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DYNAMIC VOLTAGE RESTORER AS VOLTAGE SAG CONDITIONING

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ABSTRACT

Voltage sag is severe power quality problem in power system. To mitigate voltage sag, Dynamic Voltage Restorer (DVR) is used. DVR is series connected a custom power device which detects voltage sag condition through control unit and missing voltage is injected to the line through series transformer. In this paper, different components of DVR are described. Three different modes of operation of DVR are also described in this paper. Three compensation techniques for voltage/power injection to the line are also presented with their applications.

Keywords: Dynamic Voltage Restorer, Power Quality, Voltage Sag.

I. INTRODUCTION

In present days, modern and automation industries are using computers, microprocessors and power electronics system like, adjustable speed drives. All these electrical devices are very sensitive to power quality (PQ) disturbances (sags, swell, harmonics etc.) and they can fail or malfunction when faced to problems in power supply [1]. The competition amongst energy suppliers and impact of disturbances on industrial, commercial and even residential consumers cause the attention towards PQ issues. Among all the PQ problems, voltage sags are the most common PQ problem[2-4].

Voltage sag is referred as a decrement in rms voltage or current to 0.1 to 0.9 pu for durations from 0.5 cycles to 1 min. Voltage sag is mainly caused by system faults [4, 5] but it also associated with energization of heavy loads or starting of large motors.Due to voltage sag induction motor can stop and can't reaccelerate, synchronous motor may loss synchronism, industrial drives may be tripped. Therefore, to mitigate voltage sag, a custom power device is used which is known as Dynamic Voltage Restorer (DVR) [6, 7].In this paper, the configuration, operating principle and compensation techniques of DVR are described. The components of DVR, energy storage devices, injection transformer, inverter and filter are described in section II. Three different compensation techniques of DVR are described in section IV.

II. CONFIGURATION OF DVR

DVR is a series connected device which mitigates voltage sags also it is used for mitigation of voltage swell by injecting negative sequence voltage to balance feeder or load voltage [1, 6, 7]. The DVR mainly consists of a series injected transformer, voltage source inverter, filter and energy storage device[7, 8]. The basic structure of DVR is shown in Fig. 1.

Injection Transformer: Injection transformer is connected is series to the line [9]. For three phase system, three single phase transformer are used. Star/open winding is used when positive, negative and zero sequence voltage are injected. While delta/open winding injects positive and negative sequence voltage only but it maximize the use of the dc-link voltage [8].

Filter: Filters are used to eliminate the harmonics components from the inverter output to reduce the voltage stress on the transformer [8]. Filter can be connected either at high voltage side or low voltage side of the transformer. But usually it is connected at inverter side, as in this it is closer to harmonic source [8].

*Energy Storage Device:*Energy storage device is used during the compensation mode of DVR operation. It provides real power to the load during voltage sag. Flywheel, battery, capacitor and super conducting magnetic energy storage (SMES) are used as energy storage device.Inverters are used for DC-AC conversion in case of battery, SMES and capacitor while for Flywheel, AC-AC conversion is performed [8].

Voltage Source Inverter: Voltage source inverter is used to convert the DC output of energy storage device to AC for series injection transformer. As in DVR, transformer rating is high so low voltage rating inverter is sufficient [7, 10]. Inverter is connected in series to the line through injection transformer along with filter circuit.

