Analysing the performance of D-Statcom in mitigating transients from distribution system

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ABSTRACT

Presently, power systems are required to operate at almost full capacity, which results huge power losses as well as threatening stability and security of the system. Protection against the transients results from connection or disconnection of loads in the power mains is very importance for the electric energy quality. For this reason, power system has to be smart and aware, fault tolerant and self-healing. The existing power system can be improved by using advanced power electronics technologies. FACTS Devices, such as a STATCOM, SVC, SSSC, and UPFC, can be connected in series or shunt or a combination of both series and shunt, to achieve numerous control functions. This work presents a knowledge base for switching transients and more specifically, for distribution line switching, which is connected with heavy inductive load. The objective of work is to improve the power quality and also to analyze the role of D-STATCOM for mitigating effect of transients from the system. D-STATCOM is designed using MATLAB simulink version R2012b. A test system is taken as industrial load, which involves load of 2095.91KW and 3424.31KW. The transients are originated in the system by connecting and disconnecting these different inductive loads. With the application of D-STATCOM, this work prevents them to flow in the connected power mains. The results are compared on the basis of various graphs.

Keywords D-STATCOM, FACTS devices, MATLAB simulink, Transients.

1. INTRODUCTION

Electricity is an essential ingredient for the industrial and all round development of any country. It is generated at generating stations and transmitted economically over long distances. Electrical energy is conserved at every step in the process of Generation, Transmission, Distribution and its utilization.

Presently, power systems are forced to operate at almost full capacity, it results greater power losses as well as threatening stability and security of the system. This creates undesirably increased risk of power outages of different levels of severity. For this reason, power grid has to be reinforced, to make it smart and aware, fault tolerant and self-healing, and dynamically and statically controllable.

The utilization of the existing power system can be improved with the application of advanced power electronics technologies. Flexible AC Transmission S y s t e m s (FACTS) provide technical solutions to the new operating challenges. Devices, such as a STATCOM, SVC, SSSC, and UPFC, can be connected in series or shunt (or a combination of the two) to achieve numerous control functions, including voltage regulation, power flow control, and system damping. In this way, the system performance can be improved by controlling the power flows without generation rescheduling. The benefits they offer to the electrical grid are widely referenced in scientific literature. These benefits include improvement of the stability of the grid, control of the flow of active and reactive power on the grid, loss minimization, and increased grid efficiency [14].

A power quality disturbance is generally defined as any change in power (voltage, current, or frequency) that interferes with the normal operation of electrical equipments. The equipments have become very much sensitive to even few seconds' changes in the power supply voltage, current, and frequency [7]. The power quality disturbances have been organized into seven types based on wave shape:

Transients, Interruptions, Sag / Under voltage, Swell / Overvoltage, Waveform distortion, Voltage fluctuations, Frequency variations

2. Transients

Transients are one of the most dangerous types of power quality disturbance. Protection against the transients results from connection or disconnection of loads in the power mains is very importance for the electric energy quality.

Transients fall into two subcategories:

1. Impulsive
2. Oscillatory

2.1 Impulsive Transients

These transients are sudden high peak events that raise the voltage and/or current levels in either a positive or a negative direction. Impulsive transients can be categorized further by the speed at which they occur (fast, medium, and slow) [7]. These can be very fast events (5 nanoseconds [ns] rise time from steady state to the peak of the impulse) of short-term duration (less than 50 ns).
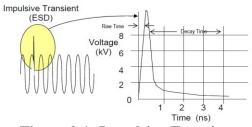
Figure 2.1: Impulsive Transients

Note: [1000 ns = 1 μs] [1000 μs = 1 ms] [1000 ms = 1 second]

A positive impulsive transient caused by electrostatic discharge (ESD) event is illustrated in **Figure 2.1.**

The impulsive transient is what, when people say they have experienced a surge or a spike. Many different terms, such power surge, and spike have been used to describe impulsive transients. Causes of impulsive transients include lightning, poor grounding, the switching of inductive loads, utility fault clearing, and Electrostatic Discharge (ESD). The results can start from the loss of data, and end with physical damage of equipment. But lightning is probably the most damaging. The amount of energy that it takes to light up the night sky can easily destroy sensitive equipment. The most common protection methods when it comes to impulsive transients pertain to the elimination of potential ESD, and the use of surge suppression devices (as transient voltage surge suppressors: TVSS, or surge protective device: SPD).

