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Maintaining Constant Voltage at load by using Dynamic Voltage Restorer(DVR)

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Abstract

Increasing complexity of power system, there so many disturbances occur in the system. That disturbance created power quality issue in the system. This power quality problem increases power losses, so the power requirement of consumers is not fulfilled.This issues are compensated by using some custom power devices like DVR, D-statcom, etc. Dynamic voltage restorer is series compensating devices, which is used to inject compensated voltage into system. This paper presents an overview of the custom power devices like- Dynamic voltage restorer (DVR) and also simulate this model in MTLAB Simulink.

Keywords: Power quality, custom power devices, DVR, FACTS.

I INTRODUCTION

Power quality is a very important issue due to its impact on electricity suppliers, equipment manufactures and customers. Power quality is described as the variation in waveforms of voltage, current and frequency in a power system. It refers to a wide variety of electromagnetic phenomena that characterize the voltage and current at a given time and at a given location in the power system. Both, electric utilities and end users of electrical power are becoming increasingly concerned about the quality of electric power. Sensitive loads such as computers, programmable logic controllers (PLC), variable speed drives (VSD) etc. need high quality supplies. Power quality is an umbrella concept for multitude of individual types of power system disturbances [4].

Quality of supply may be categorized in three parts as reliability, power quality and custom service. Power distribution systems, should ideally provide their customers with an uninterrupted flow of energy with a smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in practice, power systems, especially distribution systems, have numerous nonlinear loads, which significantly affect the quality of the power supply. As a result of these nonlinear loads, the purity of the supply waveform is lost in many places. This ends up producing many power quality problems [2].

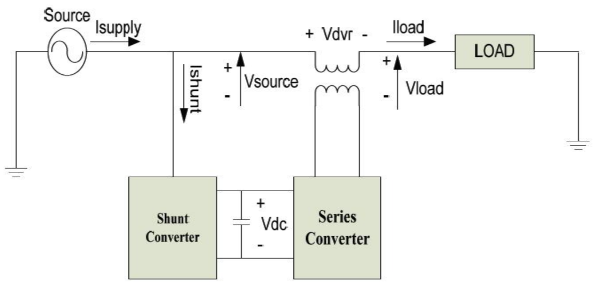
The ultimate reason that we are interested in power quality is economic value. There are economic impacts on utilities, their customers, and suppliers of load equipment.

An important percentage of all power quality problems are of the voltage-quality type where the deviation of the voltage waveform from its ideal form matters. The best known disturbances of the voltage waveform are voltage sags and swells, harmonics, inter harmonics and voltage imbalances [4].

II DYNAMIC VOLTAGE REGULATOR

A. Dynamic Voltage Restorer

The DVR, a custom power device, is connected in series with the distribution system. It injects voltage into the system in order to compensate the voltage dip in the load side and maintains the load voltage at nominal magnitude[8].



1. DVR with no energy storage and supply side connected converter

B. Voltage Source Inverter (VSI)

A voltage source inverter is a power electronic device consisting of a switching device and a storage device such as battery. VSI can generate a sinusoidal voltage at any required magnitude, phase and frequency. VSI is used to temporarily generate the part of the supply voltage that is missing. IGBT is the newer compact switching device that is used with VSI for DVR operation.

C. Injection/Boost transformer

It consists of two side voltage one is high voltage side and low voltage side. The high voltage side is normally connected in series with the distribution network while the power circuit of the DVR is connected to the low voltage side. The DVR transfer the voltage which is required for the compensation from DC side of the inverter to the distribution network through the injection transformer. The transformer also helps in isolating the line from the DVR system.

D. Passive/LC Filters

The filtering scheme in a DVR can be placed either on the high-voltage side or the inverter side of the series injection transformer. The advantage of the inverter-side filter is that it is on the low-voltage side of the series transformer and is closer to the harmonic source. Using this scheme, the high-order harmonic currents are prevented from penetrating into the series transformer, thus reducing the voltage stress on the transformer.

E. Energy storage device

For SMES, batteries and capacitors, which are dc devices, solid-state inverters are used in the power conversion system to accept and deliver power. For flywheels, which have rotating components, ac-to-ac conversion is performed. Batteries provide rapid response for either charge or discharge, but the discharge rate is limited by chemical reaction rates so that the available energy depends on the discharge rate.

III POWER TOPOLOGIES OF DVR

The function of a DVR is maintaining the voltage supply at the load to its nominal value. There are so many DVRs topologies proposed by the researchers. Normally during disturbances in a network, the DVR injects an appropriate voltage to recover the voltage at the load. In this situation the DVR need to have exchanges active and reactive power with the surrounding system.

Based on Energy Storage, there are two topologies,

- Topology with no energy storage
- Topology with energy storage

A. Topology with no energy storage

Topologies with no Energy storage can be divided into two systems configurations which are system 1 and system 2. The difference between System 1 and System 2 in DVR topologies with no energy storage is that, in system 1 the energy source is from the incoming supply through a passive shunt converter connected to the supply side.

