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An Overview of Dynamic Voltage Restorer for Voltage Profile Improvement

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Abstract

Power quality is one of major concerns in the present era. It has become important, especially, with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end use equipment's. One of the major problems dealt here is the voltage sag. To solve this problem, custom power devices are used. 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. Its appeal includes lower cost, smaller size, and its fast dynamic response to the disturbance. This paper introduces power quality problems and overview of Dynamic Voltage Restorer so that young electrical engineers come to know about such a modern custom power device for power quality improvement in future era.

Keywords: *power quality, voltage sags, Dynamic Voltage Restorer (DVR).*

I. Introduction

Power quality issues are of vital concern in most industries today, because of the increase in the number of loads sensitive to power disturbances. The power quality is an index to qualify of current and voltage available to industrial, commercial and household consumers of electricity. The problem regards both the utilities and customers. For the utilities, to provide adequate power quality is a moving objective because of changes in user equipment and requirements. For consumers, problems stemming from the sensitivity of electrical equipment to voltage quality have often very heavy consequences. Power quality is a topic embracing a large field. On one side, several different events are involved in power quality: spikes or surges, sags, swells, outages, under and

Overvoltage, harmonics, flicker, frequency deviations, and electrical noise. Accordingly, different measurements and Analysis tools are required to investigate such phenomena, and different remedial actions can be adopted to compensate them or to reduce their effects. On the other side, many electronic devices (such as computers, process controls, adjustable speed drives, solid-state-relays, optical devices, to name a few) are sensitive to a different extend to power quality. Since a certain event may be not serious problem for a given customer class, but it may represent a big problem for another class, it has Doubtful practical sense to rank the above events in terms of importance without referring to a more specific context. As far as industrial and commercial customers are concerned, several recent studies agree on the statement that voltage sags must be regarded as one of the most important concerns in power quality. This statement is particularly true for industrial facilities, where even short duration voltage sags are often responsible for much more long-lasting production downtimes and consequent large lost revenue.

II. Structure and Operation of DVR

Dynamic Voltage Restorer is one of custom power device specially used to maintain the load voltage constant in the distribution system. DVR will be in standby mode during normal operation and when the control circuit detects any disturbance in the supply voltage DVR will inject the required voltage [3]. In-phase compensation technique is used to compensate the voltage sag/swell in which only voltage magnitude is compensated.

DVR consist of an injection transformer, Voltage Source Converter (VSC), harmonic filter, storage device and control system as shown in Fig.1 [9].

A. Injection Transformer

Injection transformer is used to connect the DVR to the distribution network via High Voltage winding and injects the compensating voltage generated by VSC after the detection of any disturbance in supply voltage by control circuit. Another main task of injection transformer is that it will limit the coupling of noise and isolate VSC and control circuit from the system.

B. Voltage Source Converter (VSC)

VSC is a power electronic device used to generate the compensating voltage. Output voltage of VSC should be

a. Pure sine wave and balanced
b. Phase sequence as that of system
c. Of required magnitude

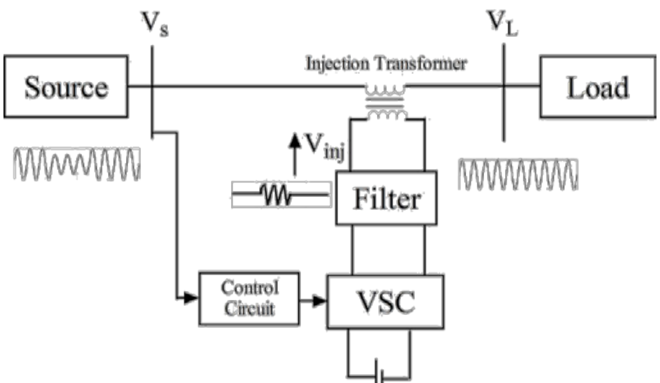

Fig.1 Structure of DVR

C. Harmonic filter

Harmonic filter is used to filter out the high frequency component from the output voltage of inverter.

D. Storage device

It is basically used to supply the necessary energy to VSC to generate the compensating voltage. In this paper DC voltage source is used for this purpose.

E. Control circuit

Control circuit continuously monitors the supply voltage. The function of control system is to detect the disturbance in the supply voltage, compare it with the set reference value and then generate the switching pulses to the VSC to generate the DVR output voltages.