2.2 Oscillatory Transients

This transient is a sudden change in the steady-state condition of a signal's voltage, current, or both, at both the positive and negative signal limits, oscillating at system frequency. In simple terms, these transient causes the power signal to alternately swell and then shrink, very rapidly [7]. These transients usually decay to zero within a cycle (a decaying oscillation). Oscillatory transients occur when you turn off an inductive or capacitive load, such as a motor or capacitor bank. These transients results because the load resists the change. For example, an electrical distribution system can act like an oscillator when power is switched on or off, because all circuits have some inherent inductance and distributed capacitance that briefly energizes in a decaying form. When these types of transients appear on an energized circuit, usually because of utility switching operations, they can be quite disruptive to electronic equipment [7]. **Figure 2.2** shows a typical low frequency Oscillatory Transient attributable to capacitor banks being energized.
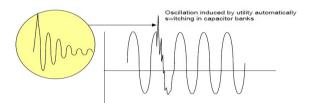

Figure 2.2: low frequency Oscillatory
Transient

The utilization of the existing power system can be improved with the application of advanced power electronics technologies. Flexible AC Transmission Systems (FACTS) provide technical solutions to the new operating challenges. Devices, such as a STATCOM, SVC, SSSC, and UPFC, can be connected in series or shunt (or a combination of the two) to achieve numerous control functions, including voltage regulation, power flow control, and system damping [1]. In this way, the system performance can be improved by controlling the power flows without generation rescheduling.

3. Distributed Static Compensator (D-STATCOM)

D-statcom (Distributed static compensator) is a parallel voltage controller, shown in figure-3.1, consists of a filter, Voltage source converter, a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. The voltage source converter converts the dc voltage across the storage device into a set of three-phase ac output voltages [1, 2]. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer.
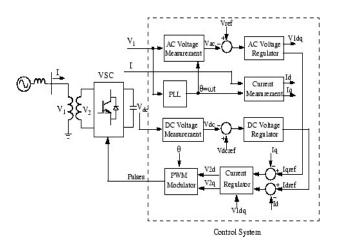

Fig. 3.1: Schematic diagram of D-statcom

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 [1, 2]. Such configuration allows the D-statcom to absorb or generate controllable active and reactive power.

3.1 Voltage Source Converter (VSC)

A Voltage source converter is power electronic switch (like IGBT/GTO). These are used as power electronic switches to operating at finite switching frequency and withstanding the high voltage rating, regarding that we choosing by the Insulated Gate Bi-polar Transistor (IGBT) [2]. Voltage Source Converter (VSC) is used for the injection of the controllable ac voltage and also generates a sinusoidal voltage with

any required frequency, magnitude and phase angle. Voltage source converters are widely used in controlling application for various devices like adjustable speed drives. It is used to either completely replace the voltage or to inject the missing voltage (the difference between the actual and nominal voltage is known as the missing voltage) [2]. Voltage source converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage.

3.2 Control System
The main motive of the control scheme is to maintain constant voltage magnitude, current and power factor at the point where a sensitive load is connected, under system disturbances [4]. The control system only measures the r.m.s voltage at the load point, i.e., no reactive power measurements are required [1]. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. The controller input is an error signal obtained from the reference voltage and the value r.m.s of the terminal voltage measured. Such error is processed by a PI controller the output is the angle δ, which is provided to the PWM signal generator [1]. It is important to note that in this case, indirectly controlled converter, there is active and reactive power exchange with the network simultaneously: an error signal is obtained by comparing the reference voltage with the r.m.s voltage measured at the load point. The PI controller process the error signal generates the required angle to drive the error to zero, i.e., the load r.m.s voltage is brought back to the reference voltage.