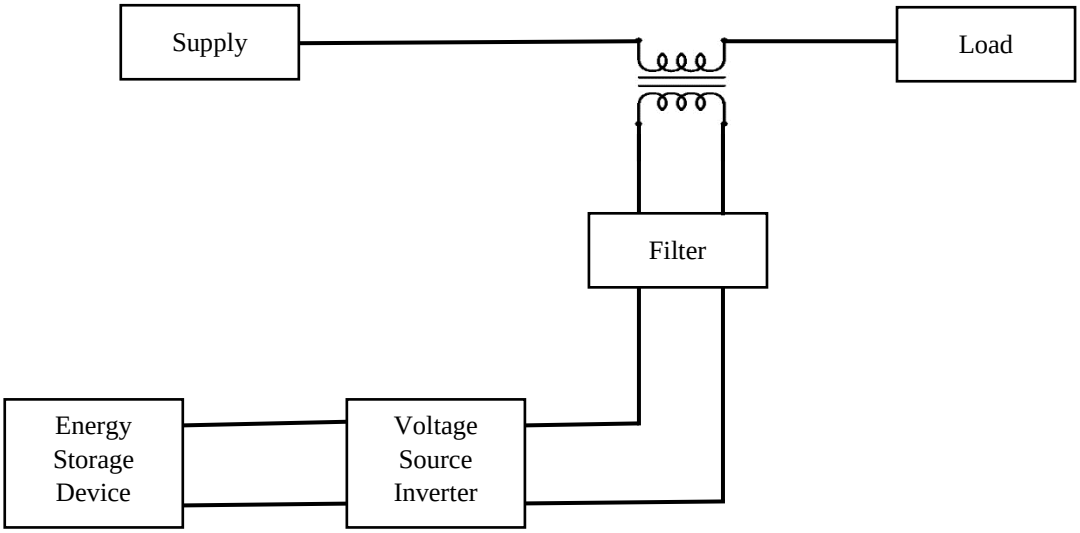

Fig. 1 Basic Structure of DVR

III. OPERATION OF DVR

The operation of DVR is to measure the missing voltage and injecting that missing voltage in the line through series injection transformer during sag event. The DVR operates in three modes: protection mode, standby mode and voltage injectionmode[11].

*Standby Mode:*Under normal condition, DVR works on this mode. In this mode DVR works on short circuit operation. Solid state by pass switches are used for this mode, which are connected between inverter circuit and low voltage side of transformer. Standby mode of DVR operation is shown in Fig. 2.

*Protection Mode:*When system parameters exceed the specific limit during the abnormal conditions on the load side then DVR have to be isolated from the line to protect it from damage. To isolate the DVR, bypass switches are used. During this mode switch S is closed. Protection mode of DVR is shown in Fig. 3.

Voltage Injection Mode: During voltage sag condition, when line voltage decreases to specific value, DVR operates. In this condition missing voltage is measured using control unit and that missing voltage is injected to the line through series transformer.

