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Engineering

COMPARING MULTI-PULSE D- STATCOM AND MULTI-PULSE DVR IN POWER QUALITY IMPROVEMENT

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ABSTRACT This paper aims to model a multi-pulse DSTATCOM and a multi-pulse DVR using a simple PI control scheme in MATLAB/Simulink environment and to study the voltage regulation capabilities of the same. A simple test system with a sensitive RL load is chosen for investigating - pulse. Also, the capabilities of six-pulse and the voltage regulation capabilities of six-pulse and twelve - pulse DVR in regulating the load voltage is studied with a test system subjected to sensitive load as well as unbalanced faults such as line-ground, line-line and double line-ground faults. A comparative study of the performance of six-pulse and twelve-pulse DSTATCOM and DVR with respect to percentage voltage compensation and generated harmonics is also presented.

KEYWORDS : DSTATCOM, DVR, PI control, Power Quality

I. INTRODUCTION

As commercial and industrial customers become more and more reliant on high quality and high reliability electric power, utilities have considered approaches that would provide different option or levels of premium power for those customers who require something more than what the bulk systems can provide. Insufficient power qualities can be caused by [7] failures and switching operations in the network, which mainly result in voltage dips, interruptions and transients and [5] network disturbances from loads that mainly result in flicker, harmonics and phase imbalance.

Momentary voltage sags and interruptions are by far considered to be the most common disturbances that adversely impact electric customer processes operations in large distribution systems [4]. When power quality problems are arising due to non-linear loads, such as arc furnaces, welding operations, voltage flicker and harmonic problems can affect the entire distribution feeders. Several devices have been designed to reduce the impact of these variations.

Custom power is commonly defined as the employment of power electronic or static controllers in distribution systems rated up to 38kV for the purpose of supplying a level of reliability or power quality that is needed by electric power customers who are sensitive to power variations [1]. Each custom power device can be considered to be a type of power conditioning device. In general, power conditioning technology includes all devices used to connect end-user problems in response to voltage sags, voltage interruptions, voltage flicker, harmonic distortion and voltage regulation problems [3].

The solution to the above power quality problems is to use Custom Power devices like DSTATCOM (Distribution Static Synchronous Compensator), DVR (Dynamic Voltage Restorer), UPQC (Unified Power Quality Conditioner) etc. These devices deal with the issues related to power quality using similar control strategies and concepts.

Most of the electricity produced today is generated in large generating stations, which is then transmitted at high voltage to the load centers and transmitted to customers at reduced voltage through local distribution systems. In contrast with the large generating stations distributed generation produce power on a customer's site or at a local distribution network. The relation between distributed generation and power quality is an ambiguous one. In areas where voltage support is difficult, distributed generation can contribute because connecting distributed generation lead to a rise in voltage in the network [2].

At the same time if faults are occurring in the system the distributed generation must be capable of providing the power supply without any problem to the customer. Hence in order to ensure the reliability of the power to the customers it is necessary to install the compensating devices such that these devices provide the required reactive power to the generators during fault instances such that the reactive power drawn from the supply will be nil and the other customers will not be affected[4].

Dynamic Voltage Restorer can compensate voltages at distribution side. When a disturbance occurs and supply voltage deviated from nominal value, DVR supplies voltage for compensation of sag [3]. The DVR applications are mainly for sensitive load that may be drastically affected by fluctuations in the system voltage.

II. POWER QUALITY PROBLEMS

Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in practice, power systems, especially the distribution systems have various nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the supply waveform is lost. This ends up producing many power quality problems.

While power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data.

Power quality is defined as any power problem manifested in voltage, current, or frequency deviations that result in failure or disoperation of custom equipment. Power quality has an economic impact on utilities, their customers, and suppliers of load equipment. The quality of power can have a direct economic impact on many industrial consumers.

