SIMULATION AND MODELING OF DYNAMIC VOLTAGE RESTORER FOR COMPENSATION OF VOLTAGE SAG AND VOLTAGE SWELL

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Abstract: *Power Quality problem in a system leads to various disturbances such as voltage fluctuations, transients and waveform distortions that 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 and swell distributed system. DVR based on VSI principle. A DVR is a series compensation device which injects a voltage in series with 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. Results are presented to assess the performance of devices as a potential custom power solution. Improve dynamic voltage control and thus increase system load ability. This paper presents modeling and simulation of DVR in MATLAB/Simulink.*

Key Words: Voltage sag, Voltage swells, Park transformation, DVR, MATLAB/Simulink.

1. INTRODUCTION

The electric power system is considered to be composed of three functional blocks - generation, transmission and distribution. For a reliable power system, the generation unit must produce adequate power to meet customer's demand, transmission systems must transport bulk power over long distances without overloading and distribution systems must deliver electric power to each customer's premises from bulk power systems. Distribution system locates the end of power system and is connected to the customer directly, so the power quality mainly depends on distribution system. With the advent of myriad sophisticated electrical and electronic equipment, such as computers, programmable logic controllers and variable speed drives which are very *sensitive to* disturbances and non-linear loads at distribution systems produces many power quality problems like voltage sags, swells and harmonics and the purity of sine waveform is lost. [1][2] Voltage sags are considered to be one of the most severe disturbances to the industrial equipment's.

Power distribution systems, ideally, should provide their customer with an uninterrupted power flow at smooth sinusoidal voltage at the contracted magnitude level and frequency .A momentary disturbance for sensitive electronic devices causes voltage reduction at load end leading to frequency deviations which results in interrupted power flow, scrambled data, unexpected plant shutdowns and equipment failure. Voltage lift up at a load can be achieved by reactive power injection at the load point of common coupling (PCC).

The common method for this is to install mechanically switched shunt capacitors in the primary terminal of the distribution transformer. The mechanical switching may be on a schedule, via signals from a supervisory control and data acquisition (SCADA) system, with some timing schedule, or with no switching at all. The disadvantage is that, high speed transients cannot be compensated. Some sag is not corrected within the limited time frame of mechanical switching devices. Transformer taps may be used, but tap changing under load is costly.

Another power electronic solution to the voltage regulation is the use of a dynamic voltage restorer (DVR). DVR's are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state switches for compensating voltage sags. The DVR applications are mainly for sensitive loads that may be drastically affected by fluctuations in system voltage.

2. CONVENTIONAL SYSTEM CONFIGURATION OF DVR

Dynamic Voltage Restorer is a series connected device designed to maintain a constant RMS voltage value across a sensitive load. The DVR considered consists of:

a. an injection / series transformer

b. a harmonic filter,

c. a Voltage Source Converter (VSC)

d. an energy storage and

e. a control system , as shown in Figure

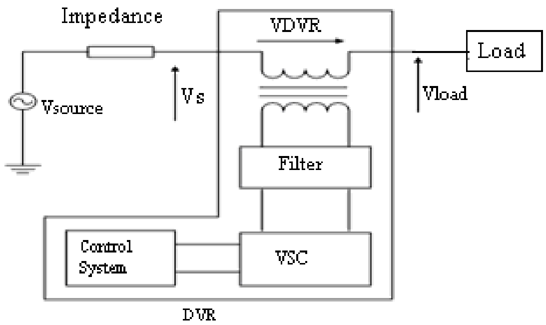

Figure 1: Schematic diagram of DVR

3. 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 favored 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.

$$\begin{bmatrix} u_d \\ u_q \\ u_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos(\theta) & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\ -\sin(\theta) & -\sin(\theta - \frac{2\pi}{3}) & -\sin(\theta + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} \quad \text{......(1)}$$

Where $\theta = \omega t + \delta_A$ the angle between the rotating and fixed coordinate system at each is time t and δ_A is an initial phase shift of the voltage.

And according inverse Parks Transformation

$$\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} = \begin{bmatrix} \cos(\theta) & -\sin(\theta) & 1 \\ \cos(\theta - \frac{2\pi}{3}) & -\sin(\theta - \frac{2\pi}{3}) & 1 \\ \cos(\theta + \frac{2\pi}{3}) & -\sin(\theta + \frac{2\pi}{3}) & 1 \end{bmatrix} \begin{bmatrix} u_d \\ u_q \\ u_o \end{bmatrix} \quad \text{.........(2)}$$

As in the Clarke Transform, it is interesting to note that the 0-component above is the same as the zero sequence component in the symmetrical components transform. For example, for voltages Ua, Ub and Uc, the zero sequence component for both the dq0 and symmetrical components transforms is $\frac{1}{3}(U_a + U_b + U_c)$.

