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Power Quality Improvement Using D-Statcom

R.Vinotha
Student, Department of Electrical and Electronics Engineering

Mrs.Poongodi.K.K
Assistant Professor, Department of Electrical and Electronics Engineering

Abstract:
This paper deals the systematic procedure of the modeling and simulationof a Distribution STATCOM (D-STATCOM) for power quality problems voltage sag, swell and harmonics based on PulseWidth Modulation (PWM) technique.A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or a mis-operation of end user equipment's.The major problems dealt here is the voltage sag, swell and harmonics. To solve this problem, custom power devices are used. One of those devices is the Distribution STATCOM (D-STATCOM), which is the most efficient and effective modern custom power device used in power distribution networks. D-STATCOM injects a current in to the system to correct the voltage sag, swell and harmonics.The control of the Voltage Source Converter (VSC) is done with the help of PWM.The proposed system is modeled and simulated using MATLAB/SIMULINK software.

Key words: *Distribution STATCOM (D-STATCOM),MATLAB/SIMULINK, Power quality problems, Pulse Width Modulation (PWM), Voltage sag and swell, Voltage Source Converter (VSC).*

1.Introduction

In recent days, modern industrial devices are mostly based on the 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 equipment’s. Voltage support at a load can be achieved by reactive power injection at the load point of common coupling. D-STATCOM injects a current into the system to correct the voltage sag and swell. Harmonics are reduced by using PWM technique. These power quality devices are power electronic converters connected in parallel or series with the lines and the operation is controlled by a digital controllers. The modeling of these complex systems that contains both power circuits and control systems can be done different bases. One of the power electronic solution to the voltage regulation is the use of a D-STATCOM.D-STATCOM is a class of custom power devices for providing reliable distribution power quality. They employ a shunt of voltage boost technology using solid state switches for compensating voltage sags and swells. The DSTATCOM applications are mainly for sensitive loads that may be drastically affected by fluctuations in the system voltage.

2.Power Quality Problems

The power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices make them more susceptible to the quality of power supply.

For some sensitive devices, a momentary disturbance can cause scrambled data, interruption in communication, system crashes and equipment failure etc. A power voltage spike can damage valuable components. Power quality problems encompass a wide range ofdisturbances such as voltage sags, swells, flickers, harmonicdistortion, impulse transients, and interruptions.

2.1.Sources Of Power Quality Problems

- Large motor starting
- Different faults
- Lightning

The above problems cause high current and large drops in lines and leads to voltage sag.

- Capacitive Loads
- Open circuits

These problems lead to voltage swell.

2.2.Causes

- Rural location remote from power source
- Unbalanced load on a three phase system
- Switching of heavy loads
- Long distance from a distribution transformer with interposed loads
- Unreliable grid systems
- Equipment's not suitable for local supply

2.3.Solutions to Power Quality Problems

There are two approaches to mitigate the power quality problems. The solution to the power quality can be done from customer side or from utility side; first approach is called load conditioning,which ensures that the equipment is less sensitiveto power disturbances, allowing the operation even under significant voltage distortion. The other solution is to install line conditioning systems that suppress or counteract the power system disturbances. Currently they are based on PWM converters and connect to low and medium voltage distribution system in shunt or in series. Series active power filters must operate in conjunction with shunt passive filters in order to compensate load current harmonics.Shunt active power filtersoperate as a controllable current source and series active power filters operate as a controllable voltage source. Both schemes are implemented in preferable with voltage source PWM inverters, with a dc bus having a reactive element such as a capacitor. However, with the restructuring of power sector and with shifting trend towards distributed and dispersed generation, the line conditioning systems or utility side solutions will play a major role in improving the inherent supply quality; some of the effective and economic measures can be identified as following

- Lightning and Surge Arrester: Arrester is designed for lightning protection of transformers, but is not limited to sufficient voltage limiting for protecting sensitive electronic control circuits from voltage surges.
- Thyristor Based Static Switch: The static switch is a versatile device for switching a new element in to the circuit when the voltage support is needed. It

has a dynamic response time of about one cycle. To correct quickly for voltage spikes, sags or interruptions, the static switch can used to switch oneor moredevises such as capacitor, filter, alternate power line, energy storage systems etc. The static switch can be used in the alternate power line applications.

- Energy Storage Systems: Storage system can be used to protect sensitive protection equipment from shutdowns caused by voltage sags or momentary interruptions. These are usually dc storage systems such as UPS, batteries, superconducting magnet energy storage (SMES), storage capacitors or even fly wheels driving dc generators. The output of these devices can be supplied to the system through an inverter on a momentary basis by a fast acting electronic switch. Enough energy is fed to the system to compensate for the energy that would be lost by the voltage sag or interruption.

3.Distribution Statcom

A D-STATCOM, which is schematically depicted in Fig.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. Such configuration allows the device to absorb or generate controllable active and reactive power. The Distribution STATCOM (D-STATCOM) has been utilized mainly for regulation of voltage, correction of power factor and elimination of current harmonics. Such a device is employed to provide continuous voltage regulation using an indirectly controlled converter.

