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Power Quality Improvement Using DVR (Dynamic Voltage Restorer)

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Abstract—
Power quality problem is major concern major today's time. It has become a necessity with the introduction of new complex devices in Restructured power system,. Power quality problem include a nonstandard voltage, current or frequency that causes failure of Consumer equipments. Some of the major problems are power sag and swell. This paper Emphasizes on the use of dynamic voltage restorer (DVR) in order to deal with voltage sags and swells in low voltage systems. Dynamic Voltage Restorer can provide the most cost effective solution to deal with the voltage sags and swells that is needed by customer. The Dynamic Voltage Restorer (DVR) is a fast, flexible and is better solution to power quality problems.

Keywords—
DVR (Dynamic Voltage Restorer), Power Quality, Voltage Sag, Voltage Swell.

I. INTRODUCTION

Power quality is need of today's environments where there is demand of electricity; power quality can be greatly influenced by principle factors like quality of service being provided. One of the greatest problems being faced by end user today is power quality problems. Presently, the main cause of power quality problems is because of various fault conditions. These Power quality problems cause voltage sag, voltage swell, transients, voltage interruption and harmonics. These problems may lead to the tripping, shutdown of commercial, domestic and industrial equipment.

Dynamic voltage restorer (DVR) can provide better solution to deal with voltage sag by having the voltage quality level, necessary. It is now being used as the active solution for dealing with power quality problems.

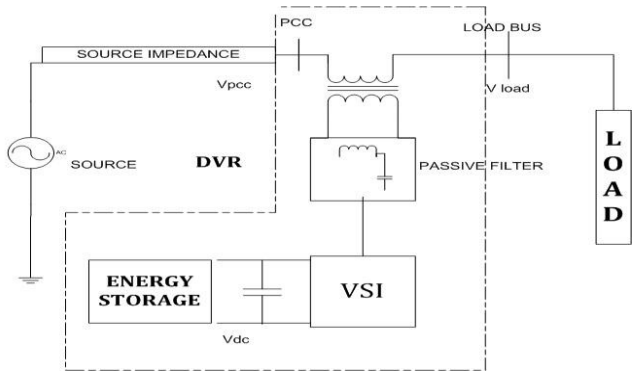

Fig. I. Basic Structure of A DVR

II. DVR (DYNAMIC VOLTAGE RESTORER)

The basic construction of a DVR is shown in Fig. I.

(i) *Energy Storage Unit:*

Energy storage unit is responsible for energy storage in DC form. Flywheels, Batteries, superconducting magnetic energy storage (SMES) and super capacitors could be used as energy storage devices. It is supplies the real power system requirements when DVR is used for compensation.

(ii) *Capacitor:*

DVR has a large DC capacitor to ensure a proper DC voltage input to Inverter.

(iii) *Inverter:*

Inverter system is used to convert dc into ac. Voltage source inverter (VSI) having low voltage and high current with step up transformer is used for conversion purpose in the DVR Compensation technique

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(iv) *Passive Filters:*

Filters convert PWM inverted waveform into a sinusoidal waveform easily. This can done by eliminating the unneeded harmonic components generated by VSI action. Higher orders harmonic components distort the compensated output voltage.

(v) *By-Pass Switch:*

It is used to save the inverter from high current in the presence of conditions which are not required. When a fault or a short circuit occurs, DVR changes its state to bypass condition mode where the VSI inverter is protected from over current flowing through the power switches.

(vi) *Voltage Injection Transformers:*

For voltage injection purpose, either three single-phase transformer units or one three phase transformer unit can be used for purpose of voltage injection .

Principal on which DVR works is to transfer the voltage sag compensation value from DC side of the inverter to the injected transformer after filter. The compensation capacity of a DVR depends on the voltage injection capability and the active power that can be supplied by the DVR to the system. When disturbance occurs, active power or energy should be injected to the distribution system from DVR. A DC system, which is connected to the inverter input, contains a large capacitor for storing energy. During faulty conditions It provides reactive power to the load. The capacitor terminal voltage decrease when the energy is drawn from the energy storage capacitors. Therefore, there is a min limit for voltage required below which the inverter of the DVR cannot provide the require voltage thus, size and rating of capacitor plays a very important role for DVR power circuit.

III. Causes And Effects Of Power Quality Problems

The various power quality problems are as under:

1. *Transients*- A transient event is a short-lived burst of energy in a system caused by a sudden change of state.

2. *Voltage sags*- A voltage sag or voltage dip is a short interval reduction in rms voltage which can be caused by a short circuit, overload or starting of electric motors.

A voltage sag happens when the rms voltage reduces between 10 and 90 percent of nominal voltage for one-half cycle to one minute

3. *Voltage swells*- Voltage swell, which is a sudden increase in voltage, happens when a heavy load turns off in a power system.

4. *Voltage interruption*- Interruptions can be classified as short-duration or long-duration variation. The term interruption‖ is often used to refer to short-duration interruption, They are described by their duration since the voltage magnitude is always less than 10% of nominal.