A. Solution to Power Quality Problems

The main task of harmonic filter is to keep the harmonic voltage content to the permissible level. There are two types of filter which are being used in order to terminate the power quality problems. They are as follows: 1. Passive filters 2. Active filters. *Passive filters* A combination of inductors, capacitors and resistors designed to eliminate one or more harmonics. The most common variety is simply an inductor in series with a shunt capacitor, which short-circuits the major distorting harmonic component from the system. *Active filters* Any number of sophisticated power electronic devices for eliminating harmonic distortion is the active filters. *Advantages of active filter over passive filter* Inductors can be avoided. Passive filters without inductors cannot obtain a high Q (low damping), but they are often large and expensive (at low frequencies), may have significant internal resistance, and may pick up surrounding electromagnetic signals. The shape of the response, the Q and the tuned frequency can often be set easily by varying resistors, in some filters one parameter can be adjusted without affecting the others. Variable inductances for low frequency filters are not practical.

The amplifier powering the filter can be used to buffer the filter from the electronic components it drives or is fed from, variations in which could otherwise significantly affect the shape of the frequency response.

B. Custom Power Devices

In this chapter, custom power devices namely DSTATCOM and DVR are introduced. The basic principle of operation and applications of these devices towards improving power quality are presented. Custom power focuses on low voltage distribution and it is a technology born in response of poor power quality and reliability of supplying to the customers. With custom power solutions in place, the end user will find tighter voltage regulation, near zero power interruptions and low harmonic voltages.

There are many types of Custom Power Devices. Some of these devices include: Active power filters(APF), Battery Energy Storage Systems(BESS), Distribution Static Compensators(DSTATCOM), Dynamic Voltage Restorer(DVR), Surge Arrester(SA),Super conducting Magnetic Energy Systems(SMES), Static Electronic Tap Changers(SETC),Solid State Transfer Switch(SSTS),Static Electronic Tap Changers(SSFCL),Static Var Compensator (SVC), Thyristor Switched Capacitor(TSC), etc.

II.OBJECTIVES

To model multipulse DSTATCOM and multipulse DVR in MATLAB environment. To develop a simple control strategy incorporating PI and SPWM techniques to enhance the voltage regulation capability of DSTATCOM and DVR. To carry out Harmonics analysis using FFT.

III. DSTATCOM

DSTATCOM is the most important controller for distribution networks. It has been widely used since the 1990s to precisely regulate system voltage, improve voltage profile, reduce voltage harmonics, reduce transient voltage disturbances and load compensation. Rather than using conventional capacitors and inductors combined with fast switches, the DSTATCOM uses a power-electronics converter to synthesis the reactive power output. A DSTATCOM converter is controlled using pulse width modulation (PWM) or other voltage/current-shaping techniques. DSTATCOMs are used more often than STATCOM controllers. Compared to STATCOM, DSTATCOMs have considerably lower rated power and, in consequence, faster power-electronics switches, thus the PWM carrier frequency used in a distribution controller can be much higher than in a FACTS controller. It has a substantial positive impact on the dynamics of the DSTATCOM.

DSTATCOM controllers can be constructed based on both voltage source inverter (VSI) topology and current source inverter (CSI) topology (Fig 2.1). Regardless of topology, a controller is a compound of an array of semiconductor devices with turn off capability (i.e. IGBT, GTO, IGCT etc.) connected to the feeder via a relative small reactive filter. The VSI converter is connected to the feeder via reactor LF and has a voltage source (capacitor CD) on the DC side. On the other side, the CSI converter is connected on the AC side via capacitor CF and has a current source (inductor LD) on the DC side. In practice, CSI topology is not used for DSTATCOM. The reason for this is related to the higher losses on the DC reactor of CSI compared to the DC capacitor of VSI. Moreover, a CSI converter requires reverse-blocking semiconductor switches, which have higher, loses than reverse-conducting switches of VSI. And finally, the VSI-based topology has the advantage because an inductance of a coupling transformer (if present) can constitute, partially or completely, the inductance of AC filter. The following text will describe properties of VSI-topology based DSTATCOM only, but in many respects they are the same as for CSI-based controller.