While in system 2 energy is taken from the grid connected side through a passive shunt converter connected to the load side.

B. Topology with energy storage

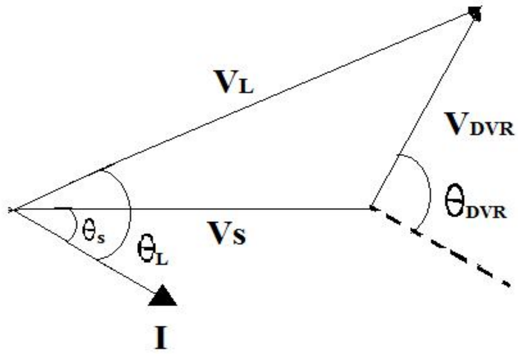
The stored energy storage supplies the real power requirements of the system when DVR is used for compensation process when there is a disturbance in the distribution system. Flywheels, lead acid batteries, Superconducting Magnetic Energy Storage (SMES) and super capacitor can be used as energy storage devices.

In voltage disturbances mitigation such as voltage sag the performance of the DVR can be improved by using energy storage even though storing electrical energy is expensive.

IV 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. There are four different methods of DVR voltage injection which are[12]

A. **Pre-sag/dip compensation method**



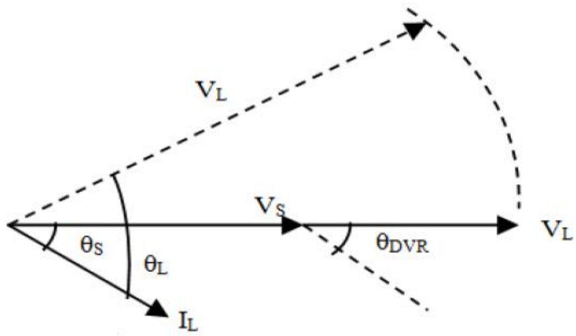
2. Single-phase vector diagram of the PDC method

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

B. **In-phase compensation method**

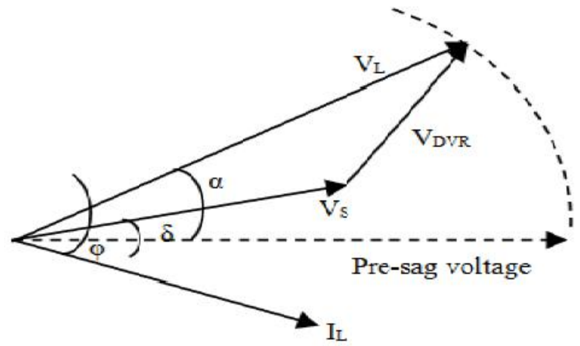
This is the most straight forward method. In this method the injected voltage is in phase with the supply side voltage irrespective of the load current and pre-fault voltage. The phase angles of the pre-sag and load voltage are different but the most important criteria for power quality that is the constant 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.



3. In-phase compensation method

C. In-phase advanced compensation method

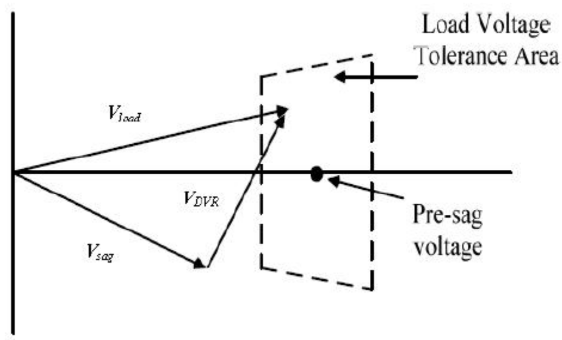
In this method the real power spent by the DVR is decreased by minimizing the power angle between the sag voltage and load current. In case of pre-sag and in-phase compensation method the active power is injected into the system during disturbances. The active power supply is limited stored energy in 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.



4. In-phase advance 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.

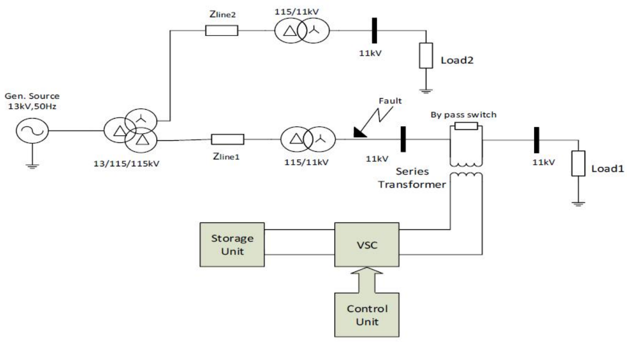


5. Voltage tolerance method with minimum energy injection

V MATLAB SIMULATIONS

There are many techniques to mitigate the voltage sag/swell and to minimize the loading of power system transmission line. Among them the best way is to use a device at the point of interest to regulate the voltage. These control strategies are simulated in MATLAB SIMULINK.

