Development and Simulation of Dynamic Voltage Restorer for Voltage SAG Mitigation using PWM Firing Control Strategy

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Abstract—The Dynamic voltage restorer is custom power device. Which is utilized to mitigate the voltage at load terminals. Power quality is one of major concerns in the present era. It has become important, especially, with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end use equipments. One of the major problems deal at here is the power sag. To solve this problem, custom power devices are used. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. DVR injects required voltage in series with supply voltage through injection transformer for correcting voltage amplitude, phase and harmonic component into line. This paper presents development, simulation and analysis of a Dynamic Voltage Restorer (DVR) using MATLAB/SIMULINK. To enhance the voltage sag restoration capability of the DVR, this paper deals with the development of a control structure using a Discrete PWM pulse generator. Results obtained shows that the developed DVR has good capability to starch the voltage level during voltage sag conditions.

Index Terms—Voltage sag, power quality improvement, dynamic voltage restorer, pulse width modulation.

I. INTRODUCTION

Nowadays, modern industrial devices are mostly based on electronic devices such as programmable logic controllers and electronic drives. The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics. Voltage dips are considered to be one of the most severe disturbances to the industrial equipments.

Voltage support at a load can be achieved by reactive power injection at the load point of common coupling. The common method for this is to install mechanically switched shunt capacitors in the primary terminal of the distribution transformer. The mechanical switching may be on a schedule, via signals from a supervisory control and data acquisition (SCADA) system, with some timing schedule, or with no switching at all. The disadvantage is that, high speed transients cannot be compensated. Some sags are not corrected within the limited time frame of mechanical switching devices. Transformer taps may be used, but tap changing under load is costly.

Another power electronic solution to the voltage regulation is the use of a dynamic voltage restorer. DVRs are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state switches for compensating voltage sags/swells. The DVR applications are mainly for sensitive loads that may be drastically affected by fluctuations in system voltage.

II. DYNAMIC VOLTAGE RESTORER

This section presents a brief description about the basic principles of a dynamic voltage restorer used in transmission system. Figure (1) shows the basic elements of a DVR in a single-phase representation.

The basic elements of a DVR are:

1 Converter: The converter is most likely a Voltage Source Converter (VSC), which Pulse Width modulates (PWM) the DC from the DC-link/storage to AC-voltages injected into the system.

Figure (1) Basic elements of a DVR in a single-phase representation

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2 **Line-filter:** The line-filter is inserted to reduce the switching harmonics generated by the PWM VSC.

3 **Injection transformer:** In most DVR applications the DVR is equipped with injection transformers to ensure galvanic isolation and to simplify the converter topology and protection equipment.

4 **DC-link and energy storage:** A DC-link voltage is used by the VSC to synthesize an AC voltage into the grid and during a majority of voltage dips active power injection is necessary to restore the supply voltages.

5 **By-pass equipment:** During faults, overload and service a bypass path for the load current has to be ensured. Illustrated in Figure (1) as a mechanical bypass and a thyristor bypass.

6 **Dis-connection equipment:** To completely disconnect the DVR during service etc.

### III. CONTROL STRUCTURE OF DEVELOPED DVR

**A. Discrete PWM-Based Control Scheme**

In order to mitigate the simulated voltage sags in the test system of each compensation technique, also to compensate voltage sags in practical application, a discrete PWM-based control scheme is implemented, with reference to DVR. The aim of the control scheme is to maintain a constant voltage magnitude at the sensitive load point, under the system disturbance. The control system only measures the rms power.

Measurement is required. Figure (2) shows the DVR controller scheme implemented in MATLAB/SIMULINK. The DVR control system exerts a voltage angle control as follows: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point. The PI controller processes the error signal and generates the required angle $\delta$ to drive the error to zero, for example; the load rms voltage is brought back to the reference voltage.

It should be noted that, an assumption of balanced network and operating conditions are made. The modulating angle $\delta$ or delta is applied to the PWM generators in phase A, whereas the angles for phase B and C are shifted by 240° or -120° and 120° respectively.

\[
V_A = \sin(\omega t + \delta) \\
V_B = \sin(\omega t + \delta - \frac{2\pi}{3}) \\
V_C = \sin(\omega t + \delta + \frac{2\pi}{3})
\]
B. Test system for DVR
Single line diagram of the test system for DVR is shown in figure (3), composed by a 13 kV, 50 Hz generation system, feeding two transmission lines through a three phase winding transformer connected in Y/Δ/Δ, 13/115/115 kV. Such transmission lines feed two distribution networks through two transformers connected in Δ/Y, 115/11 kV. To verify the working of DVR for voltage compensation a fault is applied at point X at resistance 0.66 U for time duration of 200 ms. The DVR is simulated to be in operation only for the duration of the fault. Figure (4) shows the actual simulation model developed for the proposed work.

IV. Simulation and Results
The first simulation was done with no DVR and a three phase fault is applied to the system with fault resistance of 0.66 U for a time duration of 200 ms. The second simulation is carried out at the same scenario as above but a DVR is now introduced at the load side to compensate the voltage sag occurred due to the three phase fault applied. Figure (5) shows the rms voltage at load point when the system operates with no DVR and a three phase fault is applied to the system. When the DVR is in operation the voltage interruption is compensated almost completely and the rms voltage at the sensitive load point is maintained at normal condition shown in figure (6).

Figure (4) Actual simulation model developed for DVR

Figure (5) P.U. Voltage at load point, with three phase fault, without DVR

Figure (IV) P.U. Voltage at load point, with three phase fault, with DVR

Now figure (7) shows the firing pulses generated by pulse width modulator to compensate the effect of voltage sag. Moreover figure (8) and figure (9) shows plots of three phase voltage at load point without and with developed DVR.
Figure (7) Three phase Voltage at load point, with three phase fault, without DVR

Figure (8) Three phase Voltage at load point, with three phase fault, with DVR

Figure (9) Input voltage at injection transformer, without DVR
V. CONCLUSION

This Paper addressed the most critical voltage sag restoration problem often reduces power quality in transmission line system. Compensation technique of custom power electronic device DVR has been successfully developed and simulated in MATLAB/SIMULINK. A PWM-based control scheme was implemented. As opposed to fundamental frequency switching schemes already available in the MATLAB/SIMULINK, this PWM control scheme only requires voltage measurements. This characteristic makes it ideally suitable for low-voltage custom power applications.

REFERENCES


Suman Giri received the B.E degree in electrical Engineering from the Swami Vivekanand University, Bhilai in 2009, where she is currently pursuing the M.E degree in electrical engineering (Power Electronics)

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