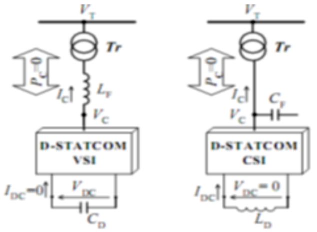


Fig 2.1 General topology of VSI-based and CSI-based DSTATCOM

Table 2.1 Properties of DSTATCOM

CHARACTERISTICS	DSTATCOM
Type	Active (controlled voltage source) shunt
V – I characteristic	Independent of voltage
Generation of instantaneous active power	Yes
Maximum time response	Negligible
Current harmonics introduction	Very low, higher order
Transient Behaviour	Very good
Load Compensation possibility	Yes
UPS Operation	No

IV. SIMULATION OF DSTATCOM

The test system is implemented in MATLAB to carry out simulations for the DSTATCOM. The test system comprises of a three phase source and a varying load. The simulation of such a network is as shown in Fig.4.1

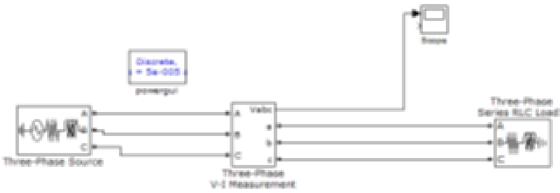


Fig 4.1 Test system in MATLAB

The voltage Vrms at the load point is obtained as shown in the Fig.4.2

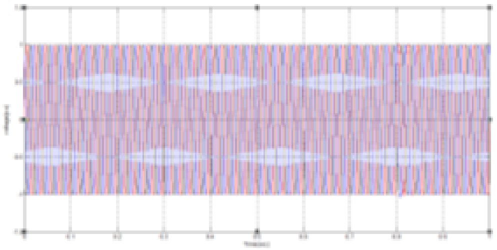


Fig 4.2 Vrms across load for the test system

The voltage of the test system is obtained as 1 pu with RL load of 500 ohm.

A. Response of Test System under Sag

The sensitive load is now installed on the network to provide sag. It is as shown in Fig. 4.3

The simulations relate to three main operating conditions.

1) In the simulation period 300–800ms, the load is increased by closing Switch. In this case, the voltage drops by almost 27% with respect to the reference value.
2) At 800 ms, the switch is opened and remains so throughout the rest of the simulation. The load voltage is very close to the reference value, i.e., 1 pu.

The Vrms at the load point under sag is as shown in the Fig. 4.4.

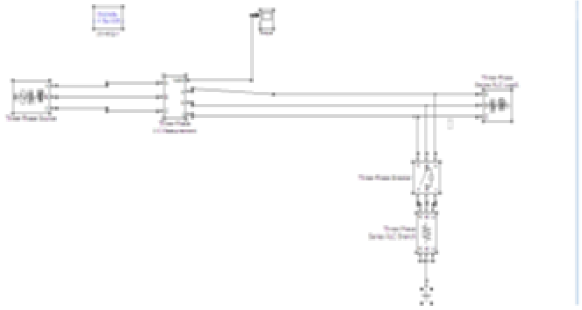


Fig 4.3 Test system with sensitive load producing sag

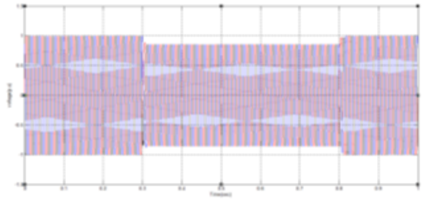


Fig 4.4 Vrms across load for the test system subjected to fault

It is observed from Fig 4.4 that the system is subjected to a sensitive load of 500 ohm. The load is connected to the system from 0.3 to 0.8 seconds. During this period the voltage is reduced to 0.8 pu.

B. Test System with Twelve Pulse DSTATCOM

The twelve pulse DSTATCOM connected to the test system is shown in Fig 4.5.

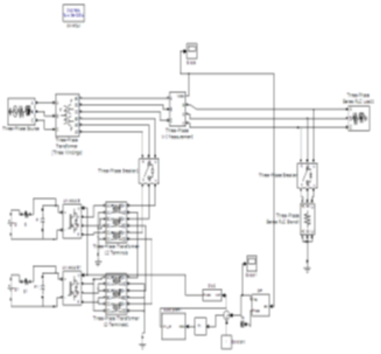


Fig 4.5 Test System With Twelve Pulse DSTATCOM

From Fig 4.5 the test system is subjected to sensitive load and is provided with 12 pulse DSTATCOM (two six pulse DSTATCOM cascaded) connected in shunt via coupling transformer.