A. MATLAB Modelling of DVR



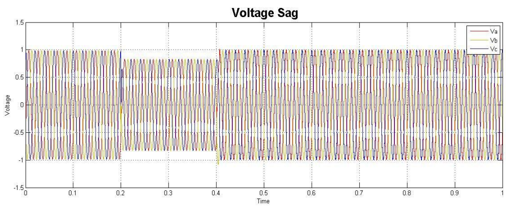
6. Single line diagram of the test system for DVR

Single line diagram of the test system for DVR [Fig.6] is composed by a 13 kV, 50 Hz generation system, feeding two transmission lines through a 3- winding transformer connected in Y/S/S, 13/115/115 kV. Such transmission lines feed two distribution networks through two transformers connected in S/Y, 115/11 kV. The DVR is simulated to be in operation only for the duration of the fault.

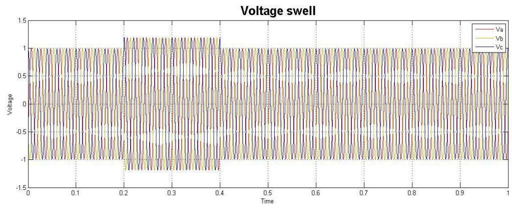
VI SIMULATION RESULTS

When fault occurs in the system then voltage sag and swell creates in the system. To verify the working of DVR for voltage compensation, a fault with the fault resistance 0.66 ohm is applied at 11kV transmission line of T/F-2 for time duration of 200 ms. The waveforms of voltage sag and swell of the system without DVR is shown in Fig.7.

The first simulation shows of three phase voltage sag is simulated. The simulation started with the supply voltage 20% sagging as shown in fig. 7(a). In fig. 7(a) also shows a 20% voltage sag initiated at 0.2s and it is kept until 0.4s, with total voltage sag duration of 0.2s. Similarly, the simulation started with the supply voltage 20% swell as shown in fig. 7(b). In fig. 7(b) also shows a 20% voltage swell initiated at 0.2s and it is kept until 0.4s, with total voltage sag duration of 0.2s.



(a)

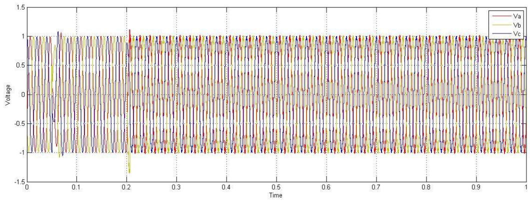


(b)

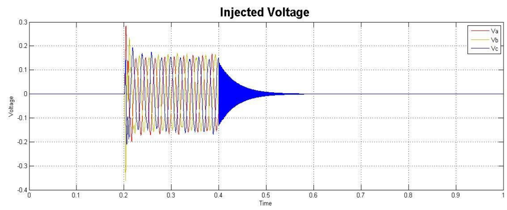
7. The waveforms of load voltage of the system without DVR, (a) voltage sag and (b) voltage swell.

For Voltage Sag

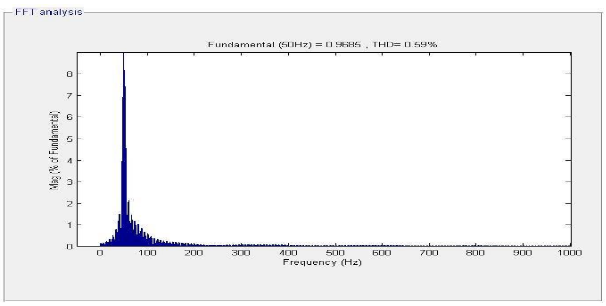
Fig. 8 (a) and (b) show the corresponding load voltage with sag compensation and the voltage injected by the DVR. As a result of DVR, the load voltage is kept at 1 p.u. Its corresponding load voltages are shown in fig.8 (a) where it is possible to see that the compensation method is keeping the load voltages constant at 1 p.u. Fig.8 (c) shows the FFT analysis after the compensation where THD of the load voltage is 0.59%.



(a)



(b)



(c)

8. Waveforms of during Voltage sag with DVR, (a) Load voltage, (b) Injected voltage and (c) FFT analysis.

VII CONCLUSION

To maintain the quality of power the problems affecting the power quality should be treated efficiently. Among the different power quality problems, voltage sag and swell is one of the major one affecting the performance of the end user appliances. By using Dynamic voltage restorer (DVR) , it is possible to reduce power quality problems. DVR is series compensation devices which are injected voltage into the system to maintain a constant voltage at load side. From the results, it shows the FFT analysis after the compensation where THD of the load voltage is 0.59%.

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