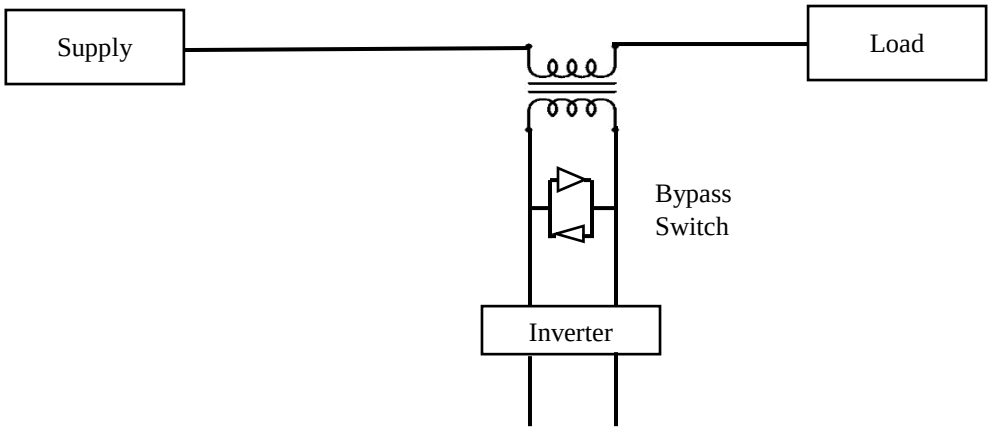

Fig. 2 Standby Mode of DVR

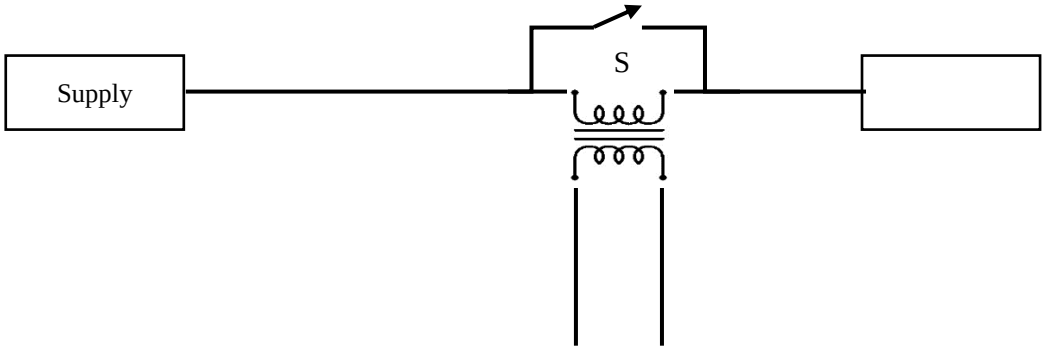

Fig. 3 Protection Mode of DVR

IV. COMPENSATION TECHNIQUES OF DVR

Voltage injection of DVR mainly depends on the power rating of DVR, types of sag and types of load[12]. To inject the voltage to the line during sag events, generally three methods are followed: Pre sag compensation, In-phase compensation and Phase advance compensation.

Pre Sag Compensation: In this method both voltage magnitude and phase angle are compensated. System voltage is tracked by control unit and if there is any disturbances in voltage then DVR injects voltage equal to difference between voltage at pre sag and sag voltage. But in this method injected active power can't be controlled and it is determined by external conditions of the system[12, 13]. This method is needed higher rated energy storage device. Pre-sag compensation method is recommended for non-linear loads. Negative sequence voltage can't be detected in this method and hence it causes phase oscillation for single phase fault [12]. Pre-sag compensation method is shown in Fig. 4.

*In-Phase Compensation:*In this method,DVR voltage is injected in phase with system voltage during sag event. Therefore, in this method only voltage magnitude is compensated. Phase angle of pre-sag voltage and sagvoltage is different in it [12, 13]. But in this method, low rating of energy storage device is sufficient as only

magnitude is compensated. This method is recommended for linear loads. In-phase compensation method is shown in Fig. 5.

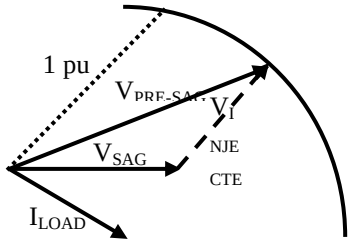

Fig. 4 Pre-Sag Compensation Method

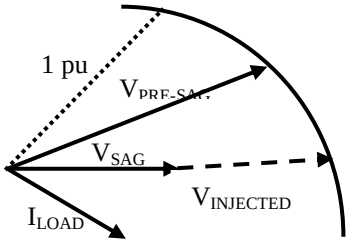

Fig. 5 In-phase Compensation Method

*Phase Advance Compensation:*In pre-sag and in-phase compensation methods, active power is injected to improve voltage profile during sag. Since injection power depends on energy storage capacity therefore restoration time of system is restricted in these methods. Therefore for controlling the injection active power, phase advance compensation technique is used[4, 12].

In phase advance compensation method, voltage is injected perpendicular to the load current, this made active power zero. Therefore in this method, instead of active power, only reactive power is injected and it reduces the consumption of energy. This method is only suitable for a particular sag events because all the sag events can't be mitigated without active power[4, 12].

V. CONCLUSION

Voltage sag is the common power quality problem in power system. It affects the industrial, commercial and even residential sensitive loads. Dynamic Voltage restorer is used as voltage sag conditioning. In this paper, configuration of DVR is described. Different components of DVR are studied in DVR configuration. Modes of operation of DVR are also described in this paper. Three different compensation techniques are presented in this paper along with their applications.

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