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Analyzing of Dynamic Voltage Restorer in Series Compensation Voltage

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Abstract: The Dynamic Voltage Restorer (DVR) is a series-connected compensator to generate a controllable voltage to against the short-term voltage disturbances. The technique of DVR is an effective and cost competitive approach to improve voltage quality at the load side. This study presents a single-phase and three-phase DVR system with reduced switch-count topology to protect the sensitive load against abnormal voltage conditions. Most basic function, the DVR configuration consist of a two level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer Connected in shunt with the ac system This study presents the application of Dynamic Voltage Restorer (DVR) on power distribution systems for mitigation of voltage sag at critical loads. DVR is one of the compensating types of custom power devices. The DVR, which is based on forced-commutated Voltage Source Converter (VSC) has been proved suitable for the task of compensating voltage sags/swells. Simulation results are presented to illustrate and understand the performances of DVR in supporting load voltages under voltage sags/swells conditions.

Key words: Dynamic Voltage Restorer (DVR), facts device, power quality, voltage sags

INTRODUCTION

Voltage sags are huge problems for many industries, and it is probably the most pressing power quality problem today. Voltage sags may cause tripping and large torque peaks in electrical machines (Reed *et al*., 2000). Generally, voltage sags are short duration reductions in rms voltage caused by faults in the electric supply system and the starting of large loads, such as motors (Padiyar and Kulkarni, 1997). Voltage sags are also generally created on the electric system when faults occur due to lightning, which are accidental shorting of the phases by trees, animals, birds, human error such as digging underground lines or automobiles hitting electric poles, and failure of electrical equipment. Sags also may be produced when large motor loads are started, or due to operation of certain types of electrical equipment such as welders, arc furnaces, smelters, etc. The customer power controllers have been presented to protect sensitive loads against the abnormal voltage conditions in the distribution system (Dolezal and Tlusty, 2001). The Unified Power Quality Compensator (UPQC) is a series-parallel-connected controller to improve voltage quality at the load side and compensate current quality at the utility side. However the cost of UPQC is very expensive and control scheme is more complicated to implement (Hochgraf and Lasseter, 1998). The distribution static synchronous reactive compensator (DSTATCOM) is a shunt-connected compensator to absorb or supply the reactive current so as to against voltage disturbances such as voltage sag, swell and flicker (Akagi and Fujita, 2007). The Dynamic Voltage Restorer (DVR) is a series-connected compensator to generate a controllable voltage to against the short-term voltage disturbances. The technique of DVR is an effective and cost competitive approach to improve voltage quality at the load side (Gutierrez *et al*., 2000). This study presents a single-phase and three-phase DVR system with reduced switch-count topology to protect the sensitive load against abnormal voltage conditions. First the single-phase DVR system with cost effective topology for low power applications is studied to improve voltage quality at the load side. The system operation and control approach are presented. The simulation study is presented to verify the validity and effectiveness of the control algorithm. Finally, three-phase DVR system for medium power applications is discussed in (Preville, 2001) and the system operation and control scheme are presented to against voltage disturbances and improve voltage quality at the load side. Some computer simulations results are provided to evaluate the system performance.

In this study the control of DVR in order to mitigating voltage sag are analyzed. In this study, the control is based on sinusoidal PWM is discussed and results are presented. This study presents a single-phase and three-phase DVR system with reduced switch-count topology to protect the sensitive load against abnormal voltage conditions.