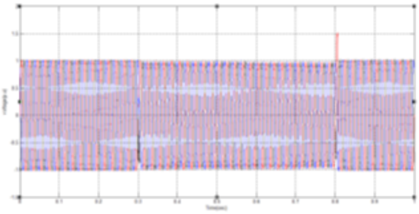


Fig 4.6 Vrms across load for the test system compensated using twelve pulse DSTATCOM

It is observed from Fig 4.6 that the voltage sag caused during the time period 0.3 to 0.8 seconds is mitigated with an error of about 0.1%.

C. FFT ANALYSIS FOR TWELVE PULSE DSTATCOM

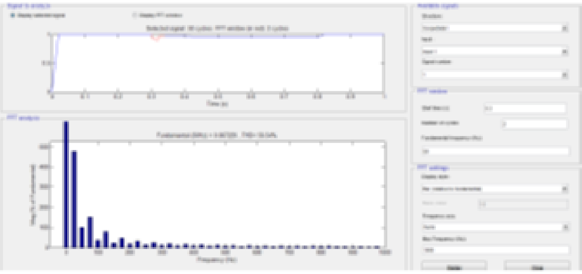


Fig 4.7 FFT analysis of twelve pulse DSTATCOM

From Fig 4.7 the THD of the test system compensated with 12 pulse DSTATCOM is found to be 56.54 %.

V. SIMULATION OF DVR

The test system is implemented in MATLAB to carry out simulations for the DVR. The test system comprises of a three phase source and a varying load. The Simulation of such a network is as shown in Fig.5.1

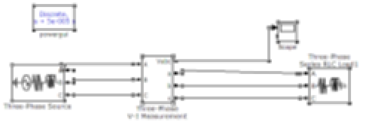


Fig 5.1 Test system in MATLAB

The voltage Vrms at the load point for the test system is obtained as shown in the Fig.5.2

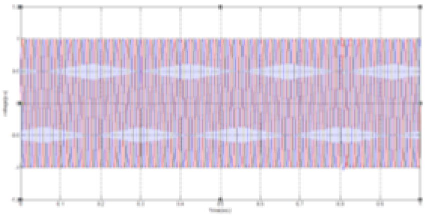


Fig 5.2 Vrms across load for the test system without any fault

The voltage of the test system is obtained as 1 p.u with load 500 ohm.

A. Response of Test System under Sag

The sensitive load is now incorporated on the network to provide sag. It is as shown in Fig. 5.3

The simulations relate to three main operating conditions.

1) In the simulation period 300–800ms, the load is introduced by closing Switch. In this case, the voltage drops by almost 20% with respect to the reference value.
2) At 800 ms, the switch is opened and remains so throughout the rest of the simulation. The load voltage is very close to the reference value, i.e., 1 pu.

The Vrms at the load point under sag is as shown in the Fig. 5.3

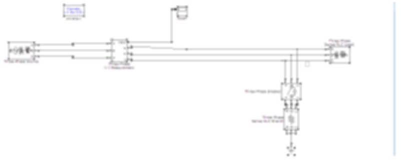


Fig 5.3 Test system with sensitive load producing sag

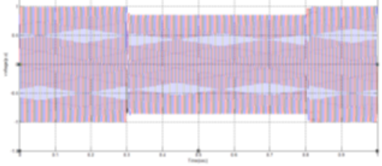


Fig 5.4 Vrms across load for the test system subjected to fault

The figure 5.4 shows that the rms voltage of the test system is reduced to 0.8 p.u between the interval 0.3 to 0.8 seconds when subjected to a sensitive load of 500 ohms.

B. Test System With Twelve Pulse DVR

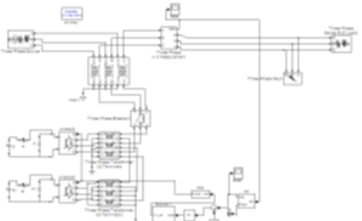


Fig 5.5 Test system with twelve pulse DVR

The test system is subjected to sensitive load and is provided with 12 pulse DSTATCOM (two six pulse DSTATCOM cascaded) connected in series via coupling transformer.