4. Matlab/Simulink
Matlab/Simulink provides a powerful mean of analysis and investigation, provided that all the system components to be studied are modelled with an adequate level of accuracy and completeness. The Matlab/Simulink environment offers wide and complete libraries where the designer can find reliable pre-defined blocks (for electronic switches, snubbers, diodes, etc.) to be used in building the application-related apparatus models. The same pertains to control and regulation blocks, which can be built up directly based on their transfer functions and logics. Matlab provide very powerful tool for electrical and electronics simulations, called PowerSim. It consist of large number of model which help in performing different test on power system disturbances, fault study , power electronics , Wind Turbine , Solar , generators fault study etc.

4.1 SYSTEM UNDER OBVERVATION:
In this test model two different inductive industrial loads with different industries have been considered, which are connected and disconnected with the help of circuit breaker at different times. This test system is analyzed with heavy inductive load under switching transient conditions.
The test system consists of a source of 33KV, 50Hz. This source is feeding two industries Load A (2095.91KW), Load B(3424.31KW)
through a three winding transformer connected in Y/Δ 33KV/380V, 50Hz.

Table 4.1. Table of system parameters

S.No.	System Quantities	Standards
1.	source	33KV, 50Hz
2.	3 Phase transformer (two winding) Y/Δ	33KV/380V, 50Hz
3.	Load A (industrial load 1)	2095.91KW
4.	Load B (industrial load 2)	3424.31KW
5	Inverter parameters	IGBT based, 3 arms, 6 pulse, carrier Frequency=2000Hz

5. SIMULINK MODEL OF TEST SYSTEM AND RESULTS (without D- STATCOM)

This simulink model present the test system without D-STATCOM .In this simulink model we have system in which source is connect to primary side of 3 phase two winding transformer as shown. The load is connected to the secondary sides of 380V. The transients are created here by providing the switching, Unit 1 : Load A{On at : 0.15sec, Off at : 0.25sec} and Unit II : Load B{On at : 0.40sec, Off at : 0.45sec}
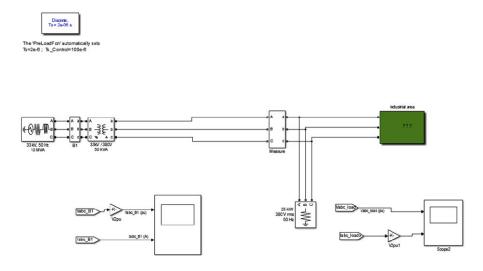

Figure 5.1: Test model without DSTATCOM

Simulation Results with transients but without D-STATCOM

From the following results it is observed that the transients get generated in the system when there is connection and disconnection of heavy inductive load.
Figure 5.2 shows transients near load in voltage and current waveform. Figure 5.3 shows transients travelling to power mains.
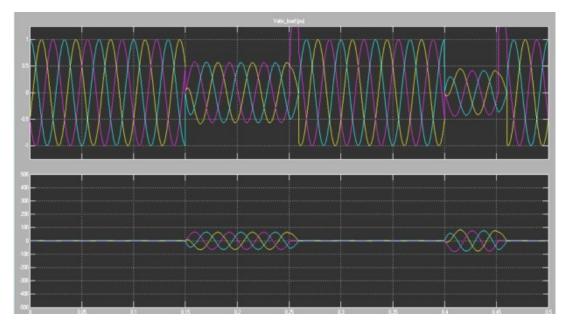
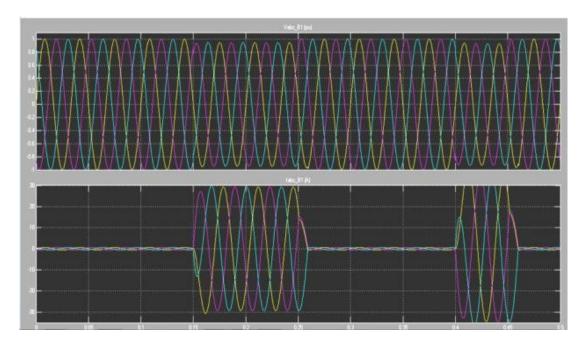**Figure 5**.2**: Transients near load in voltage and current waveform**

