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An Overview of Dynamic Voltage Restorer for Voltage Profile Improvement

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Abstract - The use of sensitive electronic equipment has increased now a days which has lead to power quality problems. The various power quality disturbances are transients, interruptions, voltage sag, voltage swell, voltage collapse, harmonics etc. To solve these power quality problems various custom power devices are used. Dynamic voltage restorer (DVR) is a custom power device used for the Compensation of voltage sag and swell. In this paper an overview of DVR, its components, functions, compensating strategies and control methods are reviewed in detail and the compensating strategies are compared.

Keywords: Power quality, Dynamic voltage restorer, compensating strategies, control methods.

I. INTRODUCTION

The various power quality problems are due to the increasing use of non linear and power electronic loads. Harmonics and voltage distortion occur due to these loads. The power quality problems can cause malfunctioning of sensitive equipments, protection and relay system[1]. Distribution system is mainly affected by voltage sag and swell power quality issue. Short circuits, lightning strokes, faults and inrush currents are the causes of voltage sags. Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers, single line to ground fault on the system lead to voltage swells. Voltage sag is a decrease of the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0,5 cycle to 1 minute. Voltage swells are momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds[2]. The use of custom power devices is one of the most efficient method to mitigate voltage sag and swells. There are many custom power devices. Each of which has its own benefits and limitations[6]. Custom power device(CPD) is a powerful tool based on semiconductor switches concept to protect sensitive loads if there is a disturbance from power line. Among the several novel CPD, the Dynamic Voltage Restorer (DVR) are now becoming more established in industry to mitigate the impact of voltage disturbances on sensitive loads.

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Power quality in the distribution system can be improved by using a custom power device DVR for voltage disturbances such as voltage sags, swells, harmonics, unbalanced voltage and etc [10].The Dynamic Voltage Restorer (DVR) is a device that detects the sag or swell and connects a voltage source in series with the supply voltage in such a way that the load voltage is kept inside the established tolerance limits[15] It is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR also has added other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations.

II. DYNAMIC VOLTAGE RESTORER

Dynamic voltage restorer is a static var device that has applications in a variety of transmission and distribution systems. It is a series compensation device, which protects sensitive electric load from power quality problems such as voltage sags, swells, unbalance and distortion through power electronic controllers that use voltage source converters (VSC). The first DVR was installed in North America in 1996 - a 12.47 kV system located in Anderson, South Carolina. Since then, DVRs have been applied to protect critical loads in utilities, semiconductor and food processing. Today, the dynamic voltage restorer is one of the most effective PQ devices in solving voltage sag problems.

The basic principle of the dynamic voltage restorer is to inject a voltage of required magnitude and frequency, so that it can restore the load side voltage to the desired amplitude and waveform even when the source voltage is unbalanced or distorted. Generally, it employs a gate turn off thyristor (GTO) solid state power electronic switches in a pulse width modulated (PWM) inverter structure. The DVR can generate or absorb independently controllable real and reactive power at the load side. In other words, the DVR is made of a solid state DC to AC switching power converter that injects a set of three phase AC output voltages in series and synchronism with the distribution line voltages.

Dynamic voltage restorer is a series connected device designed to maintain a constant RMS voltage across a sensitive load[12]. The structure of DVR is shown in Fig.1.

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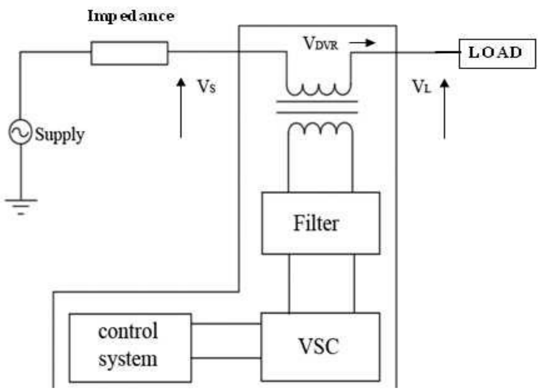

Fig:1 Schematic diagram of DVR

The DVR consists of:

A. Voltage Source Converter (VSC):

Voltage Source Converter converts the dc voltage from the energy storage unit to a controllable three phase ac voltage. The inverter switches are normally fired using a sinusoidal Pulse Width Modulation scheme.

