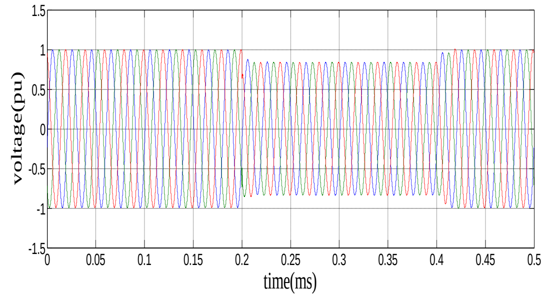
Fig. 6(a) Supply voltage (b) injected voltage (c)load voltage (d) THD of Load Voltage after Compensation

The sag mitigation is performed with a smooth, stable, and rapid DVR response; no transient overshoots are observed when the DVR comes in and out of operation. It should be noted that in the DVR, the dc voltage is supplied by a dc source as opposed to the dc capacitor used in the D-STATCOM. Several simulations were carried out to assess the performance of the DVR. As expected, the DVR required a higher rating of dc storage device to provide appropriate levels of sag mitigation when the fault was applied in point A. This is due to the short electrical distance between the point in fault and the DVR coupling transformer. Clearly, the controller must be designed to satisfy the most severe case, where the voltage sag is due to a fault quite close to the sensitive load.

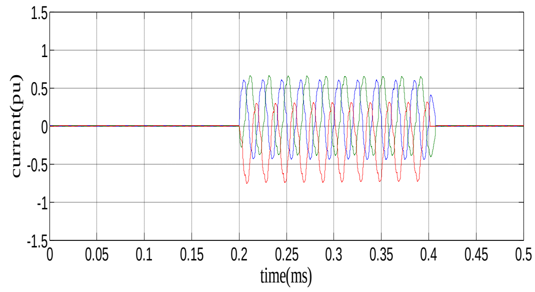
B. D-STATCOM SIMULATION RESULTS

In one of the feeders, a sudden load is included from the period 0.2 to 0.4ms. This introduction of a sudden load produces a reduction in voltage causing voltage sag.

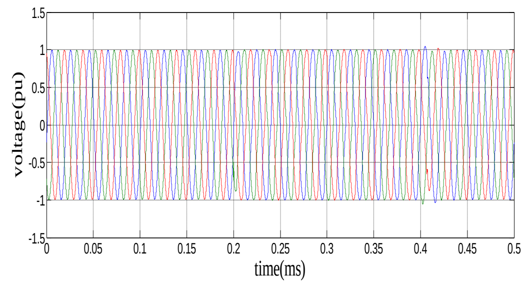
Fig. 7(a) shows the rms voltage at the load point for the case when the system operates without D-STATCOM. Similarly, a new set of simulations was carried out but now with the DSTATCOM connected to the system. The results are shown in Fig. 7(c), where the very effective voltage regulation provided by the D-STATCOM can be clearly appreciated. Magnitude of these transients is kept very small with respect to the reference voltage.



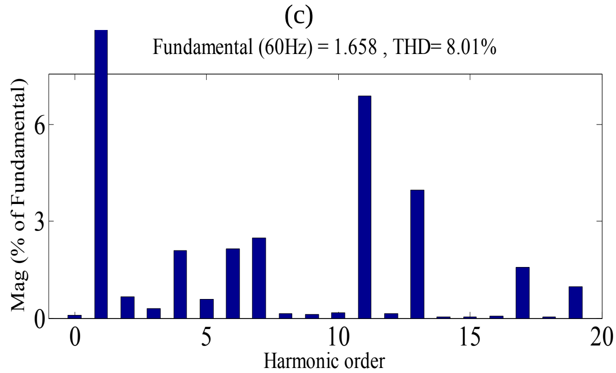
(a)



(b)



(c)



(d)

Fig. 7(a) generated voltage sag (b)injected current (c) restored voltage using D-STATCOM (d) THD of Load Voltage after Compensation

V. CONCLUSIONS

This paper has presented simulation models of VSC based equipment DVR and D-STATCOM and their characteristics were studied in voltage quality enhancement. A new SPWM-based control scheme has been implemented to control the power electronic valves in the VSC used in the DVR and D-STATCOM, this PWM control scheme only requires voltage measurements. This makes it tremendously suitable for low-voltage applications at consumer point. The control scheme has been examined at a wide range of operating conditions, and it was observed to be very robust in every case. The carried simulation results shows DVR, D-STATCOM are efficient at voltage regulation by mitigating voltage sag.

The dc storage device and coupling transformer characteristics are the two factors which ensure the capability of voltage quality enhancing and will decide the extent value of mitigation that can be expected from DVR or D-STATCOM. DVR acts slowly but is good in reducing the harmonic content.

ACKNOWLEDGMENT

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