Power Quality Improvement Using D-Statcom

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Abstract: A power quality problem occurs due to the nonstandard voltage, current or frequency this result in failure of user equipments. So the present work is to identify the prominent concerns in this area and hence the measures that can enhance the quality of the power are recommended. This paper deals with the enhancement of voltage sag/swell, harmonic distortion and low power factor using Distribution Static Compensator (D-SATACOM) This paper deals with the performance, analysis of, operating principles of a new generation of power electronics based equipment called (D-STATCOM) aimed at enhancing the reliability, and quality of power flow in low voltage distribution network. The model is based on the Voltage Source Converter (VSC) principle. The D-STATCOM injects a current into the system to mitigate the voltage sags. LCL Passive Filter was then added to D-STATCOM to improve harmonic distortion and low power factor. The simulations were performed using MATLAB SIMULINK version R2009b.

Index Terms— D-STATCOM, Power Quality, Voltage sag, Voltage source converter, harmonic distortion.

1. Introduction

With the advent of power semiconductor switching devices, like thyristors, GTO's (Gate Turn off thyristors), IGBT's (Insulated Gate Bipolar Transistors) and many more devices, control of electric power has become a reality. Such power electronic controllers are widely used to feed electric power to electrical loads, such as adjustable speed drives (ASD's), furnaces, computer power supplies, HVDC systems etc. Power Quality (PQ) has become an important issue since many loads at various distribution ends like adjustable speed drives, process industries, printers; domestic utilities, computers, microprocessor based equipments etc. have become intolerant to voltage fluctuations, harmonic content and interruptions.

2. Power Quality

Power quality is defined as the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment. There are many different reasons for the enormous increase in the interest in power quality. Some of the main reasons are: Electronic and power electronic equipment has especially become much more sensitive. Equipment has become less tolerant of voltage quality disturbances, production processes have become less tolerant of incorrect operation of equipment, and companies have become less tolerant of production stoppages. The main perpetrators are interruptions and voltage dips, with the emphasis in discussions and in the literature being on voltage dips and short interruptions. High frequency transients do occasionally receive attention as causes of equipment malfunction.

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Basic Level</th>
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<tbody>
<tr>
<td>Magnitude variations-Voltage shall be between 207 and 244 V</td>
<td></td>
</tr>
<tr>
<td>Voltage unbalance</td>
<td>Up to 2%</td>
</tr>
<tr>
<td>Voltage fluctuations-Not exceeding the flicker curve</td>
<td>In between 49.5 and 50.5 Hz</td>
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3. SHUNT ACTIVE FILTERS

The objectives and functions of active power filters have expanded from reactive power compensation, voltage regulation, etc. to harmonic isolation between utilities and consumers, and harmonic damping throughout the distribution as harmonics propagate through the system.

AF’s can be classified based on the topology used as series or shunt filters, and unified power quality conditioners use a combination of both. Combinations of active series and passive shunt filtering are known as hybrid filters. Fig 3.1 is an example of an active shunt filter, which is most widely used to eliminate current harmonics, reactive power compensation (also known as STATCOM, and balancing unbalanced currents. It is mainly used
at the load end, because current harmonics are injected by nonlinear loads. It injects equal compensating currents, opposite in phase, to cancel harmonics and/or reactive components of the nonlinear load current at the point of connection. It can also be used as a static VAR generator (STATCOM) in the power system network for stabilizing and improving the voltage profile.

4. DSTATCOM

The DSTATCOM is a power quality device, which can protect the industries against the sags and swells. Usually sags and swells are related to remote faults. A DSTATCOM compensates for these voltage disturbances provided that supply grid does not get disconnected entirely through breaker trips. It can exchange both active and reactive power with the distribution system by varying the amplitude and phase angle of the converter voltage with respect to the line terminal voltage.

4.1 Principle and Operation of DSTATCOM

A D-STATCOM (Distribution Static Compensator), which is schematically depicted in Figure 4.1, consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power.

\[ I_{sh} = I_L - I_s = I_L - \left( V_{th} - V_L \right)/ Z_{th} \quad \text{-------- 4.1} \]

The complex power injection of the D-STATCOM can be expressed as,

\[ S_{sh} = V_L I_{*sh} \quad \text{-------- 4.3} \]

4.2 Control Scheme for the DSTACOM

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system only measures the r.m.s voltage at the load point, i.e., no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. Since custom power is a relatively low-power application, PWM methods offer a more flexible option than the Fundamental Frequency Switching (FFS) methods favored in FACTS applications. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses.

"Fig. 4.2 Indirect PI controller"

The sinusoidal signal \( V_{control} \) is phase-modulated by means of the angle \( \delta \),

\[ i_A = \sin (\omega t + \delta) \quad \text{-------- 4.4} \]

\[ V_B = \sin (\omega t + \delta - 2\pi/3) \quad \text{-------- 4.5} \]

\[ V_C = \sin (\omega t + \delta + 2\pi/3) \quad \text{-------- 4.6} \]
Fig. 4.3 Phase-Modulation of the control signal

The modulated signal $V_{\text{control}}$ is compared against a triangular signal in order to generate the switching signals for the VSC valves. The main parameters of the sinusoidal PWM scheme are the amplitude modulation index of signal, and the frequency modulation index of the triangular signal. The amplitude index is kept fixed at 1 pu, in order to obtain the highest fundamental voltage component at the controller output.

$$m = \frac{V_{\text{control}}}{V_{\text{Tri}}} = 1 \text{ pu}$$

$V_{\text{control}}$ is the peak amplitude of control signal, $V_{\text{Tri}}$ is the peak amplitude of triangular signal.

The switching frequency is set at 1080 Hz. The frequency modulation index is given by,

$$m_f = \frac{f_s}{f_1} = \frac{1080}{60} = 18$$

Where $f_1$ is the fundamental frequency.

5. SIMULINK MODEL FOR THE TEST SYSTEM

6. CONCLUSION

This paper has presented the power quality problems such as voltage dips, swells and interruptions, consequences, and mitigation techniques of custom power electronic device D-STATCOM. The design and applications of D-STATCOM for voltage sags, interruptions and swells, and comprehensive results are presented. A new PWM-based control scheme has been implemented to control the electronic valves in the two-level VSC used in the D-STATCOM.

7. REFERENCES


