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Analysis of Total Harmonic Distortion (THD) Level of Distribution Network Using DVR

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Abstract
The modern sensitive, Non-linear and sophisticated load affects the power quality. Dynamic Voltage Restorer (DVR) provides the fast, flexible and efficient solution to improve the power quality for such distribution network [8]. The active power, reactive power, variation of voltage, flicker, harmonics, and electrical behavior of switching operations are the major source of affecting power quality. The intent of this paper is to demonstrate the improvements obtained with DVR in power system network using MATLAB/SIMULINK. In this paper, an overview of the DVR, its functions, configurations, components, control strategies are reviewed. The Simulation results are presented to illustrate the performance of DVR in Total Harmonic Distortion (THD). The results showed clearly the performance of using DVR in improving THD level.
Keywords: Dynamic Voltage Restorer (DVR), PI controller, Power Quality, Pulse Width Modulation (PWM), Total Harmonic Distortion (THD).

I. INTRODUCTION

Power quality or, simply, the usability of electric power is of vital concern to modern life. Both current and frequency rarely cause problems for end users. That's because electric current is dictated by load, and the utility -- to maintain stability of the grid -- very tightly controls the frequency of AC power [2]. Due to various pieces of equipments or due to any abnormal conditions in the network, the quality of the power changes and thus it becomes less suitable for any further application. Earlier the prime focus for power system reliability was on generation and transmission system but now a day's distribution system receives more attention. Because 90% of the average customer interruptions occur in the distribution network and causes huge amount of financial losses. As a result, voltage quality represents the lone rogue element. Indeed, statistics reflecting so-called power quality problems show that over 95% of them are, in fact, voltage problems. These include voltage levels that are too high or too low; voltage sags (transient drops in voltage); and power interruptions (absence of voltage). Ultimately, voltage quality affects not only the operational reliability and life of sensitive electronics, as well as other electric devices, but it also has a significant impact on energy consumption and efficiency. In an ideal world, the voltage supplied to an electric device would always let the device operate perfectly, across its expected lifetime. The best measure of power quality is the ability of electrical equipment to operate in a satisfactory manner, given proper care and maintenance and without adversely affecting the operation of other electrical equipment connected to the system.

In order to overcome these problems the concept of custom power devices is introduced recently. 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. The Dynamic Voltage Restorer (DVR), also referred to as the Series Voltage Booster (SVB) or the Static Series Compensator (SSC), is a device that utilizes solid state (or static) power electronic components, and is connected in series to the utility primary distribution circuit. It is normally 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. Pulse width modulated inverter is used to vary the amplitude and the phase angle of the injected voltages, thus allowing the control of both real and reactive power exchange between the distribution system and the load. For proper voltage sag compensation, it is necessary to derive suitable and fast control scheme for inverter switching [5]. The general requirement of a control scheme is to obtain an ac waveform with minimum total harmonic distortion (THD) and best dynamic response against supply and load disturbance when the DVR is operated for voltage sag compensation.

This paper organized as follows: Section II describes the DVR configuration; Section III represents a MATLAB/SIMULINK based distribution network. Section IV presents the control strategy employed for DVR and Section-V compares the Simulation results. Section-VI presents the conclusion.

II. DVR CONFIGURATION

Among all the custom power devices, DVR is a fast and efficient device for improving power quality in a distribution network [1]. The DVR is a series connected custom power device used to mitigate the voltage unbalance, sags, swells, harmonics and any abrupt changes due to abnormal conditions in the system. DVR is also called Series Voltage Booster (SVB) or Static Series Compensator (SSC), and is connected in series to the utility primary distribution circuit. The basic configuration of DVR consists of: (i) Injection / Booster transformer: The Injection / Booster transformer is a specially designed transformer that attempts to limit the coupling of noise and transient energy from the primary side to the secondary side;