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

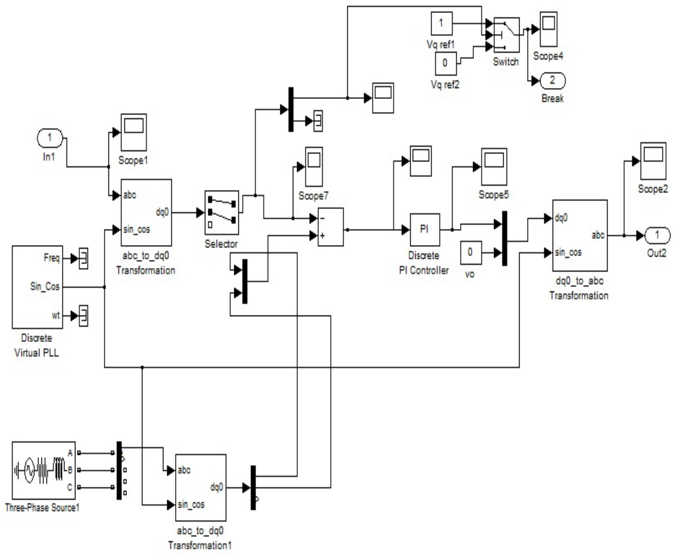

Figure 2 Schematic diagrams of control block.

4. DYNAMIC VOLTAGE RESTORER

Among the power quality problems like sag, swell, harmonic etc, voltage sag is the most severe disturbances in the distribution system. To overcome these problems the concept of custom power devices is introduced lately. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks.

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 generally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can also added other features like line voltage harmonics compensation, reduction of transients in voltage and fault current limitations.

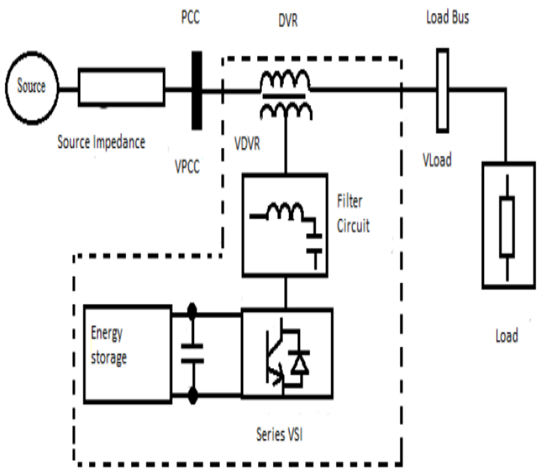

Figure 3 DVR series connected topology

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.

Sr. no.	System quantities	Standards
1.	Main Supply Voltage per phase	440V
2.	Line Impedance	Ls =1 mH Rs = 0.5 Ω
3.	Linear/Isolation transformer	1:1 turns ratio, 440/440 V
4.	DC Bus Voltage	135 V
5.	Load resistance	5 Ω
6.	Inverter	IGBT based,3 arms, 6 Pulse, Carrier Frequency =1000 Hz, Sample Time= 5 μs
7.	Load inductance	1 mH
8.	Line Frequency	50Hz

1 .Parameter table

5. SIMULATION RESULTS AND DISCUSSION

5.1 SIMULINK MODEL OF THE DVR TEST SYSTEM IN STEADY STATE AND TRANSIENT CONDITIONS

In this simulink model we have a system in which two parallel feeders are shown. In both the feeders further loads are also connected in parallel. In one feeder DVR is connected in series with line and the other feeder is kept as it is. Here system is presented without DVR and fault.

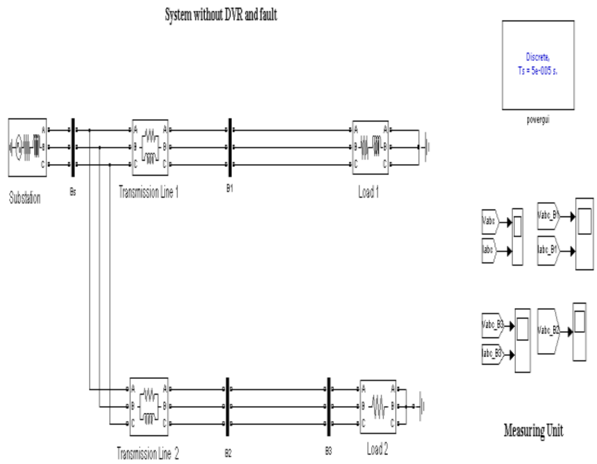

Figure 4 simulink model of the DVR test system in steady state conditions

Result for the above system in which without DVR and fault is given below. The output voltage for source side, load 1 and load 2 is same. The wave shapes in figure-5.8 represent source voltage, load 1 and load 2 with respect to time.

