DYNAMIC VOLTAGE RESTORER BASED ON HYSTERESIS VOLTAGE CONTROL FOR VOLTAGE SAG MITIGATION AND HARMONICS ELIMINATION

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***Abstract*-Power quality is one of major issues in the present era. Custom power devices are used to overcome power quality issues. Dynamic voltage restorer (DVR) is one of the most effective custom power devices that can compensate voltage sags, swells and harmonics coming from supply side. Main components of DVR are: Voltage Source Converter (VSC), injection transformer, passive filter, energy storage unit, DC link, and control system. There are many control techniques used for the operation of dynamic voltage restorer. This paper presents the hysteresis voltage control technique for generation of gating pulses for inverter of dynamic voltage restorer. The system is modeled in MATLAB/Simulink environment and simulations are carried out to verify improvement in power system operation.**

Keywords-Power Quality, Custom Power Devices, DVR, Hysteresis Voltage Control.

I. INTRODUCTION

Among various power quality problems (sags, swells, harmonics) voltage sag is the most severe issue [8]. In order to overcome these power quality problems the custom power devices are introduced recently. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most effective modern custom power device used in power distribution networks. DVR is a series connected power electronic device and is normally installed in a power distribution system between the supply and the critical load [11]. DVR is used to mitigate voltage distortion and unbalance present in source voltage and make load voltage perfectly balanced and regulated. The DVR can compensate voltage sags by means of the injection of inverter voltage through the series transformer. In this way, the voltage on the sensitive load remains almost unchanged providing safe operation of the loads. The DVR has following advantages: 1) It has capacity to manage the active power flow. 2) It has less cost 3) It requires less maintenance.

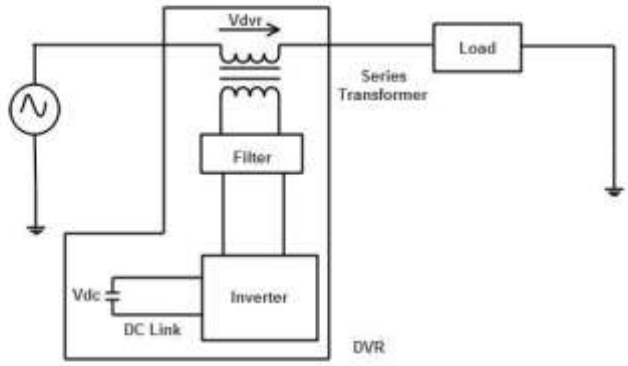

Fig.1. Schematic block diagram of DVR

There are many control schemes used for the operation of dynamic voltage restorer**.** These control schemes influences the design of DVR. The Hysteresis Voltage Control can provide fast transient response. It is best explained in further section.

II. DYNAMIC VOLTAGE RESTORER

A. Basic configuration of DVR

1. **Boost/injection transformer:** It connects the DVR to the distribution network via the HV-windings and transforms and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage.

2. **Hysteresis Voltage controller:** Hysteresis voltage controller is used to generate switching pulses for operation of VSI. The switching pulses is obtained by the error which we get from comparing the reference voltage with the actual voltage.

3. **Voltage source inverter:** VSI temporarily replaces the supply voltage or to generate the part of the supply voltage which is missing.

4. **DC-link and Energy Storage:** A DC-link voltage is used by the VSC to synthesize an AC voltage into the grid. During voltage dips active power injection is necessary to restore the supply voltages.

B. Operating Modes of DVR:

1. **Protection mode:** If the current present on the load side exceeds a reasonable value because of short circuit, the DVR could be separated from the system by utilizing the bypass switches and supplying a different path for current.
2. **Standby mode (voltage injected by DVR is zero):** In standby mode there is no switching of semiconductors occurs and through the converter the series injection transformers low voltage winding is shorted .i.e. in this mode voltage injected by DVR is zero.
3. **Injection/Boost mode:** In the Injection/Boost mode the DVR is injecting a compensating voltage through the series transformer due to the detection of a disturbance in the supply voltage.

III. CONTROL ALGORITHM

In this work, Hysteresis Band Voltage control is used to control load voltage and determine switching pulses for inverter switches. The main functions of a controller in a DVR are the detection of voltage sag/swell and harmonics distortion events in the system, computation of the compensating voltage, generation of gating pulses for converter and termination of the switching pulses when the event has passed.

The hysteresis voltage control of DVR mainly consists of two parts, which are: (1) the detection of the start and the end of the voltage sag and (2) hysteresis voltage controller. There are bands above and below the reference voltage. If the difference between the reference and inverter voltage reaches to the upper (lower) limit, the voltage is forced to decrease (increase). The hysteresis voltage control has the advantage of variable switching frequency, very fast response and simple operation than other control method. Fig.2 explains the main control diagram of dynamic voltage restorer with hysteresis voltage controller. It mainly consists of IGBT inverter, Energy storage, injection transformer and the hysteresis voltage controller. The series active power filter is controlled such that it injects voltages which cancel out the distortions and unbalances present in the supply voltages and thus making the voltages at the load terminal perfectly balanced and sinusoidal with the desired amplitude. In other words, the sum of the supply voltage and the voltage injected by series active power or DVR makes the desired voltage at the load terminals. Reference signal is the desired load voltage.

To generate injected voltages, sensed series APF output voltages are compared with reference signals and these signals are given to the hysteresis controller along with the sensed series APF output voltages. The output of the hysteresis controller controls the switches of the VSI of the series APF. Hysteresis voltage controller generates the switching signals such that the voltage at the load becomes the desired sinusoidal reference voltage. Therefore, the injected voltage across the series transformer through the ripple filter cancels out the harmonics and unbalance present in the supply voltage.

