Dynamic Voltage Restorer Using Synchronous Reference Frame Theory

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Abstract – *Power quality means quality of the normal voltage supplied to your facility. Voltage provided should be as close as possible to nominal voltage. The waveform must be pure sine wave free from any harmonics and other disturbances. The growing use of microprocessors and electronic equipment has made us to focus on power quality. Equipment and machinery can be damaged or even fail when subjected to power anomalies. Some of the power quality issues are voltage sag, swell, harmonics, flicker, interruption etc. Among these issues voltage sag is an important issue. This paper investigates about the causes of voltage sag, consequences and its mitigation. Many mitigation devices are available and the most economic effective solution is Dynamic Voltage Restorer (DVR). Simulation has been carried out to evaluate performance. A DVR is simulated in MATLAB/SIMULINK using synchronous reference frame theory.*

Key Words: Dynamic Voltage Restorer, SRF, Voltage sag , etc…

1. INTRODUCTION

Pat any point of time, a power system operating condition should be stable, meeting various operational criteria and it should be secure in the event of any contingency. Nowadays power systems are being operated closer to their stability limits due to economic ad environment constraints. To maintain a stable and secure operation of a power system becomes a challenging issue.

Due to growth in power electronics, the loads which are considered linear in nature has many impact. As a result, the nonlinear loads has increased dramatically. Because of these it has become necessary to establish criteria for limiting problems from system voltage reduction.

Any power problem manifested in voltage, current or frequency deviations that results in failure or disoperation of customer equipment is termed as power quality [1]. The parameters that describe power quality are voltage sag, swell, interruption, harmonics, notch, noise, transients, flicker, under voltage etc. From an EPRI study conducted in 2001 it is shown that voltage sag constitute 46%.It is caused by utility systems and industrial plants.

To protect the sensitive devices in modern industries different methods of compensation of sags have been used. The voltage sag mitigating devices are coil hold in devices, ferro resonant transformers, UPS, flywheel and motor-generator set, DVR, sag proofing transformer etc. Out of these most efficient and economic device is DVR.

2. DYNAMIC VOLTAGE RESTORER

2.1 Structure of DVR

DVR is a device that utilizes power electronic components and is connected in series to distribution line. It provides three phase controllable voltage, whose vector adds to the source voltage to restore the load voltage to presage condition [2].

The main components of DVR are energy storage unit, inverter circuit, filter unit and series injection transformer. For energy storage unit two configurations are possible [6]. One using stored energy to supply the delivered power and the other having no internal energy storage, where energy is taken from incoming supply through a shunt converter. The inverter controls the dc energy stored to a controllable three phase ac voltage. High frequency harmonics at the inverter output can be filtered using filtering circuit. Series injection transformer injects the missing voltage to the system at the load bus. Fig-1 shows the basic structure of DVR.

The compensation strategies for DVR are pre sag compensation, in phase compensation and minimum energy injection.

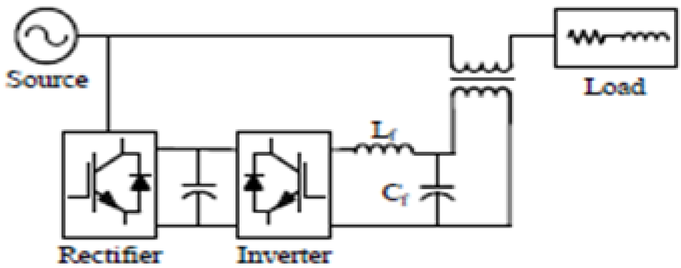

Fig -1: Basic components of DVR

2.2 Control Of DVR

Fig-2 shows the control block of the DVR proposed in synchronus reference frame theory which is used for the control of self supported DVR.The voltage at PCC is converted to rotating reference frame using abc-dqo conversion.Using low pass filter(LPF) harmonics and oscillatory components of voltage are eliminated.The components in d-axis and q-axis are

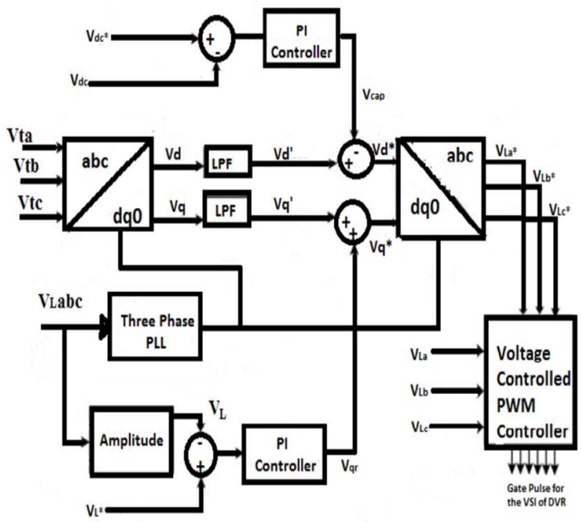

Fig -2:Block Diagram of SRF Theory

$$Vsd=Vsd(ac)+Vsd(dc) \quad ....2.1$$
$$Vsq=Vsq(ac)+Vsq(dc) \quad ....2.2$$

Three phase reference supply voltage (VLa*,VLb*,VLc*) are derived using sensed load voltages,terminal voltage (Vta,Vtb,Vtc)and dc bus voltage(Vdc) of the DVR.

SRF method is used to obtain the direct axis (Vd) and quadrature axis (Vq) components of load voltage.By Park's transformation three phase load voltage is converted to dqo frame.To synchronise these signals with the terminal voltage a three phase PLL is used.The dq components are passed through LPF to extract dc components of Vd* and Vq*.

