

Power Quality Improvement using Dual Voltage Source Converter Based DVR

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Abstract— In any power system, The modelling and simulation of three and seven-level Dual Voltage Source Converter based dynamic voltage restorer (DVR) aimed at correcting the supply voltage sag/swell and interruption in low voltage distribution networks. The proposed design models of DVSC based DVR are expected to be most powerful solutions to minimize supply voltage disturbances of the sensitive loads. A DVR is a VSC based power electronics device connected in series between the supply and the critical loads, which are to be protected from the supply side voltage quality problems, other than outages, by injecting the required compensating voltage through DVR into the distribution line. The proposed models of DVR together with the controllers are simulated by using MAT LAB Simulink and the results are presented to assess the performance of each device.

Keywords— FACTS, Power quality, DVSC.

I. INTRODUCTION

Recently, power quality problems become a major concern of industries due to massive loss in terms of time and money. Hence, there are always demands for good power quality, which positively resulting in reduction of power quality problems like voltage sag, harmonic and flicker, interruptions, harmonic distortion. Preventing such phenomena is particularly important because of the increasing heavy automation in almost all the industrial processes. High quality in the power supply is needed, since failures due to such disturbances usually have a high impact on production costs. There are number of methods to overcome voltage sags. One approach is to use Dynamic Voltage Restorers with energy storage. The DVR is a power electronics device that is able to compensate voltage sags on critical loads dynamically. By injecting an appropriate voltage, the DVR restores a voltage waveform and ensures constant load voltage.

The DVR consists of Voltage Source Converter (VSC), injection transformers, passive filters and energy storage (lead acid battery). The Dynamic Voltage Restorer (DVR) with the lead acid battery is an attractive way to provide excellent dynamic voltage compensation capability as well as being economical when compared to shunt-connected devices.

The DVR employs IGBTs to maintain the voltage applied to the load by injecting single-phase output voltages whose magnitude, phase and frequency can be controlled.

The basic function of DVR is to inject dynamically voltage required, VDVR to compensate sagging occurrence. Generally, the operation of DVR can be categorized into two modes; standby mode and injection mode. In standby mode, DVR either in short circuited operation or inject small voltage to cover voltage drop due to transformer reactance losses. The DVR is turn into injection mode as soon as sagging is detected. VDVR is injected in series with load with required magnitude and phase for compensation. The common causes of voltage sag are faults or short circuit in the system, starting of large loads and faulty wiring. This will lead to increase in both production and financial loss for industries. [16]

II. PROBLEM FORMULATION

Power quality in electric networks is one of today's most concerned areas of electric power system. The power quality has serious economic implications for consumers, utilities and electrical equipment manufacturers. Modernization and automation of industry involves increasing use of computers, microprocessors and power electronic systems such as adjustable speed drives. Integration of non-conventional generation technologies such as fuel cells, wind turbines and photo-voltaic with utility grids often requires power electronic interfaces.

The power electronic systems also contribute to power quality problems (generating harmonics). Under the deregulated environment, in which electric utilities are expected to compete with each other, the customer satisfaction becomes very important. The impact of power quality problems is increasingly felt by customers – industrial, commercial and even residential.

III. MOMENTARY PHENOMENA

Transients

Transients are unwanted decay with time and hence not a steady state problem. A broad definition is that a transient is "that part of the change in a variable that disappears during transition from one steady state operating situation to the other". Another synonymous term which can be used is surge. [5]

Transients are further classified into two categories:

- a) Impulsive
- b) Oscillatory

Long Duration Voltage Variations

When rms (root mean square) deviations at power frequency last longer than one minute, then we say they are long duration voltage variations. They can be either over voltages which is greater than 1.1p.u or under voltages which is less than 0.9p.u. Over voltage is due to switching off a load or energizing a capacitor bank. Also incorrect tap settings on transformers can result in over voltages. Under voltage are the results of actions which are the reverse of events that cause over voltages i.e. switching in a load or switching off a capacitor bank.[5][16]

