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ELECTRICAL POWER ENGINEERING

Designing and Modeling of Dynamic Voltage Restorers for Power Quality Control in Myanmar Info-Tech

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***Abstract*— Voltage sags and swells in the medium and low voltage distribution grid are considered the most frequent type of power quality problems based on recent power quality studies. Their impact on sensitive loads is severe. Different solutions have been developed to protect sensitive loads against such disturbances. Among them, DVR is considered to be the most efficient and effective solution. Its appeal includes lower cost, smaller size and its dynamic response to the disturbance. This paper described DVR principles and voltage restoration methods for balanced and/or unbalanced voltage sags and swells in a distribution system. DVR is a powerful custom power device used for short duration voltage compensation of sensitive loads against voltage disturbances in power distribution lines. The presentation will focus on the technical market requirements and the proposed solution for Myanmar Info-Tech, which is the largest computer and software industry in Myanmar. Myanmar Info-Tech is often encountering power quality problem including voltage sag/swell and short interruption. To overcome these problems, the DVR solution is introduced in this paper with Matlab simulation.**

***Keywords*— Dynamic Voltage Restorer (DVR), voltage sags/swells, power quality, MOSFET VSI**

I. INTRODUCTION

One of the major concerns in electricity industry today is power quality problems to sensitive loads. This is due to the advent of a large numbers of sophisticated electrical and electronic equipment. The use of these equipments very often requires power supplies with very high quality. Voltage sag, which is a momentary decrease in rms voltage magnitude in the range of 0.1 to 0.9 per unit (p.u.), is considered as the most serious problem of power quality [1]. It is often caused by faults in power systems or by starting of large induction motors. It can interrupt or lead to malfunction of any electric equipment, which is sensitive to voltage variations. It occurs more frequently than any other power quality phenomenon does.

During power disturbances DVR installed in front of a critical load will appropriately provide correction to that load only. It is noteworthy that during normal operation due to the series connection a DVR may have to provide a small amount of voltage drop mainly at the coupling transformer. Also DVR cannot provide compensation during full power interruptions. In this paper modeling and simulation of DVR for protection against voltage sag/swell for Myanmar Info-Tech is described. Then, a design modeling and simulation of the DVR is presented.

II. DYNAMIC VOLTAGE RESTORERS

The main components of DVR are energy storage unit, voltage source inverter circuit and filter unit and series injection transformers as shown in Fig.1. DVR is used for the protection of sensitive loads from voltage sags/swells coming from the network. The sags/swells voltages are occurred for short time intervals (transient condition). The voltage sags are due to the fault conditions and the swells are caused by the drop-out of the large load from the system. Thus the DVR is located at the incoming sides of sensitive load as shown in Fig. 1. If a fault occurs on nearby lines, DVR insert a series voltage V_{DVR} and compensate the load voltage to prefault value. In the same way, if a large load is shut-down, the DVR insert the negative DVR voltages which are 180° phase shift from the supply voltage. Thus the load voltage will be constant at the nominal value under transient condition. This means that any differential voltage caused by transient disturbances in the AC feeder will be compensated by an equivalent voltage generated by the DVR.

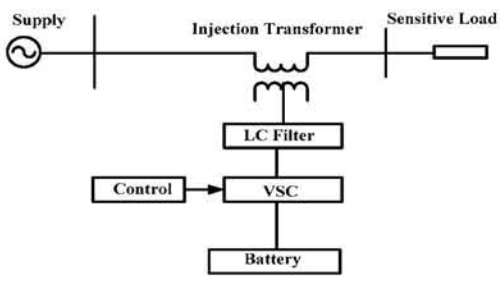

Fig. 1 Schematic diagram of DVR system

DVR has two modes of operation as standby mode and boost mode. In standby mode, the injection transformer primary winding is shorted causing no switching of the semiconductor switches and reduced the losses. The DVR will be operated most of the time in this mode. In boost mode, the DVR is injecting compensation voltage through the injection transformer due to the detection of a supply voltage disturbance. An equivalent circuit diagram of the DVR and the principle of series injection for sag compensation are depicted in Fig. 2.