In this paper, the D-STATCOM is used to regulate the voltage at the point of connection. The control is based on PWM

and only requires the measurement of the RMS voltage at the load point.

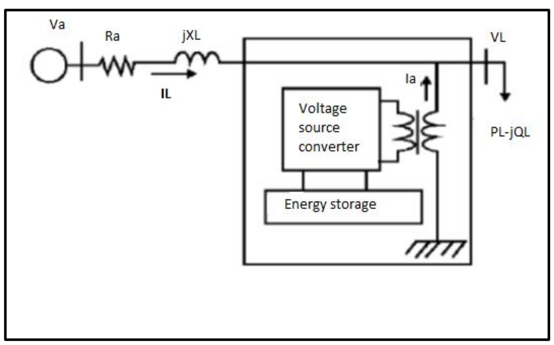

Figure 1: Schematic representation of the D-STATCOM

3.1.Equations Related to D-STATCOM

From the Fig.1, the shunt injected current I_{SH} corrects the voltage sag by adjusting the voltage drop across the system impedance Z_{TH} The value of I_{SH} can be controlled by adjusting the output voltage of the converter. The shunt injected current I_{SH} can be written as,

$I_{SH}=I_L-I_S$ (1)

Where,

$I_S = (V_H-V_L)/Z_{TH}$ (2)

Therefore,

$I_{SH}=I_L-I_S= I_L-((V_H-V_L)/Z_{TH})$ (3)

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

$S_{SH} = V_L I_{SH}^*$ (4)

It may be mentioned that the effectiveness of the D-STATCOM in correcting voltage sag depends on the value of Z_{TH} or fault level of the load bus. When the shunt injected current I_{SH} is kept in quadrature with V_L, the desired voltage correction can be achieved without injecting any active power into the system. On the other hand, when the value of I_{SH} is minimized, the same voltage correction can be achieved with minimum apparent power injection into the system.

3.2.Voltage Source Converter (VSC)

A voltage source converter (VSC) is a power electronic device, which can generate a three-phase ac output voltage is controllable in phase and magnitude. These voltages are injected into the ac distribution system in order to maintain the load voltage at the desired voltage reference. VSCs are widely used in adjustable speed drives, but can also be used to mitigate the voltage sags and swells. The VSC is used to either completely replacing the voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between the nominal voltage and the actual voltage. The converter is normally based on the some kind of energy storage, which will supply the converter with a dc voltage.

4.PWM Based Control

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbance. The control system only measures the RMS voltage at the load point i.e., no reactive power measurements are required. The VSC switchingstrategy is based on sinusoidal PWM technique which offers simplicity and good response. The PI controller process identifies the error signal and generates the required angle δ to drive the error to zero, i.e., the load RMS voltage is brought back to the reference voltage. Inthe PWM generator, the sinusoidal signal $V_{control}$ is compared against a triangular signal (carrier) in order to generate the switching signals for the VSC values. The main parameters of the sinusoidal PWM scheme are the amplitude modulation index Ma of signal $V_{control}$, and the frequency modulation index M_f of the triangular signal. The amplitude index M_a is kept fixed at 1 pu.

$M_a = V_{control} / V_{tri}$ (5)

Where, M_a is amplitude index.

$V_{control}$ is the Peak amplitude of the signal.

V_{tri} is the peak amplitude of the Triangular signal.

In order to obtain the highest fundamental voltage component at the controller output, the switching frequency is set at 450 Hz. The frequency of modulation index is given by,

$M_f = F_s/F_f$ (6)

Where, M_f is the frequency of modulation index.

F_s, is the switching frequency.

F_f, is the fundamental frequency.

In this paper balanced network and operating conditions are assumed. Themodulation angle δ is applied to the PWM generator in phase A. The angle for phases B and C are shifted by 240° and 120°, respectively.

5.Simulation And Results

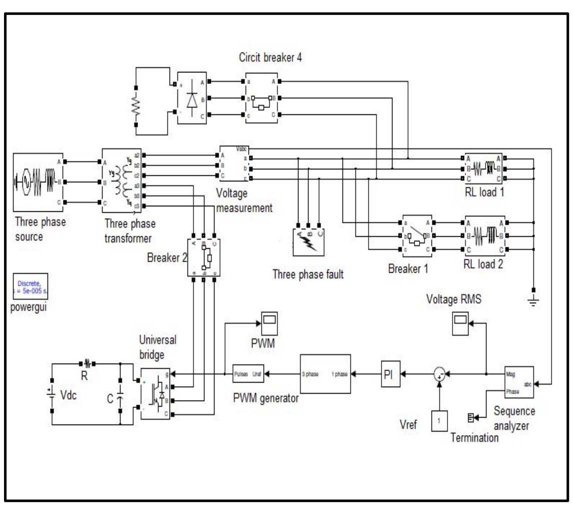

Figure 2: Control and test system implemented in MATLAB/SIMULINK

5.1.D-STATCOM Results For Voltage Swell

The test system composes a 230 kV, 50 Hz generation system, represented by a Thevenin equivalent, feeding into the primary side of a 3-winding transformer. A varying load is connected to the 11 kV, secondary side of the transformer. A two-level D-STATCOM is connected to the 11kV tertiary winding to provide instantaneous voltage support at the load point.Fig.3, shows the Vrms at load point with three phase fault using D-STATCOM.