B. Injection Transformer:

Injection transformers used in the DVR plays a crucial role in ensuring the maximum reliability and effectiveness of the restoration scheme. It is connected in series with the distribution feeder.

C. Passive Filters:

Passive Filters are placed at the high voltage side of the DVR to filter the harmonics. These filters are placed at the high voltage side as placing the filters at the inverter side introduces phase angle shift which can disrupt the control algorithm.

D. Energy storage device/ Control system:

Examples of energy storage devices are dc capacitors, batteries, super-capacitors, superconducting magnetic energy Storage and flywheels. The capacity of energy storage device has a big impact on the compensation capability of the system. Compensation of real power is essential when large voltage sag occurs.

III. VOLTAGE INJECTION METHODS

Voltage injection or compensation methods by means of a DVR depend upon the limiting factors such as; DVR power ratings, various conditions of load, and different types of voltage sags. Some loads are sensitive towards phase angel jump and some are sensitive towards change in magnitude and others are tolerant to these. Therefore the control strategies depend upon the type of load characteristics. There are four different methods of DVR voltage injection which are

i. Pre-sag compensation method

ii. In-phase compensation method

iii. In-phase advanced compensation method

iv. Voltage tolerance method with minimum energy injection

A. Pre-Sag/Dip Compensation :

The pre-sag method tracks the supply voltage continuously and if it detects any disturbances in supply voltage it will inject the difference voltage between the sag or voltage at PCC and pre-fault condition, so that the load voltage can be restored back to the pre-fault condition. Compensation of voltage sags in the both phase angle and amplitude sensitive loads would be achieved by pre-sag compensation method. In this method the injected active power cannot be controlled and it is determined by external conditions such as the type of faults and load conditions.

VDVR = Vprefault – Vsag

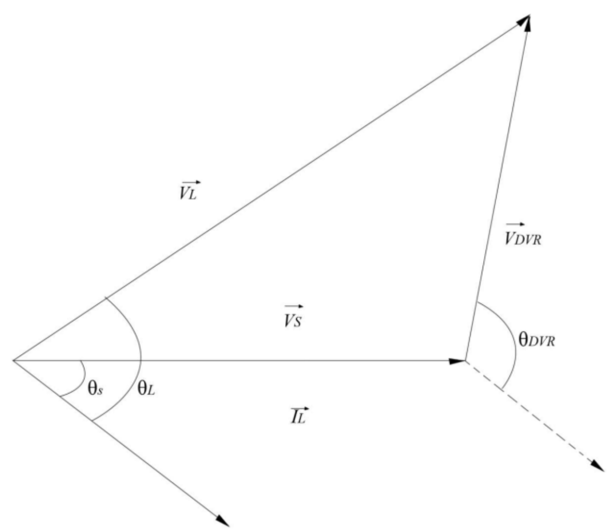

Fig2 : Pre sag compensation

B. In phase Compensation method :

This is the most straight forward method. In this method the injected voltage is in phasewith the supply side voltage irrespective of the load current and pre-fault voltage. The phase angles of the pre-sag and load voltage are different but the most important criteria for power quality that is the constant magnitude of load voltage are satisfied. One of the advantages of this method is that the amplitude of DVR injection voltage is minimum for a certain voltage sag in comparison with other strategies.

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C. In Phase advanced compensation :

In this method the real power spent by the DVR is decreased by minimizing the power angle between the sag voltage and load current. In case of pre-sag and in-phase compensationmethod the active power is injected into the system during disturbances. The active power supplyis limited stored energy in the DC links and this part is one of the most expensive parts of DVR.The minimization of injected energy is achieved by making the active power component zero byhaving the injection voltage phasor perpendicular to the load current phasor.In this method the values of load current and voltage are fixed in the system so we canchange only the phase of the sag voltage. IPAC method uses only reactive power andunfortunately, not al1 the sags can be mitigated without real power, as a consequence, this method is only suitable for a limited range of sags.