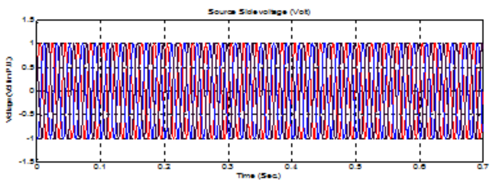

Figure 5 Waveform in Steady state condition

A detailed system as shown in Figure 8 has been modeled by MATLAB/SIMULINK to study the efficiency of suggested control strategy. The system parameters and constant value are listed in Table I. It is assumed that the voltage magnitude of the load bus is maintained at 1 pu during the voltage sags/swells condition. The results of the most important simulations are represented in Figures 6-7.

Voltage Sag

The first simulation shows of three phase voltage sag are simulated. The simulation started with the supply voltage 50% sagging as shown in Figure 6 (a).In Figure 6 (a) also shows a 50% voltage sag initiated at 0.15s and it is kept until 0.35s, with total voltage sag duration of 0.2s. Figures 5 (b) and (c) show the voltage injected by the DVR and The corresponding load voltage with compensation.

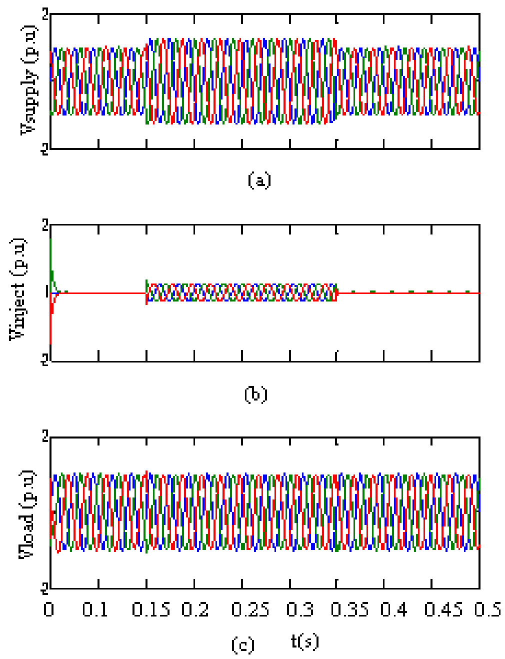

Figure 7 Three-phase voltages swell: (a)-Source voltage, (b)-Injected voltage, (c)-Load voltage

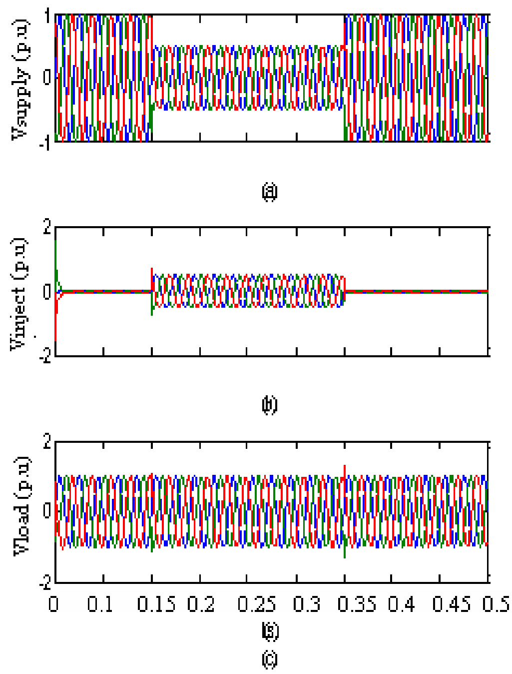

Figure 6 Three-phase voltages sag: (a)-Source voltage, (b)-Injected voltage,(c)-Load

Voltage Swell

The second simulation shows the DVR performance during a voltage swell condition. The simulation started with the supply voltage swell is generated as shown in Figure 7 (a). As observed from this figure the amplitude of supply voltage is increased about 25% from its nominal voltage. Figures 7(b) and (c) show the injected and the load voltage respectively. As can be seen from the results, the load voltage is kept at the nominal value with the help of the DVR. Similar to the case of voltage sag, the DVR reacts quickly to inject the appropriate voltage component to correct the supply voltage.

6. CONCLUSION

The modeling and simulation of a DVR using MATLAB/SIMULINK has been presented. A control system based on dqo technique which is a scaled error of the between source side of the DVR and its reference for sags/swell correction has been presented. The simulation shows that the DVR performance is satisfactory in mitigating voltage sags/swells.