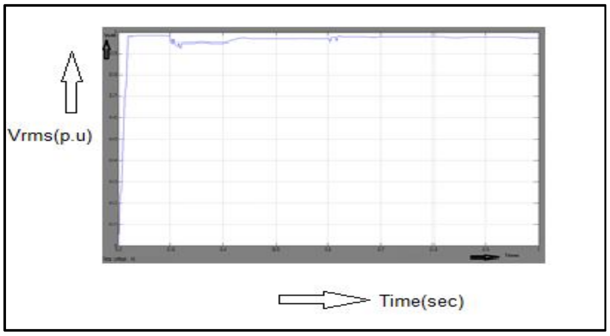

Figure 3: Vrms at load point with 3-phase fault

The simulation contains D-STATCOM and a three phase fault is applied at point A, via a fault resistance of 0.4 ohms, during the period 300-600 ms. the voltage swell at the load point is 30% with respect to the reference voltage.

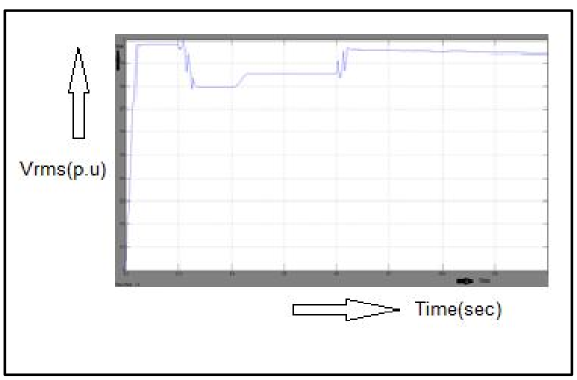

Figure 4: Vrms at load point with L-G fault

Vrms at load point with line to ground fault using DSTATCOM is shown inFig.4, .The simulation contains D-STATCOM and a line to ground fault is applied at point A, via a fault resistance of 0.4 ohms, during the period 300-600 ms.The voltage swell at the load point is 28% with respect to the reference voltage.

5.2.D-STATCOM Results For Harmonics

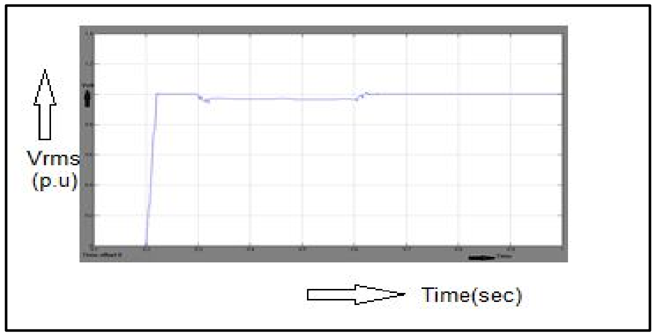

Figure 5: Harmonic reduction for 3-phase fault

Fig.5 shows harmonic reduction for three phase fault using D-STATCOM with 0.4 ohms fault resistance. The three phase fault is injected by using fault resistance. Where, 5% of THD and 3% of individual harmonic have been reduced by using D-STATCOM.

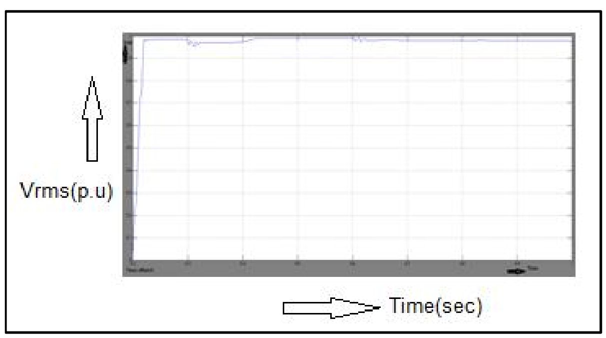

Figure 6: Harmonic reduction for L-G fault

Fig.6 shows harmonic reduction for line to ground fault using D-STATCOM with fault resistance of 0.4 ohms. The line to ground fault injected to the system by using the 0.4 fault resistance. The individual harmonic components are reduced up to 3% by using D-STATCOM.

6.Conclusion

This paper has presented the power quality problems such as voltage swell and harmonics. Compensation techniques of custom power electronic device D-STATCOM was presented. The design and applications of D-STATCOM for voltage swells, harmonics and comprehensive results have been presented. The Voltage Source Converter (VSC) was implemented with the help of Pulse Width Modulation (PWM).The control scheme was tested under a wide range of operating conditions, and it was observed to be very robust in every case. For modeling and simulation of a D-STATCOM by using the highly developed graphic facilities available in MATLAB/SIMULINK were used. The simulations carried out here showed that the D-STATCOM provides relatively better voltage regulation capabilities.

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