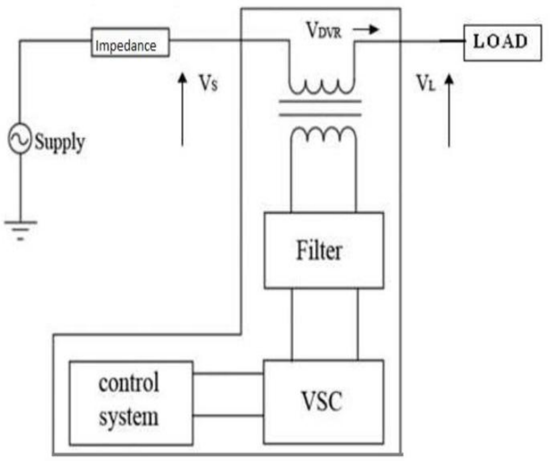

Fig.1. DVR Configuration

(ii) Harmonic Filter: The main task of harmonic filter is to keep the harmonic voltage content generated by the VSC to the permissible level; (iii) Energy Storage Unit: It is responsible for energy storage in DC form. Flywheels, batteries, superconducting magnetic energy storage (SMES) and super capacitors can be used as energy storage devices [9]. The purpose of storage devices is to supply the necessary energy to the VSC via a dc link for the generation of injected voltages; (iv) Voltage Source Converter (VSC): A VSC is a power electronic system consists of a storage device and switching devices, which can generate a sinusoidal voltage at any required frequency, magnitude, and phase angle; (v) Capacitor: DVR has a large DC capacitor to ensure stiff DC voltage input to inverter.

Metal Oxide Semiconductor Field Effect Transistors (MOSFET), Gate Turn-Off Thyristors (GTO), Insulated Gate Bipolar Transistors (IGBT), and Integrated Gate Commutated Thyristors (IGCT) are various types of switching devices that can be used as a VSC [7].

III. SIMULINK MODEL

SIMULINK model of two parallel line distribution systems is shown in Fig.2. In this model Dynamic Voltage Restorer (DVR) is installed on one distribution line and the other parallel distribution line is uncompensated. Both the lines are of 11KV rating and terminated by load. IGBT based DVR is installed in the compensated line.

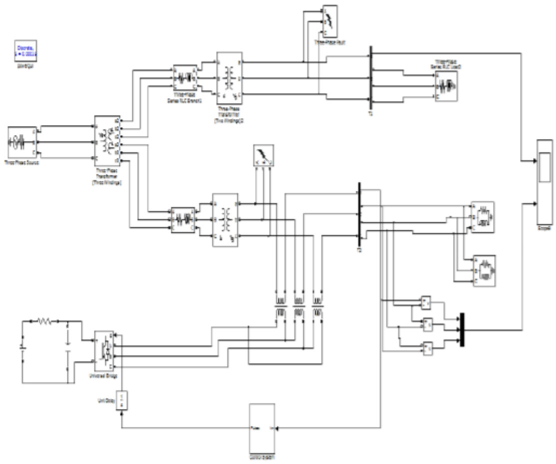

Fig.2 SIMULINK Model of Distribution System

IV. CONTROL STRATEGY

The control strategy for DVR for controlling purpose is shown in Fig.3. This control strategy provides the pulses to IGBT converter in order to control the operation of DVR. The control strategy shows that at the beginning the current input signal (I_{in}) is compared with the current reference signal ($I_{ref.}$) and the output i.e. actuating signal is then provided to PI controller. The output of PI controller calculates the converter injected voltage (V_{inj}), which is the required voltage to compensate the voltage reduced due to voltage sag/swell. The subsystem consists of constants, trigonometric functions and product. The output of this subsystem is applied to PWM pulse generator, which generates the pulses and fed it to IGBT converter through a unit delay in order to control the operation of DVR.

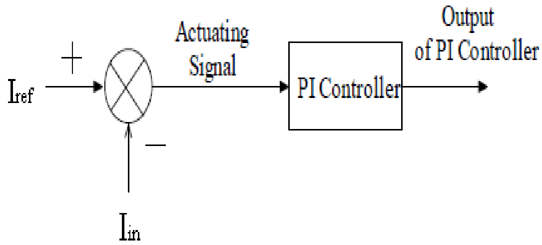

Fig.3. Control Strategy

V. SIMULATION RESULTS

The two parallel line distribution system is simulated by MATLAB/SIMULINK. One line is compensated by DVR and other is without DVR. The inverter consists of IGBT based three phase voltage source converters. The DVR can control the line voltage and reduce THD level even under disturbances. The disturbances used are single phase fault on both the lines, at time t=0.4 and cleared at t=0.6. The Simulation results are discussed below:

Case1: During single phase fault the voltage of faulted phase of compensated line is not reduced to zero, whereas voltage reduced to zero of uncompensated line i.e. line without DVR