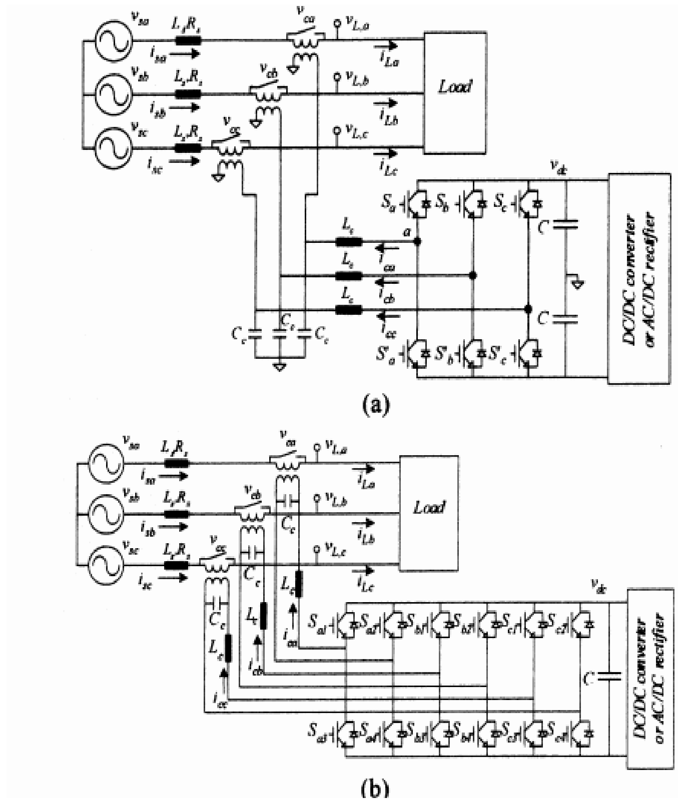

Fig. 1: Three-phase series voltage compensator based on, (a) three-phase three-leg inverter with split dc capacitors, (b) three-phase six-leg inverter

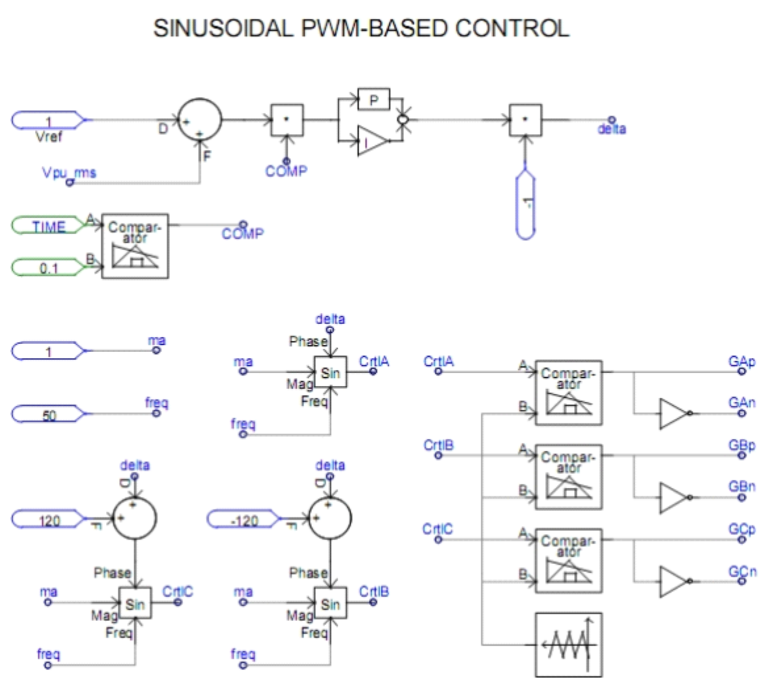

Fig. 2: Control scheme for the test system implemented in PSCAD/EMTDC to carry out the DVR simulations

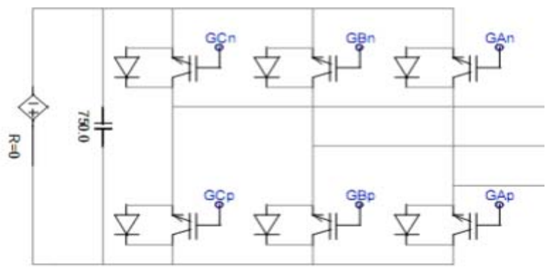

Fig. 3:One line diagram of the DVR test system

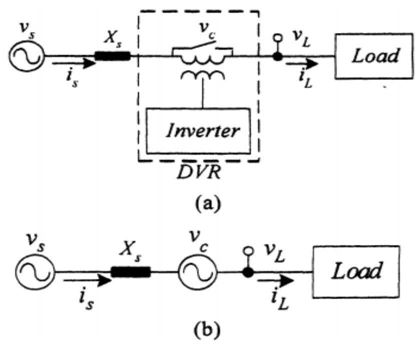

Fig. 4: (a) Schematic diagram of a series compensator system (b) series compensator worked as a variable voltage source

Dynamic Voltage Restorer (DVR): In its most basic function, the DVR configuration consist of a two level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer Connected in shunt with the ac system, and associated control circuit as shown in Fig. 1. The VSC converts the dc voltage across the storage device into a set of three phase ac output voltages (Moreno *et al*., 2002). 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 DVR output voltages allows effective control of active and reactive power exchanges between the DVR and the ac system.