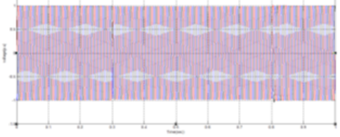


Fig 5.6 Vrms across load for the test system compensated using twelve pulse DVR

It is observed from the Fig 5.6 that the voltage sag caused during time period 0.3 to 0.8 seconds is mitigated from 0.8 to 1 pu.

C. FFT Analysis for Twelve Pulse DVR

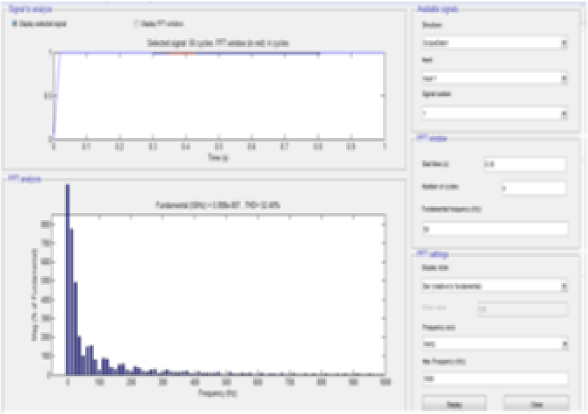
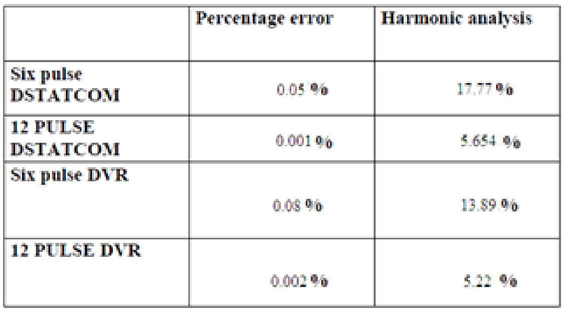


Fig 5.7 FFT analysis for twelve pulse DVR

From Fig 5.7 the THD of the test system compensated using 12 pulse DVR is found to be 52.40 %.

Table 5.1 comparison table of DVR and D-Statcom



	Percentage error	Harmonic analysis
Six pulse DSTATCOM	0.05 %	17.77 %
12 PULSE DSTATCOM	0.001 %	5.654 %
Six pulse DVR	0.08 %	13.89 %
12 PULSE DVR	0.002 %	5.22 %

From the comparison table 5.1, it is inferred that with the increase in the number of pulses, compensation capability of the devices increases. And the voltage harmonics of system also increases. These harmonics can be eliminated by the use of filter.

IV. CONCLUSION

In this project work, modeling of a multi-pulse DSTATCOM and a multi-pulse DVR using a simple PI control scheme is reported. MATLAB/Simulink environment is chosen to model the Custom power devices and to study the voltage regulation capabilities of the same. The voltage regulation capabilities of six- pulse and twelve-pulse DSTATCOM are presented with a simple test system subjected to sensitive load. The effectiveness of six- pulse and twelve- pulse DVR in mitigating the voltage sag is also studied with a test system induced with sensitive load as well as unbalanced faults such as line-ground, line-line and double line-ground faults. FFT analysis is carried out for both six- pulse and twelve- pulse DSTATCOM and DVR and their comparative performance with respect to voltage regulation and generated harmonics is presented. The obtained results show that the performance of twelve- pulse DSTATCOM and DVR in regulating the load voltage is better compared to six- pulse DSTATCOM and DVR. However, the percentage THD is higher for twelve pulse DSTATCOM and DVR which can be minimized with the help of filters.

VI. FUTURE SCOPE

In this thesis work it has been shown that custom power devices like twelve pulses DSTATCOM and twelve pulses DVR can compensate harmonics in current. The work can be expanded under the following areas.

1. Other advanced controllers like fuzzy controller, DSP controller, and adaptive fuzzy controllers can be employed with DSTATCOM to increase the efficiency of DSTATCOM in distribution networks.
2. Dynamic loads can be considered in future work and the effect of DSTATCOM with them can be studied.

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