Figure 5.3: Transients travelling to power main

6. Simulation of test system with D-STATCOM

In this simulink model we have system which fed the load through two winding transformer as shown. The D-STATCOM is connected in between the industrial load and secondary of the transformer. The system is shown in following figure 6.1.
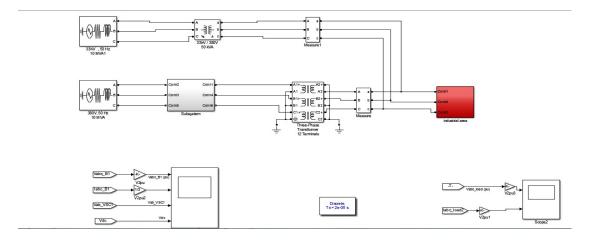

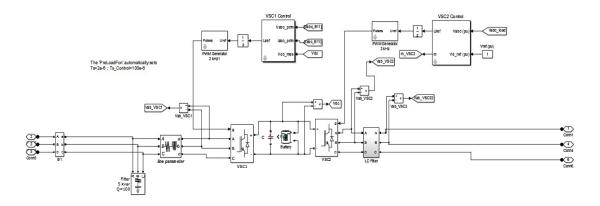**Figure 6.1: Test model with DSTATCOM**

Figure 6.2: Simulink model of DSTATCOM

Simulation Results with transients and with D-STATCOM:
From the following results it is clear that the D-STATCOM mitigates the effect of transients from the system and also improves the power quality. Figure 6.3 shows voltage and current waveform near load when connecting and disconnecting heavy industrial load. Figure 6.4 shows waveforms of voltage, current, output of PWM generator, Stored DC voltage in the charging unit respectively.
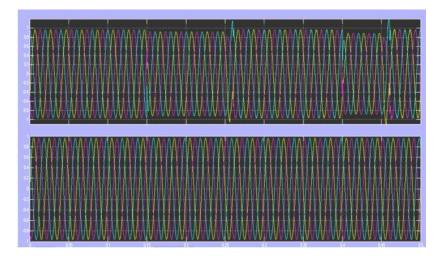
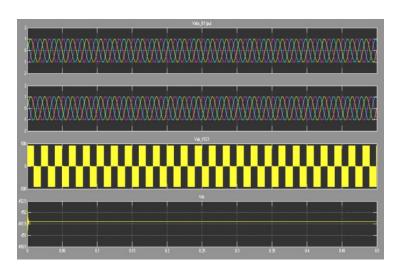**Figure 6.3: Voltage and current waveform near load when connecting and disconnecting heavy industrial load.**

Figure 6.4: Waveforms of voltage, current, output of PWM generator, Stored DC voltage in the charging unit respectively.

7. Conclusion

D-STATCOM is designed using MATLAB simulink version R2012b. A test system is taken as industrial load, which involves load of 2095.91KW and 3424.31KW. With the application of D-STATCOM, my proposed work prevents transients to flow in the connected power mains. When comparing with the help of FFT analysis, results are:
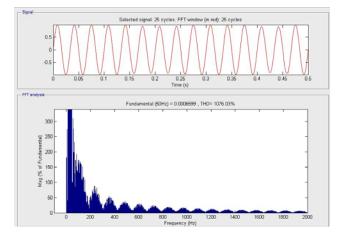
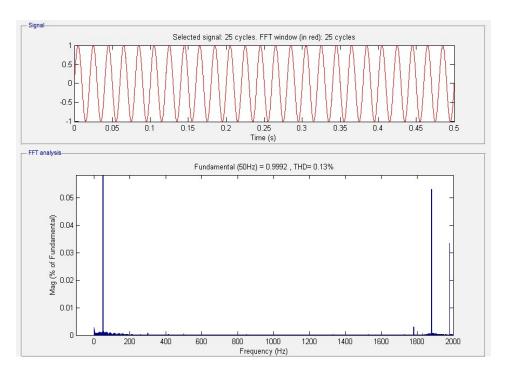**Figure 7.1: FFT analysis with transients but without D-STATCOM**