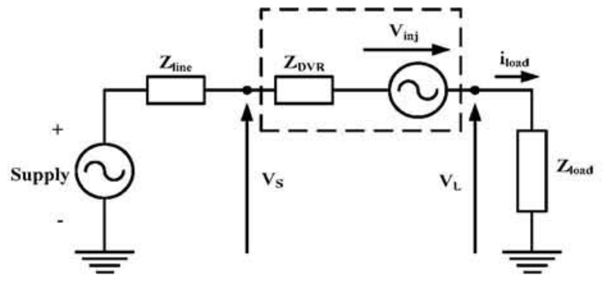

Fig. 2 Equivalent circuit of DVR

As the mathematical expression:

$$V_L\ (t) = V_s\ (t) + V_{inj}\ (t) \tag{1}$$

where v_L (t) is the load voltage, v_s (t) is the sagged supply voltage and v_{inj} (t) is the voltage injected by the mitigation device as shown in Fig. 2. Under nominal voltage conditions, the load power on each phase is given by (2):

$$S_L = V_L\ I_L^* = P_L - j\,Q_L \tag{2}$$

where I_L is the load current, and P_L and Q_L are the active and reactive power taken by the load, respectively, during a sag/swell. When the mitigation device is active and restores the voltages back to normal, the following applies to each phase:

$$S_L = P_L - j\,Q_L = (P_s - j\,QS_s) + (P_{inj} - j\,Q_{inj}) \tag{3}$$

where the sag subscript refers to the sagged supply quantities. The inject subscript refers to quantities injected by the mitigation device [2].

III. PRINCIPLE OF THE DVR OPERATION

The DVR is connected in series with power distribution line as shown in Fig. 1. The DVR is able to control the voltage across a sensitive load by injecting an appropriate voltage phasor through an injection transformer. As a result, any voltage disturbance appears in up-stream can be compensated through the DVR and the disturbance is unseen to the load.

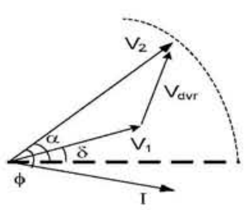

Fig.3 Phasor diagram of power distribution systemduring sag

In Fig. 3, V_1, V_2, V_{dvr} are the post-sag supply voltage magnitude, compensated load voltage magnitude and the DVR injected voltage magnitude respectively. Moreover I, p f, δ, α represent load current, load power factor angle, supply voltage phase angle deviation and load voltage advance angle respectively. If P_{in} and P_{out} are the input powers from the source and load power respectively, then the DVR supply can be obtained as follow;

$$P_{out} = P_{dvr} + P_{in} \tag{4}$$

where P_{dvr} is the DVR supplied power during the sag/swell condition. It has been shown that the supply of energy by the DVR for voltage restoration can be kept minimum, by advancing all three phases with a certain advance angle α. This control method is usually known as α-control. The magnitude of the DVR injection voltage and the real power supplied by the DVR can be calculated from Fig. 4 by using cosine rule as;

$$V_{dvr}^2 = V_2^2 + V_{1j}^2 - 2\,V_2\,V_{1j}\ \cos(\alpha - \delta_j) \tag{5}$$

where j represents for phases a, b and c. Then the power rating of DVR with the three phase balanced fault is;

$$P_{dvr} = 3\,V_{dvr}\ I\cos\theta \tag{6}$$

Also, the energy needs to be stored in the DVR storage unit can be formulated as:

$$E_{dvr} = P_{dvr} \times T_{sag} \tag{7}$$

where T_{sag} is the maximum sag/swell duration in second. The necessary condition for correcting a sag/swell without supplying energy from DVR will be obtained when θ is 90°.

IV. MODELING OF DVR

The compensation of voltage sag/swell can be limited by a number of factors, including finite DVR power rating, loading conditions, power quality problems and types of sag/swell. DVR is able to handle most sags/swells and the performance must be maximized according to the equipment inserted. Otherwise, the DVR may not be able to avoid tripping and even cause additional disturbance to the loads.

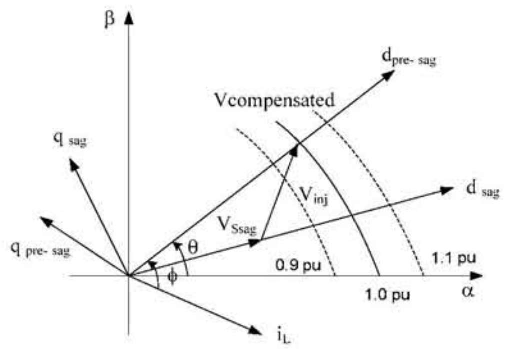

Fig. 4 Compensation strategy of DVR for voltage sag