5. *Harmonics*- Due to non linear loads harmonics is the integral multiple of frequencies voltages and currents in an electric power system. Harmonic frequencies in *the* power grid are main causes of power quality problems.

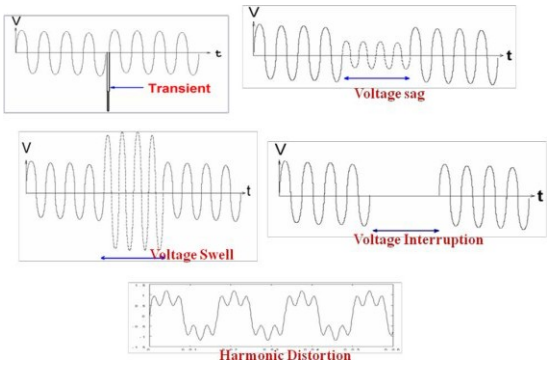

Fig. II. Power Quality Problems

Causes of Power Quality Problems:

- Transient – Due to Lightning, Turning major equipment on or off, back to back capacitor energization.
- Voltage Sags – Due to starting of large Motors, Energization of heavy loads, incorrect VAR compensation.
- Voltage Swells – Energizing a large capacitor bank, Switching off a large load, incorrect VAR compensation
- Interruption – Faults (Short circuit), Equipment failures, Control malfunctions (attempting to isolate electrical problem).

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- Harmonics – IT equipment, Variable frequency drives, Electro Magnetic Interference from appliances, fluorescent lighting, Arc Furnace (Any non linear load).

Effects of Power Quality Problems:

- Transient – Tripping, Processing error, Data loss, hardware reboot required, Component failure.
- Voltage Sags--Dim lights, Equipment shutdown, Data error, shrinking display screens, Memory loss.
- Voltage Swells –Bright lights, Data error, shrinking display screens, Memory loss.
- Interruption – Faults, Equipment failures, Control malfunctions
- Harmonics – Line current increases, Losses increase, transformer and neutral conductor heating leading to reduced equipment life span.

IV. DVR Operating States

1. During a voltage sag/swell on the line: The DVR injects the difference between the pre-sag and the sag voltage, by supplying the real power requirement from the energy storage device together with the reactive power. The maximum injection capability of the DVR is limited by the ratings of the DC energy storage and the voltage injection transformer ratio. In the case of three single-phase DVRs the magnitude of the injected voltage can be controlled individually. The injected voltages are made synchronized (i.e. same frequency and the phase angle) with the network voltages.

2. During the normal operation: As the network is working under normal condition the DVR is not injecting any voltages to the system. In that case, if the energy storage device is fully charged then the DVR operates in the standby mode or otherwise it operates in the self-charging mode. The energy storage device can be charged either from the power supply itself or from a different source.

3. During a short circuit or fault in the downstream of the distribution line: In this particular case the by-pass switch is activated to provide an alternate path for the fault currents. Hence the inverter is protected from the flow of high fault current through it, which can damage the sensitive power electronic components.

V. DVR Compensation Techniques

The compensation control technique of the DVR is the method used to track the supply voltage and synchronized that with the pre-sag supply voltage during a voltage sag/swell in the upstream of distribution line. Generally voltage sags are associated with a phase angle jump in addition to the magnitude change. Therefore the control technique adopted should be capable of compensating for voltage magnitude, phase shift and thus the wave shape. But depending on the sensitivity of the load connected downstream, the level of compensation of the above parameters can be altered. Basically the type of load connected influences the compensation strategy. For example, for a linear load, only magnitude compensation is required as linear loads are not sensitive to phase angle changes.

Further when deciding a suitable control technique for a particular load, the limitations of the voltage injection capability and the size of the energy storage device should be considered.

Compensation is achieved through real power and reactive power injection. Depending on the level of compensation required by the load, three types of compensation methods are defined and discussed below namely pre-sag compensation, in-phase compensation and energy optimization technique.

The circuit for a simple power system with a DVR is shown in Figure III below. The supply voltage, Load voltage, Load current and the voltage injected by the DVR are denoted by Vs , Vload , Iload and VDVR respectively.

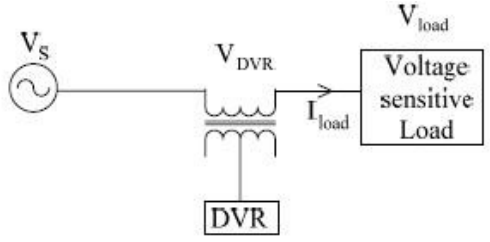

Fig III. Simple Power System Using a DVR

In a system under the normal condition, the supply voltage (Vs) is identified as pre-sag voltage and denoted by Vpre-sag. In such state since the DVR is not injecting any voltage to the system, load voltage (V_{load}) and the supply voltage will be alike. During the voltage sag, magnitude and the phase angle of the supply voltage can be altered and it is denoted by V_{sag}. The DVR is in functioning state in this case and the voltage injected will be VDVR. If the voltage sag is fully compensated by the DVR, the load voltage during the voltage sag will be Vpre-sag.

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