Figure7.2: FFT analysis with transients and with D-STATCOM

8. Future scope

Further investigation of the D-STATCOM applications and the rising demand in utility application provide a lot of opportunities of power flow control. With the promotion and development of smart grid and renewable energy application in the power system, the D-STATCOM applications will extend to different areas, from the high voltage transmission system to the distribution system.

The control circuit can be change. The other controller like fuzzy, PQ technique and adaptive PI fuzzy controller may employ in the compensation scheme.

9. REFERENCES

[1]   Sai Kiran Kumar.Sivakoti,Y.Naveen Kumar & D.Archana "Power Quality Improvement In Distribution System Using D-Statcom In Transmission Lines" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 ,Vol. 1, Issue 3, pp.748-752.

[2]   R.Sasi Kumar, P.Rajaguru, "Power quality improvement in distribution system using D-statcom" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering ,Vol. 2, Issue 12, December 2013.

[3]   Shaik Khaja Greeb Nawaj, Shaik Hameed," Mitigation of power quality problems by using D-statcom" International Conference on Electrical Electronics and Computer Science-EECS-17th Nov 2013-ISBN:978-93-81693-53-7.

[4]   Akil Ahemad, Sayyad Naimuddin," Simulation of D-statcom in power system" Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676, p-ISSN: 2320-3331 PP 01-08.

[5]   Rakesh kumar B.Shah, Sanjay vyas "Modelling & Comparative Analysis of Statcom Utilising Cascaded Multilevel Inverter (H Bridge)" IJSR – International Journal of Science and Research, Volume : 4 | Issue : 2 | February 2015, ISSN No 2277 – 8179.

[6]   Mohit Bajaj, Vinay Kumar Dwivedi, Ankit Kumar, "Design and Simulation of D-statcom for Power Quality Enhancement in Distribution Networks under Various Fault Condition" International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 4, April 2013).

[7]   Joseph Seymour, "The Seven Types of Power Problems" Schneider Electric's Data Center Science Center DCSC@Schneider-Electric.com, White Paper 18.

[8]   Arvind Pahade and Nitin Saxena "Transient stability improvement by using shunt FACT device (STATCOM) with Reference Voltage Compensation (RVC) control scheme" International Journal of Electrical, Electronics and Computer Engineering 2(1): 7- 12(2013) ISSN No. (Online) : 2277-2626.

[9]   Rodda Shobha Rani1, B. Jyothi2, "VSC Based DSTATCOM & Pulse-width modulation for Power Quality Improvement" International Journal of Engineering Trends and Technology- Volume2Issue2- 2011, ISSN: 2231-5381.

[10]   John J. Paserba*,Gregory F. Reed, "FACTS and Custom Power Equipment for the Enhancement of Power Transmission System Performance and Power Quality" 512 Keystone Drive, Warrendale, Pennsylvania, USA 15086: j.paserba@ieee.org.

[11]   A. I. Ibrahim, "A Knowledge Base for Switching Surge Transients" Presented at the International Conference on Power Systems Transients (IPST'05) in Montreal, Canada on June 19-23, 2005 Paper No. IPST05 – 050.

[12]   Gerard Scoonenberg, René smeets, "Control of inductive load switching transients" C I R E D 22nd International Conference on Electricity Distribution Stockholm, 10-13 June 2013.

[13]   Ranjit Kumar Bindal, "A Review of Benefits of FACTS Devices in Power System" International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-3, Issue-4, April 2014.

[14]   H. Amaris et al., Reactive Power Management of Power Networks with Wind Generation, Lecture Notes in Energy 5, DOI 10.1007/978-1-4471-4667-4_2, London 2013