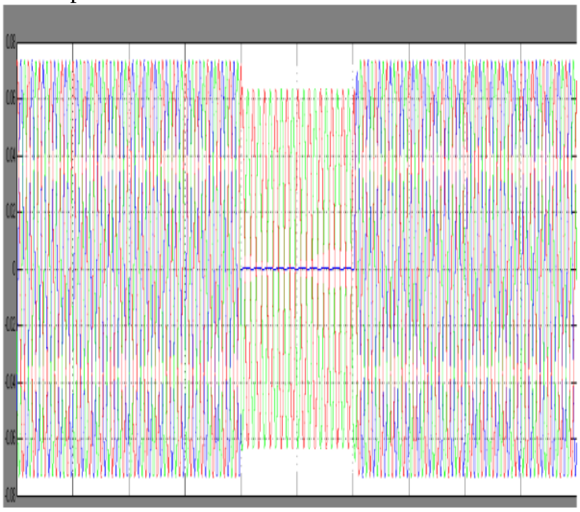

Fig. 5.1 Line Voltage without DVR

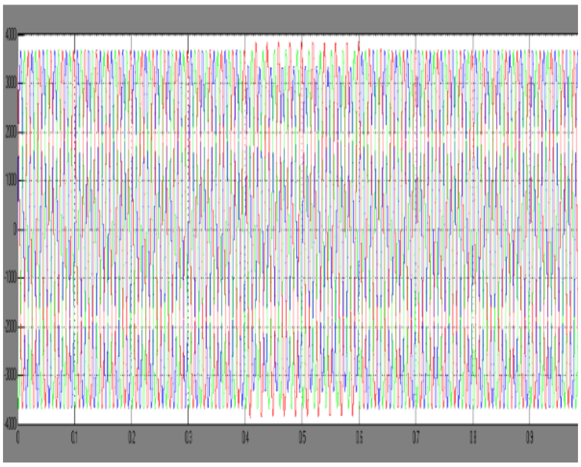

Fig. 5.2 Line Voltage with DVR

Case 2: Fig.5.3 and Fig.5.4 shows the THD level of line without DVR and with DVR. It is cleared that under fault condition, the THD level is reduced to much low level by installing DVR in the line.

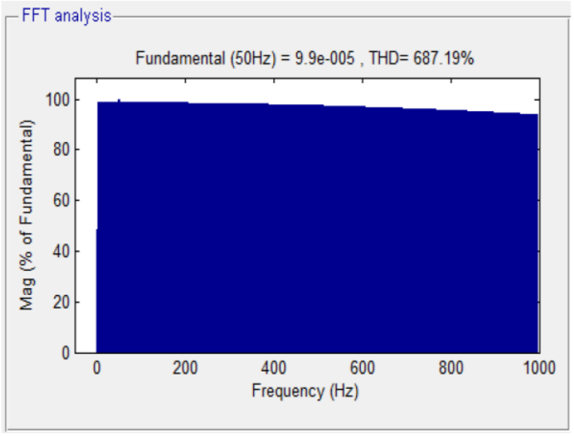

Fig.5.3 THD Level without DVR

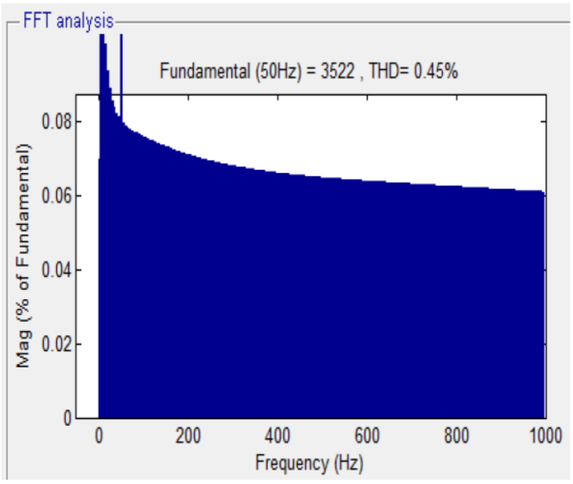

Fig.5.4 THD Level with DVR

VI. CONCLUSION

The DVR performance is satisfactory in mitigating voltage sags/swells, distortions and harmonics. A PWM – based control scheme was implemented, this PWM control scheme only requires voltage measurements, which makes DVR a reliable and cost effective solution in mitigation of voltage sag / swell etc. It is concluded that the line which is compensated by IGBT based DVR has very low THD level (0.45%) as compared to uncompensated line (687.19%) and the zero Voltage does not occurred after DVR installed in the line. This characteristic makes it ideally suitable for low and medium voltage custom power applications.

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