Sustained Interruptions

If the supply voltage becomes zero for a period of time which is greater than one minute, then we can say that it is a sustained interruption. Normally, voltage interruption lasting for more than one minute is often unending and requires human intervention to restore the supply. The term “outage” is also used for long interruption. However it does not bring out the true impact of the power interruption. Even an interruption of half a cycle can be disastrous for a customer with a sensitive load.[7]

Short Duration Voltage Variations

The short duration voltage variations are generally caused by fault conditions like single line to ground or double line to ground and starting of large loads such as induction motors. The voltage variations can be temporary voltage dips i.e. sag or temporary voltage rise i.e. swells or an absolute loss of voltage which is known as interruptions[7]

Voltage Sags

Voltage sag is defined as the reduction of rms voltage to a value between 0.1 and 0.9p.u and lasting for duration between 0.5 cycles to 1 minute. Voltage sags are mostly caused by system faults and last for durations ranging from 3 cycles to 30 cycles depending on the fault clearing time. It is to be noted that under-voltages (lasting over a minute) can be handled by voltage regulation equipment. Starting of large induction motors can result in voltage dip as the motor draws a current up to 10 times the full load current during the starting. Also, the power factor of the starting current is generally poor[14].

Voltage Swells

A voltage swell is defined as a raise in rms voltage which is between 1.1 and 1.8p.u for time duration between 0.5 cycles to 1 minute. A voltage swell is characterized by its magnitude (rms) and duration. As with sag, swell is associated with system faults. A SLG (single line to ground) fault can result in a voltage swell in the healthy phases. Swell can also result from energizing a large capacitor bank. On an ungrounded system, the line to ground voltages on the ungrounded phases is 1.73p.u during a SLG fault. However in a grounded system, there will be negligible voltage rise on the unfaulted phases close to a substation where the delta connected windings of the transformer provide low impedance paths for the zero sequence current during the SLG fault.[14]

Interruption

If the supply voltage or load current decreases to less than 0.1 p.u for a period of time not more than one minute is known as interruption. Interruption can be caused either by system faults, equipment failures or control malfunctions. The interruptions are measured by their duration alone. The duration due to a fault is determined by the operating time of the protective devices. Duration of an interruption due to equipment malfunction can be irregular. Some interruptions may also be caused by voltage sag conditions when there are faults on the source side.[14]

IV. 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. 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.[9][17]

Principle of DVR Operation

A DVR is a solid state power electronics switching device consisting of either GTO or IGBT, a capacitor bank as an energy storage device and injection transformers. It is linked in series between a distribution system and a load that

shown in Figure 6.2. The basic idea of the DVR is to inject a controlled voltage generated by a forced commuted converter in a series to the bus voltage by means of an injecting transformer. A DC to AC inverter regulates this voltage by sinusoidal PWM technique. All through normal operating condition, the DVR injects only a small voltage to compensate for the voltage drop of the injection transformer and device losses. However, when voltage sag occurs in the distribution system, the DVR control system calculates and synthesizes the voltage required to preserve output voltage to the load by injecting a controlled voltage with a certain magnitude and phase angle into the distribution system to the critical load.[16]

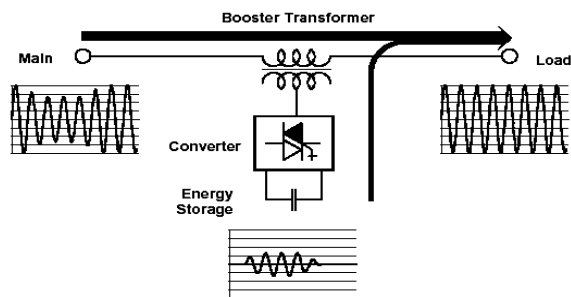


Fig 4.1 Principle of DVR System

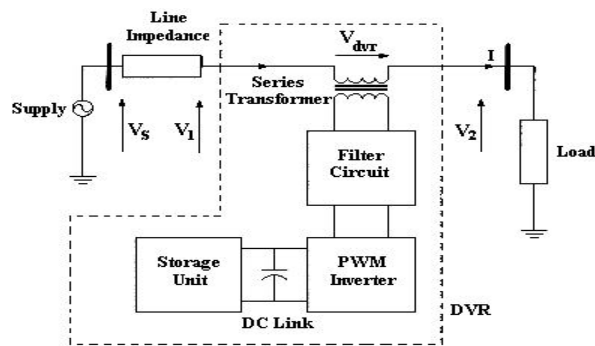


Fig 4.2 Schematic Diagram of DVR

V. MODELING OF DVR

The DVR is designed to inject a dynamically controlled voltage i.e. VDVR, which is generated by a forced commutated converter. This voltage is injected in series to the bus voltage by means of an injection transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to remove any harmful effects of a bus fault