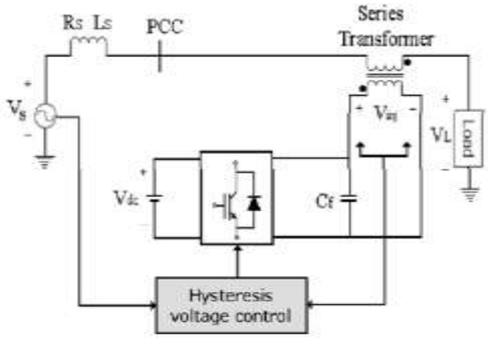

Fig.2. Structure of DVR with Hysteresis Voltage Control Technique

IV.SIMULATION RESULTS

- **SAG:**

The first scenario shows the DVR performance during voltage sag. In this case, programmable voltage source is used as a supply voltage to simulate voltage sag. A sag voltage starts at 0.07s and ends at 0.3s. In fig.3.the first graph shows sag in supply voltage. The second graph indicates compensated load voltage after voltage injection and the third graph shows the injected voltage.

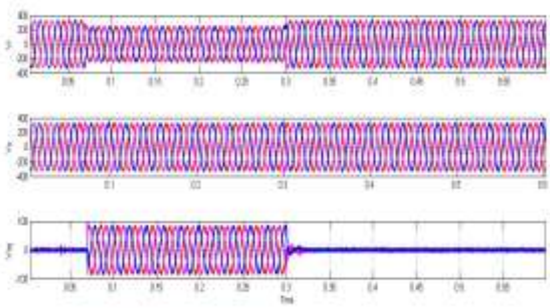

Fig.3 Supply voltage, Load voltage and injected voltage waveforms

Fig.3. shows that DVR compensated 100 percentage of voltage sag condition. The general equation for voltage sag compensation by the DVR can be written as

$$V_{sag} = \sqrt{V_s^{\,2} + V_{pcc}^{\,2} - 2V_s\,\mathrm{V_{pcc}}\cos(\theta_s - \theta_{pcc})}$$

- **HARMONICS:**

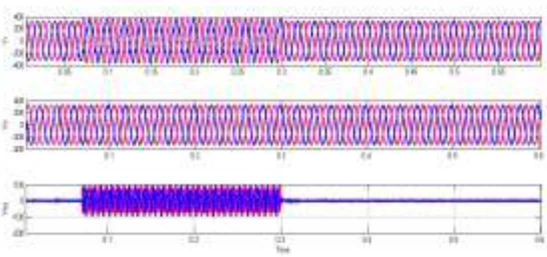

Fig. 4 Supply voltage, Load voltage and injected voltage waveforms

In the second scenario, the DVR operation under harmonic distortion is verified. By the use of programmable voltage source, the fifth and seventh harmonics are programmed to be superimposed on the fundamental signal of the source. The magnitudes of the fifth and seventh harmonics are 25% and 5% of supply phase voltage, respectively. The distorted supply voltage, the load voltage which is maintained at constant level and the injected voltage which is produced by the DVR in order to compensate the load voltage are shown in figure.4. The THD of the supply voltage is 22.04% whereas THD of the load voltage is 1.65%. This indicates that the DVR can eliminate harmonic distortion. The load voltage is sinusoidal and constant in magnitude due to the injection of opposite harmonic voltage by DVR. The results from the system simulation demonstrate the effectiveness of the DVR in providing balanced, sinusoidal voltages at the load bus, even though the supply voltages are unbalanced and contain appreciable harmonics.

THD ANALYSIS:

Total harmonic distortion, or THD, is the summation of all harmonic components of the voltage or current waveform compared against the fundamental component of the voltage or current wave:

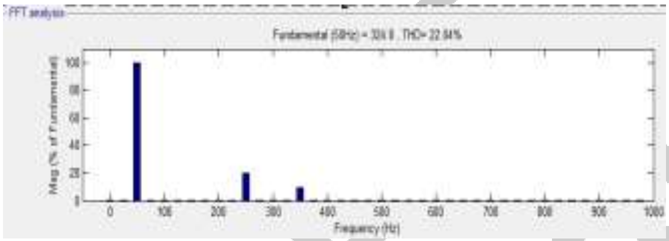

Fig.5.THD of source voltage

In Fig.5.THD of the source voltage is shown and it is 22.04%. In Fig.6.THD of the load voltage is shown and it is 1.65%. THD of the load voltage is reduced because DVR is maintaining the load voltage constant.

$$THD_{v}\% = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} \times 100$$

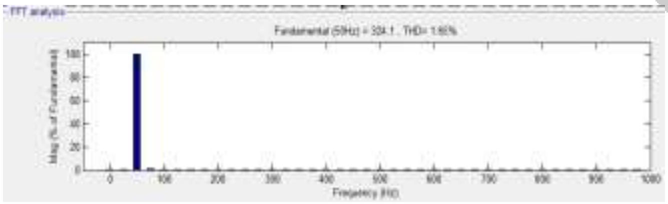

Fig.6.THD of load voltage

V. CONCLUSION

DVR is used to mitigate voltage distortion and unbalance present in source voltage and make load voltage perfectly balanced and regulated. In this work, a DVR based on hysteresis voltage control has been modelled using Matlab SimPowerSystem toolbox. Simulation of the DVR under different conditions including voltage sag and distorted supply voltage has been carried out to verify the ability of DVR to maintain the load voltage around nominal value. Simulation results show the DVR abilities in harmonic elimination and voltage sag mitigation. It is concluded that DVR successfully mitigated voltage sags and harmonic distortions and perfectly restored the load voltage.

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