The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes , Voltage regulation and compensation of reactive power, Correction of power factor; and Elimination of current harmonics (Jintakosonwit *et al*., 2002; Schauder and Mehta, 1993). The design approach of the control system determines the priorities and functions developed in each case. In this case the control is based on sinusoidal PWM and only requires the measurement of the rms voltage at the load point.

PWM-based control scheme: A sinusoidal PWM-based control scheme is implemented; with reference to the

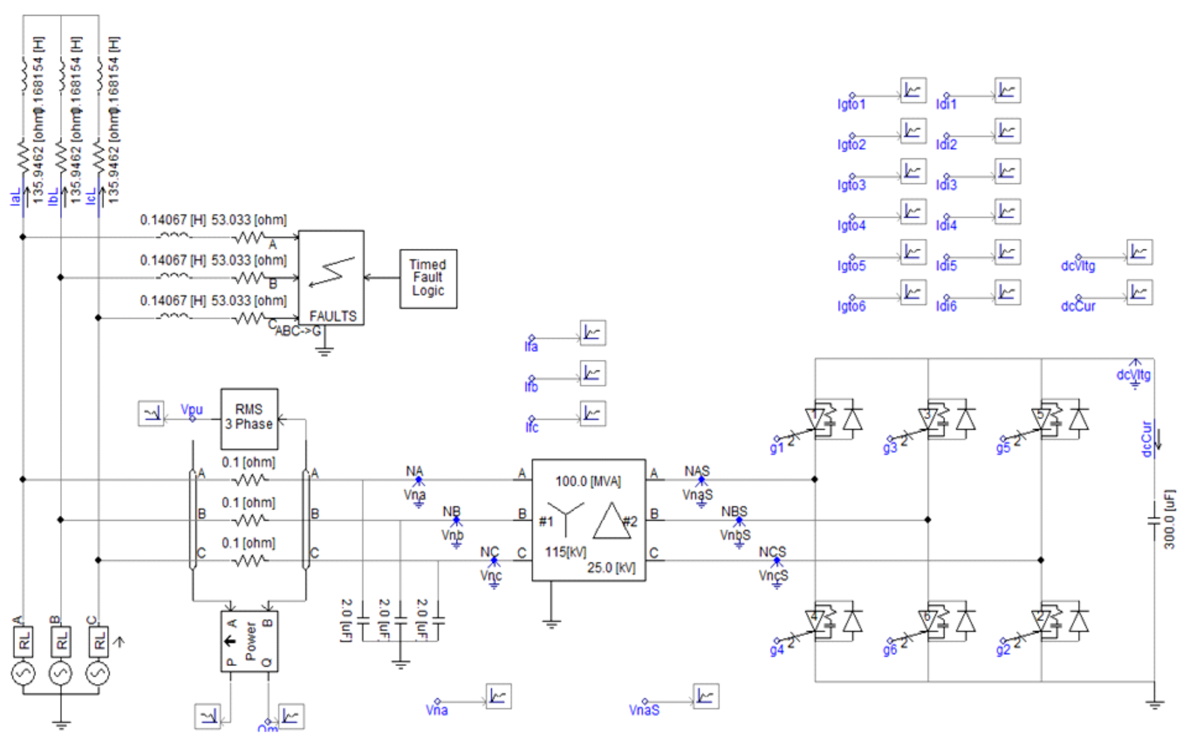

Fig. 5: Schematic diagram of the test system with DVR connected to the system

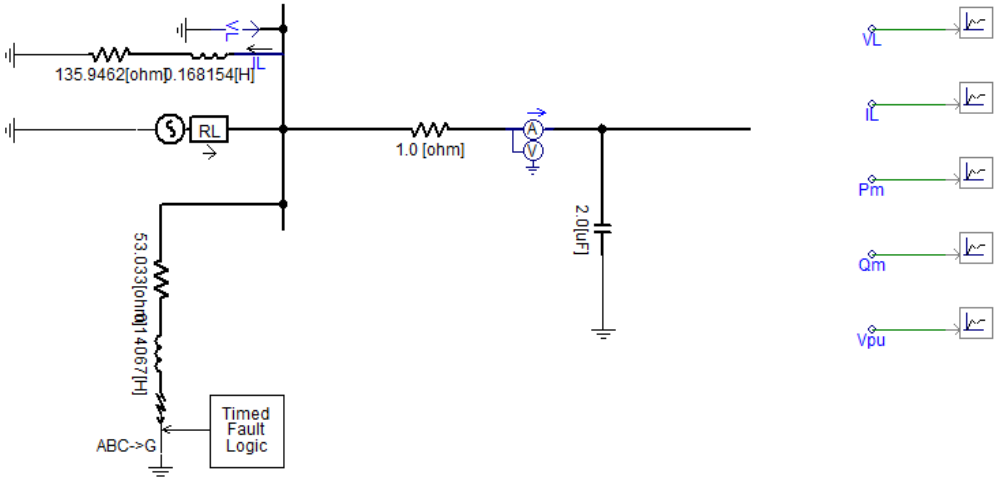

Fig. 6: Schematic diagram of the test system without DVR

DVR is shown in Fig. 2. The aim of the control scheme is to maintain a constant voltage magnitude at the point where sensitive load is connected, under the system disturbance. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response (Chen and Joos, 2000). Besides, high switching frequencies can be used to improve the efficiency of the converter, without incurring significant switching losses. The DVR control system exerts voltage angle control as follows: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point. The PI controller processes the error signal and generates the required angle δ to drive the error to zero, in example; the load rms voltage is brought back to the reference voltage.

The main parameters of the sinusoidal PWM scheme are the amplitude modulation index, ma, of signal vcontrol, and the frequency modulation index, mf, of the triangular signal. The switching frequency mf is set at 450 Hz, mf = 9. The vcontrol in the Fig. 2 are nominated as CtrlA, CtrlB and CtrlC. It should be noted that, an assumption of balanced network and operating conditions are made. A 750 μF capacitor on the dc side provides the DVR energy storage capabilities. Figure 3 shows the build of the DVR in PSCAD/EMTDC which is the two-level voltage source converter and the realization of the test system being employed shown in Fig. 5.