III. VOLTAGE SAG

IEEE Standard 1100-1992 (IEEE Emerald Book) defines sag as "an rms reduction in the AC voltage, at the power frequency, for durations from a half-cycle to a few seconds". Note: The IEC terminology for sag is dip. They may be accompanied with phase jumps. If the voltage is reduced to zero, the disturbance is said to be a momentary outage or micro interruption. The most obvious way to characterize voltage sag is in terms of the reduced voltage rms, duration and probably accompanied phase jump. Voltage dips (sags) are generally caused by faults occurring in the customers' installations on in the public distribution system. They are unpredictable, largely random events. The annular frequency varies greatly depending on the type of the supply systems and on the point of observation. Moreover, the distribution over the year can be very irregular. Voltage sags are often generated by starting of large loads, such as motors, transformer energizing, equipment faults, transmission and distribution system faults. Faults on the distribution and transmission systems can be caused by numerous sources such as lightning strikes, conductors blowing together in a storm, contact with objects (e.g. tree branches, animals, etc.) or vandalism. Most of these faults (70-80%) are temporary in nature; they are self-clearing within a few milliseconds. The fault that does not clear will cause a protective device/s (e.g. fuse, circuit breaker, or recloser) to operate to interrupt current to that part of the system in the affected area.

IV. Location of DVR

The intention is only to protect one consumer or a group of consumers with value added power. Applying a DVR in the medium or low voltage distribution system would often be possible and a radial grid structure is the only type of system Considered here. In Europe three wire systems are common in the medium voltage systems and four wires in low voltage systems. In both systems the main purpose is to inject synchronous voltages during symmetrical faults and in some cases inject an inverse voltage component during non-symmetrical faults

A main difference between a Low Voltage (LV) connection and a Medium Voltage (MV) connection is the flow of zero sequence currents and the generation of zero sequence voltages. In the four-wire system, the DVR must secure low impedance for zero sequence currents and the zero sequence must either flow in the power converter or in a delta winding of the injection transformer.

V. Basic DVR Operating Principles

The DVR functions by injecting three single phase AC voltages in series with the three phase incoming network voltages during sag, compensating for the difference between faulty and nominal voltages. All three phases of the injected voltages are of controllable amplitude and phase. Three pulse-width modulated (PWM) voltage source inverters (VSI) fed from a DC link supply the active and reactive power.

During undisturbed power supply condition, the DVR operates in a low loss standby mode. In the normal operation mode (no sag) the low voltage side of the booster transformer is shorted either by solid state bypass switch or by switching one of the inverter legs and it functions as a short-circuited current transformer. Since no VSI switching takes place, the DVR produces conduction losses only. These losses should be kept as low as possible so as not to cause steady state power loss. The required energy during sags has to be supplied by an energy source. The necessary amount of energy that must be delivered by the energy source depends on load MVA requirement, control strategy applied, deepest sag to be protected. Under normal conditions, the short circuit impedance of the injection transformer determines the voltage drop across the DVR. This impedance must be low and has an impact on the fault current through the VSI on secondary side caused by a short-circuit at load side. The filter design is also affected by the impedance of the injection transformer. In case of fault or over current exceeding the rating of DVR on the load side, solid state bypass switches or electromechanical bypass switches must be added as a measure to protect DVR from getting damaged.

VI. Control of DVR

The control of a DVR is not straight forward because of the requirements of fast response, large variation in the type of sags to be compensated and variation in the type of connected load. The DVR must also be able to distinguish between background power problems and the voltage sags to be compensated. Sags are often nonsymmetrical and accompanied by a phase jump.

The possibility of compensation of voltage sags can be limited by a number of factors including finite DVR power rating, different load conditions, background power quality problems and different type of sags. If the DVR should be a successful device, the control may be able to handle most sags and the performance must be maximized according to the equipment inserted. Otherwise, the DVR may not be able to avoid load tripping and even cause additional disturbance to load.

A control strategy for voltage sags with phase jump should be included, to be able to compensate this particular type of sag. The control strategy can depend on the type of the load connected. Some loads are very sensitive to phase jump and the load should be protected from them. Other types of loads are more tolerant to phase jump and the main task is to maintain the nominal voltage on all three phases. Three basic control strategies for a DVR can be stated as:

Method 1: Pre-sag compensation; the supply voltage is continuously monitored and the load voltage is compensated to the pre-sag condition. The method gives nearly undisturbed load voltage, but can often exhaust the rating of the DVR.

Method 2: In-phase compensation; the generated DVR voltage is always in phase with the measured supply voltage regardless of the load current and presage voltage.

Method 3: Energy optimal compensation; to fully utilize the energy storage, information about the load current is used to minimize the depletion of the energy storage.

VII. CONCLUSIONS

With the development of more complicated process control equipment in the industry, more sensitive devices to the changes on the incoming supply voltage takes place on the market. This increase the severity of the power quality problems caused by non-ideal bus voltages. These non-idealities can be under-voltage, over-voltage, harmonics, shortages or sags. Although it does not seem so severe, every year large cost of lost production is paid by different manufacturers in the industry due to voltage sag, short periods of under-voltage, up to a few hundreds of milliseconds.

This paper introduces detailed overview of Dynamic Voltage Restorer so that young electrical engineers come to know about such a modern custom power device for power quality improvement in future era.

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