to the load voltage V_L . This means that any differential voltages caused by transient disturbances in the ac feeder will be compensated by a equivalent voltage generated by the converter and injected on the medium voltage level through the injection transformer. The DVR has three modes of operation which are: protection mode, standby mode, injection/boost mode.

In protection mode, if the current on the load side exceeds a tolerable limit due to any fault or short circuit on the load, DVR will isolate from the system. In standby mode the voltage winding of the injection transformer is short circuited through converter. In the Injection/Boost mode the DVR is injecting a compensating voltage through the injection transformer due to the detection of a disturbances.[17]

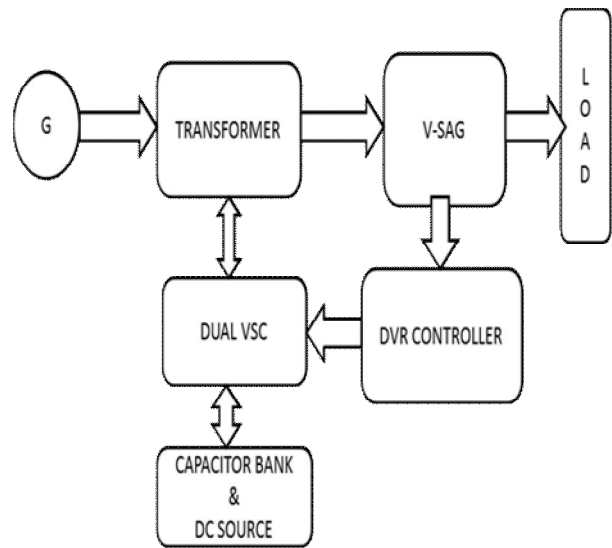


Fig 5.1 Proposed scheme

VI. PROPOSED SCHEME ADVANTAGES

1. The dynamic voltage restorer (DVR) has become popular as a cost effective solution for the protection of sensitive loads from voltage sags and swells.
2. It provides technically advanced and economic solution to compensate voltage sag and reactive power in both transmission and distribution system.
3. Dual voltage converter across voltage stress low. (least cost)
4. Super capacitor bank (multiple capacitor) to inject requirement reactive power.

The control system of a DVR plays an important role, with the requirements of fast response in the face of voltage sags and variations in the connected load. Generally, there are two control schemes, open loop and closed loop which are used in the DVR applications. This project presents an extensive analysis to develop suitable control strategies for the DVRs. The DVR control system consists of a open loop load voltage using phase locked loop (PLL). The PLL circuit is used to generate a unit sinusoidal wave in phase with mains voltage. The three phase voltages can be converted into $\alpha\beta$ using $\alpha\beta$ transform.

$$\begin{bmatrix} V_\alpha \\ V_\beta \\ V_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix}$$

$\alpha\beta$ Co-ordinate system can be transformed into the dq plane.

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix}$$

$$V_{DVR} = V_L + Z_{TH} - V_{TH}$$

Where

V_L : The desired load voltage magnitude.

Z_{TH} : The load impedance.

V_{TH} : The system voltage during fault condition.

When V_L is considered as a reference equation can be rewritten as,

$$V_{DVR} \angle \phi = V_L \angle 0 + Z_{TH} \angle (\beta - \theta) - V_{TH} \angle \delta$$

ϕ , β , δ are angles of V_{DVR} , V_{TH} , Z_{TH} respectively and θ is Load power angle,

$$\theta = \tan^{-1} \left(\frac{\theta_L}{P_L} \right)$$

The complex power injection of the DVR can be written as,

$$S_{DVR} = V_{DVR} I_L^*$$

It requires the injection of only reactive power and the DVR itself is capable of generating the reactive power.