Basic configuration and function of DVR: The DVR is a three phase and shunt connected power electronics based device. It is connected near the load at the distribution systems. The major components of the DVR are shown in Fig. 4. It consists of a dc capacitor, three phase inverter module such as IGBT or thyristor, ac filter, coupling transformer and a control strategy. The basic electronic block of the DVR is the voltage sourced converter that converts an input dc voltage into three phase output voltage at fundamental frequency (Dolezal and Tlusty, 2001; Inzunza and Akagi, 2005).

Referring to Fig. 4, the controller of the DVR is used to operate the inverter in such a way that the phase angle between the inverter voltage and the line voltage is dynamically adjusted so that the DVR generates or absorbs the desired VAR at the point of connection. (Preville, 2001) The phase of the output voltage of the thyristor based converter, Vi, is controlled in the same way as the distribution system voltage, Vs. For instance, if Vi is equal to Vs, the reactive power is zero and the DVR does not generate or absorb reactive power. When Vi is greater than Vs, the DVR ‘sees’ an inductive reactance connected at its terminal. Hence, the system ‘sees’ the DVR as a capacitive reactance. The current, I, flows through the transformer reactance from the DVR to the ac system, and the device generates capacitive reactive power.

Simulation model and parameters: The description of output parameters such as voltage and current of load and active power and current of DVR that injected to PCC are discussed in this study. Figure 5 shows the three phase diagram of test system.

Fig. 6 shows the single line diagram of test system without DVR.

RESULTS

Figure 7-11, shows the simulation results with and without DVR. When DVR is implanted the profile of load voltage is improved.

