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FAULT CURRENT INTERRUPTION IN A RADIAL DISTRIBUTION SYSTEM BY USING THE DVR

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ABSTRACT: With the increase in use of electronic equipments there has been rise in problems related to power quality. Power quality deals with utilization of electric energy from the distribution system successfully without interference or interruption. The various power quality disturbances are transients, interruptions, voltage sag, voltage swell, voltage collapse, harmonics etc. These power quality related problems can be solved with the help of various custom power devices. Dynamic voltage restorer (DVR) is a custom power device used for the compensation of voltage sag and swell. It can provide the most commercial solution to mitigation voltage sag by injecting voltage as well as power into the system. In this paper an overview of DVR, its components, functions, compensating techniques and control methods are reviewed in detail and the compensating techniques are compared.

Keywords: Power quality, Dynamic voltage restorer, control methods, compensating techniques

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. 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. 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. CONTROL STRATEGY

Different type of voltage sag and load conditions can limit the possibility of compensating voltage sag. Therefore, the control strategy depends on the type of load characteristics. There are three different methods to inject DVR compensating voltage.

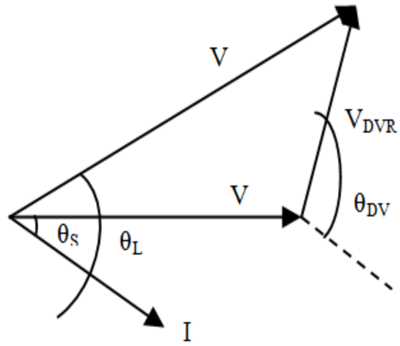

fig 1.0 Prefault compensation method

B. In-phase Compensation

In-phase voltage compensation method restores voltage to be in phase with the voltage sag. In other words, the phase angle will be same as the angle of sagged voltage while the voltage magnitude is restored to pre-fault value. Fig 3 shows the single-phase vector diagram for in-phase compensation method

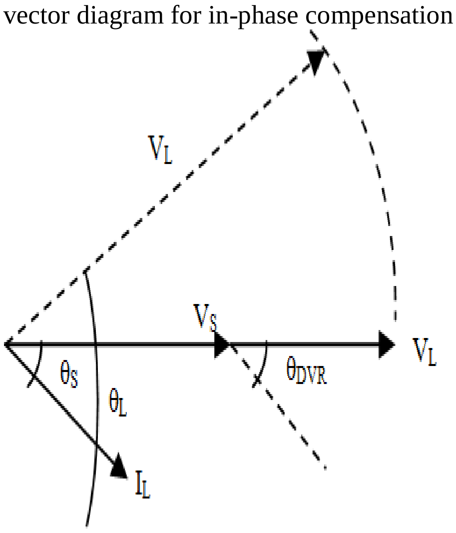

Fig 2.0 In-phase compensation method

For restore the voltage sag or disturbance by applying pre-sag and in-phase compensation method, must inject active power to loads. The disadvantage of the active power is the amount of injection which depends on the stored energy in the storage unit. DVR restoration time and performance are important in pre-sag and in-phase compensation methods, due to the limited energy storage of the capacity unit.

III. VOLTAGE INJECTION METHODS

Voltage injection or compensation methods by means of a DVR depend upon DVR power ratings, various conditions of load, and different types of voltage sags. Some loads are sensitive towards phase angle jump while some are sensitive towards change in magnitude. Therefore the control strategies depend upon the type of load characteristics. There are four different methods of DVR voltage injection which are

1. Pre-sag compensation method
2. In-phase compensation method
3. In-phase advanced compensation method
4. Voltage tolerance method with minimum energy injection

A Pre-Sag Compensation:

The pre-sag method tracks the supply voltage continuously and compensates load voltage during fault to pre-fault condition When it detects any disturbances in supply voltage it injects 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 This method is achieved by using a fault detector to freeze the output from the Phase Locked Loop (PLL) circuit, when the fault occurs.
The voltage of DVR is given as:
VDVR = Vprefault – Vsag

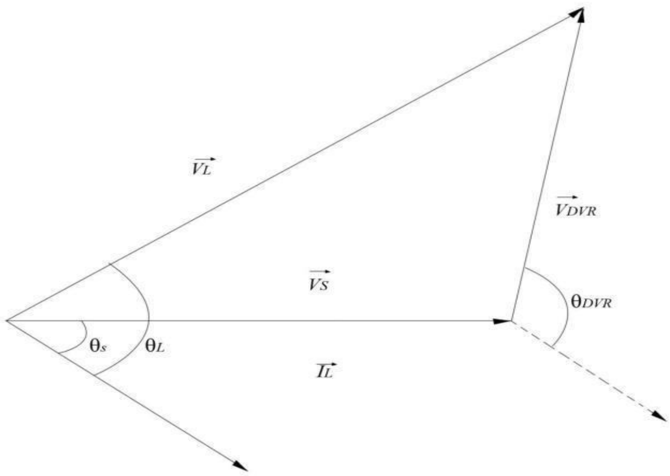

Fig 3 : Pre sag compensation

B. In phase Compensation method:

It is the most straight forward method in which the injected voltage is in phase with 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 is that 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 certain voltage sag in comparison with other strategies.