VII. SIMULINK MODEL OF DVR

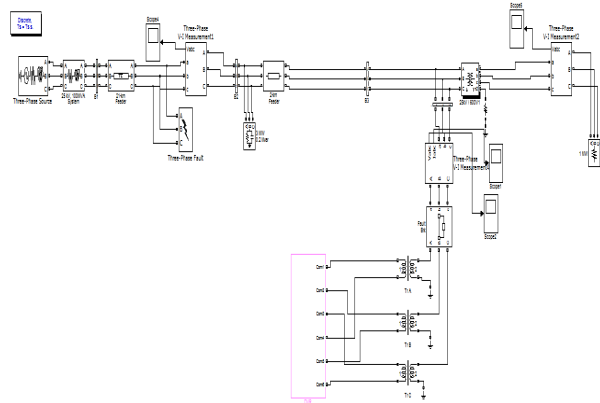


Fig 7.1 Schematic Diagram of DVR

VIII. RESULT & DISCUSSION

A structure for voltage sag mitigation and power quality improvement are proposed .get the output for 17.80%.

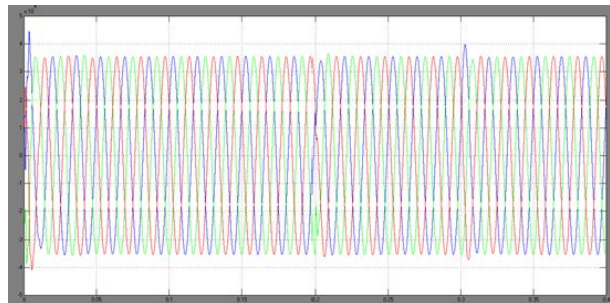


Fig.8.1 Circuit Breaker Closed Condition

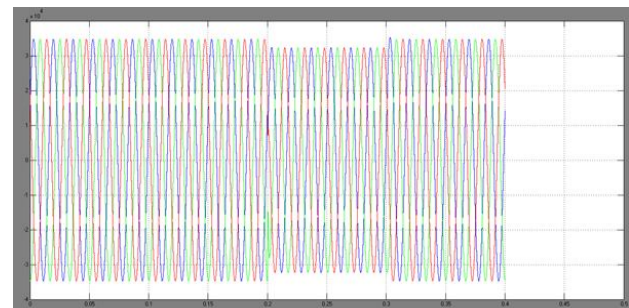


Fig.8.2 Circuit Breaker Open Condition

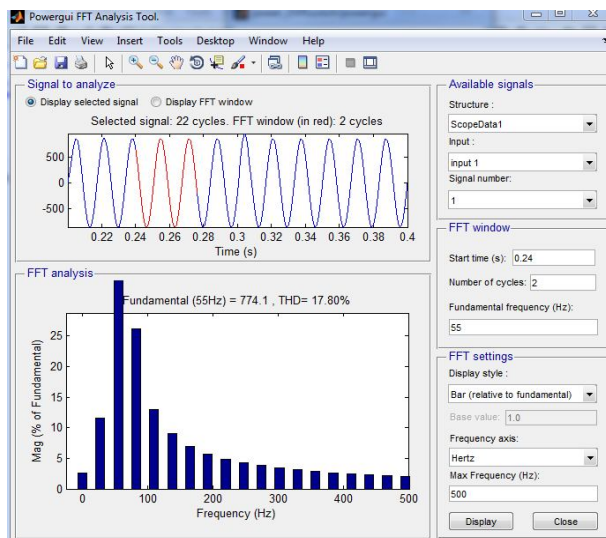


Fig 8.3 Total Harmonics Distortion Analysis

IX. CONCLUSION

This paper presents simulation models of DVSC based DVR in a distribution system. Uni-polar and PSHM based SVPWM techniques are used to control the DVR. The simulation results have demonstrated the effectiveness of the DVR under different fault conditions and provided excellent voltage regulation capability by using DVSC (Dual Voltage Source Converter).

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