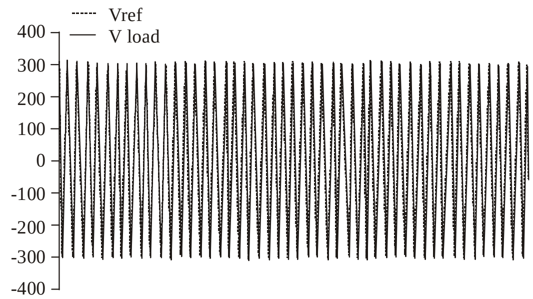

Fig. 7: The result of voltage of load before occurring fault without DVR

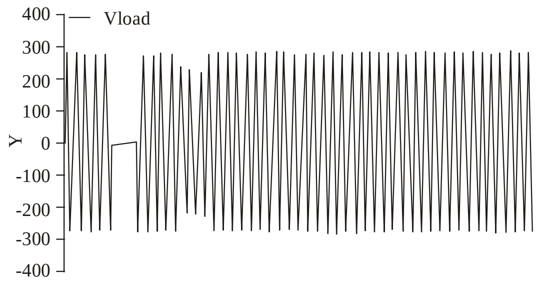

Fig. 8: The result of voltage of load after occurring fault without DVR

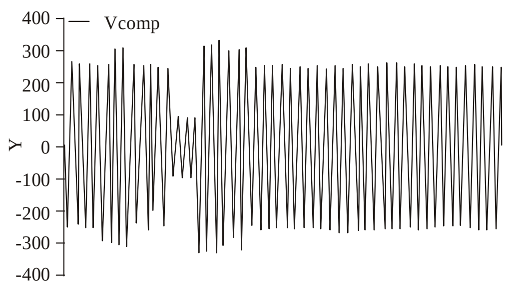

Fig. 9: The compensated voltage of DVR

The active and reactive of injected from DVR to PCC changes, that this help to mitigate voltage sag and improve characterization of load.

CONCLUSION

In this study the effect of one series controller in distribution system as dynamic voltage restorer is analyzed in order to mitigate voltage sag. The Dynamic Voltage Restorer (DVR) offers an alternative to conventional series shunt compensation. In the traditional power transmission system, controllable devices are restricted to the slow mechanisms such as transformer tap changers and switched capacitor. In the late 1980's, thanks to the major developments in the semiconductor technology, it became possible to apply

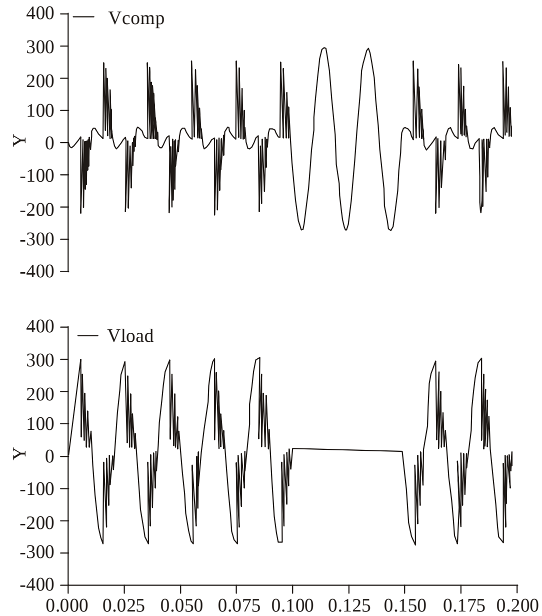

Fig. 10: The comparison between load voltage and generated voltage with DVR

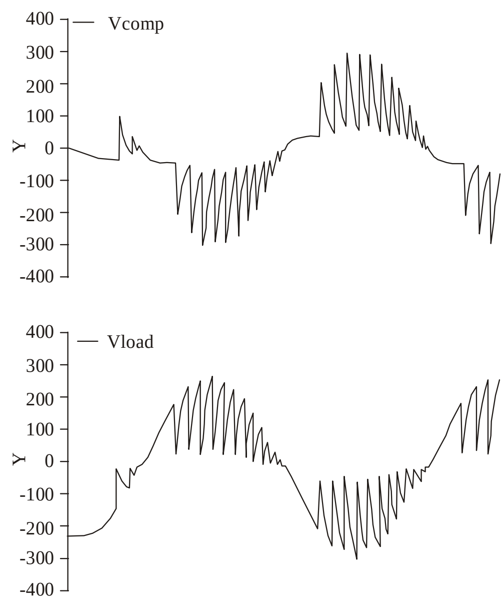

Fig. 11: The instantaneous variations of load and DVR voltage

power electronics in the control of DVR. Based on the simulation, there's a room for improvement. DVR is a device that promises a prominent feature in power system in mitigating power quality related problems in the future. Nowadays, reliability and quality of electric power is one of the most discuss topics in power industry. There are numerous types of power quality issues and power problems and each of them might have varying and diverse causes. The types of power quality problems that a customer may encounter classified depending on how the voltage waveform is being distorted. There are transients, short duration variations (sags, swells, and interruption), long duration variations (sustained interruptions, under voltages, over voltages), voltage imbalance, waveform distortion (dc offset, harmonics, inter harmonics, notching, and noise), voltage fluctuations and power frequency variations. Among them, two power quality problems have been identified to be of major concern to the customers are voltage sags and harmonics, but this project is focusing on voltage sags. In this study the effect of one series controller in distribution system as dynamic voltage restorer is analyzed in order to mitigate voltage sag.

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