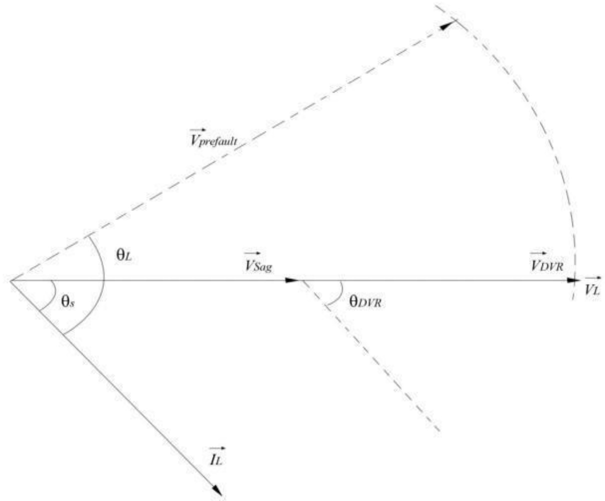

Fig 4 : In Phase compensation method

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 compensation method the active power is injected into the system during disturbances. The active power supply is 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 by having 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 can change only the phase of the sag voltage. IPAC method uses only reactive power and unfortunately, not al1 the sags can be mitigated without real power, as a consequence, this method is only suitable for a limited range of sags.

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.

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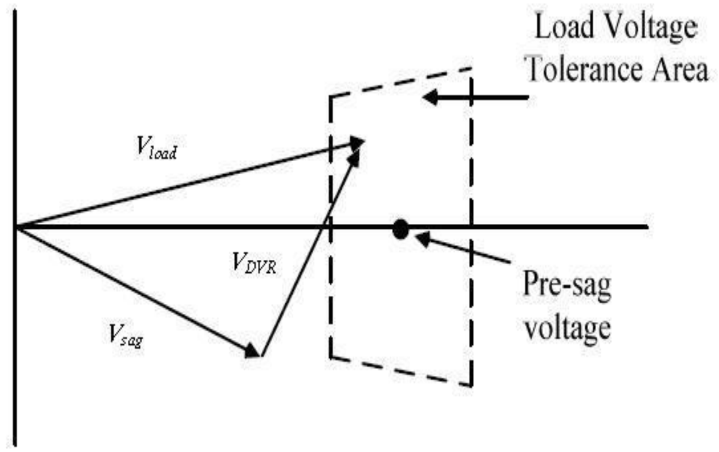
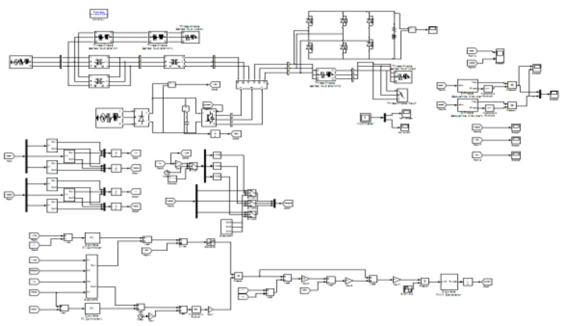
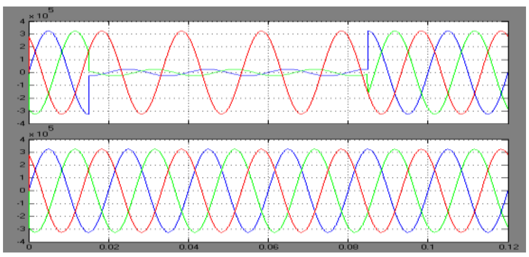


Fig. 5. Voltage tolerance method with minimum energy injection





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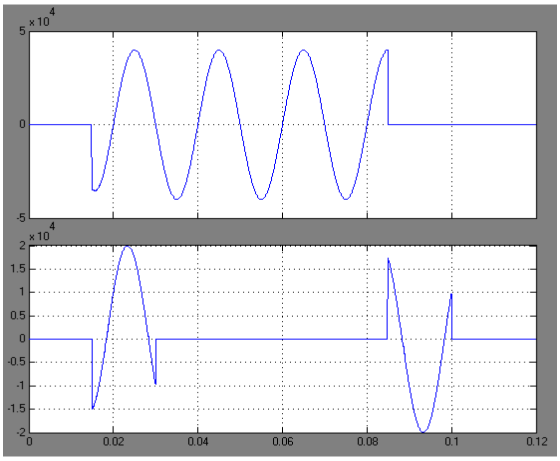

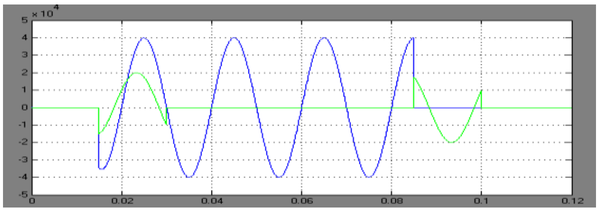

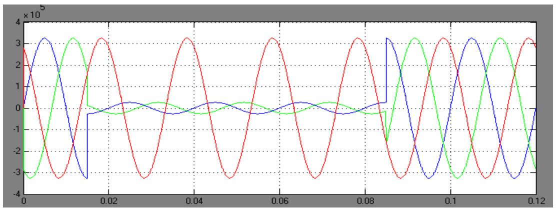

IV. CONCLUSION

In this paper, the operation and capability of DVR used in system network is introduced. Detailed components and working principles of DVR were explained. Methods of control strategies for voltage compensation for three different types of control systems were illustrated in detail. Calculations of DVR were derived in order to minimize the input of real power. Based on the calculation, the magnitude of injection of voltage and current (real power and reactive power) by DVR can be obtained. The capability of the simulation with and without DVR, were demonstrated on 30-bus generic distribution system. The efficiency of the mitigation devices can be seen from the results obtained with and without DVR.

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