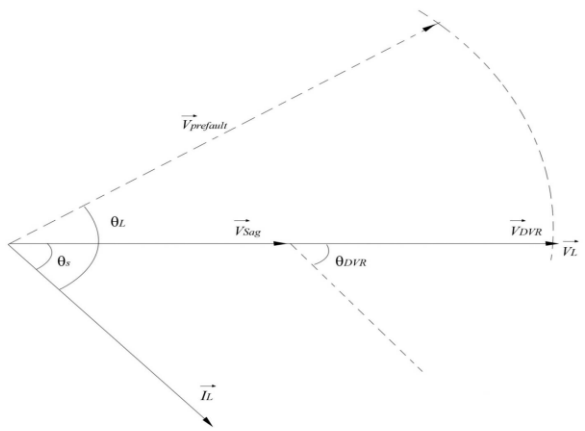
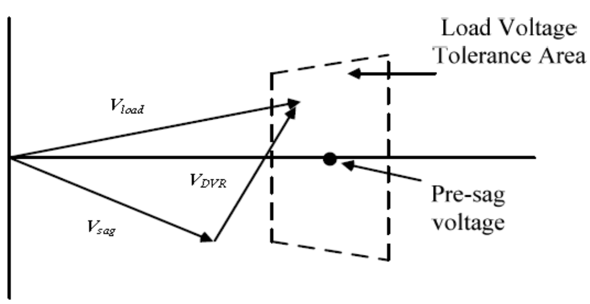


Fig 3 : In Phase compensation method

D. Voltage tolerance method with minimum energy injection:

A small drop in voltage and small jump in phase angle can be tolerated by the load itself. If the voltage magnitude lies between 90%-110% of nominal voltage and 5%-10% of nominal state that will not disturb the operation characteristics of loads. Both magnitude and phase are the control parameter for this method which can be achieved by small energy injection.



IV. CONTROL TECHNIQUES

A. Linear controllers :

The three main voltage controllers, which have been proposed in literature, are Feedforward (open loop), Feedback (closed loop) and Multi-loop controller [13]. The feed-forward voltage controller is the primary choice for the DVR, because of its simplicity and fastness. The supply voltage is continuously monitored and compared with a reference voltage; if the difference exceeds a certain tolerance, the DVR injects the required voltage. The drawback of the open loop controller is the high steady state error. In the feedback control, the load voltage is measured and compared with the reference voltage, the missing voltage is supplied by the DVR at the supply bus in a feedback loop. This controller has the advantage of accurate response, but it is complex and time-delayed. Multi-loop control is used with an outer voltage loop to control the DVR voltage and an inner loop to control the load current. This method has the strengths of feed-forward and feedback control strategies, on the expense of complexity and time delay.

B. Non-linear Controllers:

It appears that the nonlinear controller is more suitable than the linear type since the DVR is truly a non-linear system due to the presence of power semiconductor switches in the inverter bridge. The most non-linear controllers are the Artificial Neural Networks (ANN), Fuzzy Logic (FL) and Space Vector Pulse Width Modulation (SVPWM) [16]. ANN control method has adaptive and self-organization capacity. The ANN has inherent learning capability that can give improved precision by interpolation. FL controllers are an attractive choice when precise mathematical formulations are not possible. When a FL controller is used, the tracking error and transient overshoots of PWM can be considerably reduced. SVPWM control strategy is to adopt a space vector of the inverter voltage to get better performance of the exchange is gained in low switching frequency conditions.

V. CONCLUSION

A review of performance of DVR is presented in this paper. By the use of different control techniques it is viewed that DVR is suitable for voltage sag and swell mitigation. The basic structure of DVR, its operation, compensation methods and control techniques are discussed in detail. DVR has the advantage of low cost, require less computational efforts and its control is simple as compared to other methods. DVR provides simpler implementation for voltage profile improvement. Linear controllers provide simpler operation and less computational efforts when compared to other methods.

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