To maintain dc bus voltage of self supported capacitor, the error between sensed dc voltage and reference dc voltage (Vdc*) are given to a PI controller and its output(Vcad) is considered as loss component of voltage and is added to the dc component of Vd to generate Vd*The reference d axis load voltage as

$$Vld^*=Vsd(dc)+Vloss \quad ....2.3$$

To regulate the amplitude of the load voltage (VL) another PI controller is used.The amplitude VL at PCC is calculated as

$$VL=(2/3(VLa^2 + VLb^2+VLc^2))^{1/2} \quad ....2.4$$

The amplitude of load voltage and output of PI controller is considered as reactive component of voltage(Vqr) for voltage regulation of load terminal voltage added with dc component of Vq to generate Vq*.The reference q-axis load voltage is given as

$$VLq^*=Vsq(dc)+Vqr \quad ....2.5$$

The resultant voltages (Vd*,Vq*,Vo) are again converted into the reference supply voltages using reverse Park's transformation.Reference supply voltages (VLa*, VLb*,VLc*) and the sensed load voltages(VLa, VLb,VLc) areused in PWM current controller to generate gating pulses for the switches[3],[4].

3. SIMULATION RESULTS

In this system a DVR is introduced in the distribution system to compensate voltage sag. The DVR connected system consisting of a three phase supply, three phase critical load, and the series injection transformer is modeled in MATLAB/SIMULINK environment along with a sim power system toolbox and is shown in Fig-3.An equivalent load considered is a 8kVA 0.8pf lag linear load[5].

The control algorithm for the DVR shown in Fig-2 is also modeled in MATLAB.The performance of DVR is demonstrated under a voltage sag condition. A sag is introduced by using a three phase breaker fault. Fig-4 shows the transient performance of the system under voltage sag conditions. At 0.05s,a 30% sag in supply voltage is created for three cycles .It is observed that load voltage is regulated to constant amplitude under sag condition by injecting missing voltage. PCC voltage, compensated load voltages and injected voltage are depicted. The Fig-5 and Fig-6 shows the injected voltage and compensated load voltage respectively.

Table -1: Parameters of the system

Parameters	Value
Source Voltage	415V,50Hz
Load	8kVA,0.8pf lag
DC link voltage	300V
DC Capacitor	1500µF
Series Transformer	10kVA,300/300V

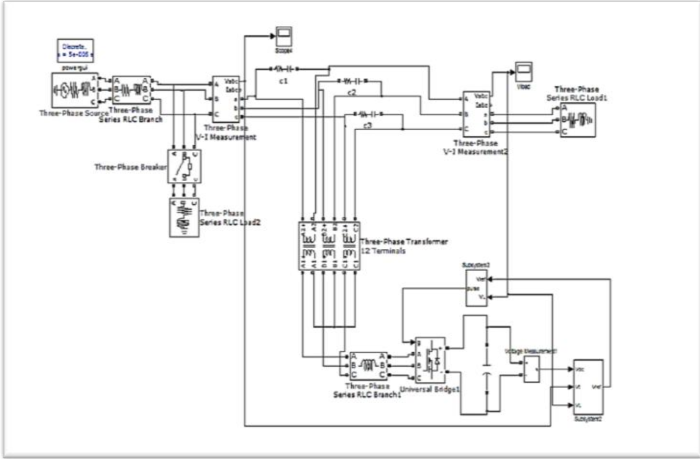

Fig -3:MATLAB/SIMULINK Model of DVR

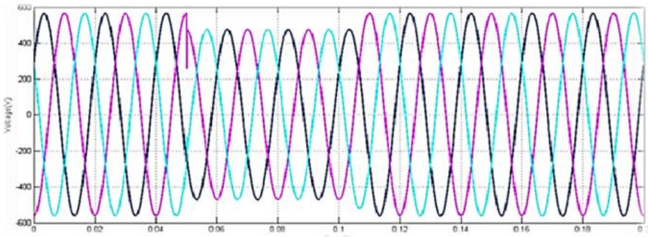

Fig -4:Voltage Sag at PCC

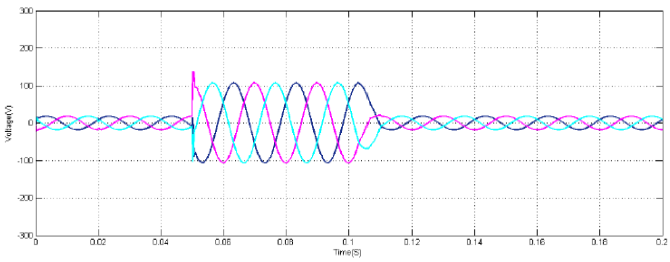

Fig -5:Injected Voltage

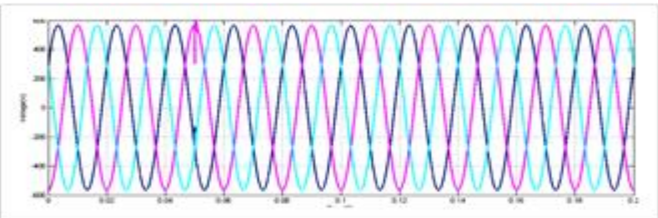

Fig -6: Compensated Load Voltage

3. CONCLUSIONS

The main concern of consumers is the quality and reliability of power centers at various load center where they are located. Power quality problems especially voltage sag will effect the industrial loads. To overcome the negative impact of power quality such as voltage sag on equipment and business,DVR is an efficient device. Its advantages are lower cost, small size, and its fast dynamic response to the disturbance. The reference voltage has been generated using SRF theory. The modeling and simulation of a DVR is done in MATLAB/SIMULINK. The experiment shows that the proposed DVR successfully mitigate the voltage sag and also capable of providing self-support to its dc bus capacitor.

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BIOGRAPHIES

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