Simulation and Analysis of DSTATCOM in Power System

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***Abstract*— Power and energy are two essentials inputs for economic development and improving the quality of life. With the increasing size and complexity of the transmission networks, the performance of the power system decreases due to the complex challenges problems related with power quality. FACTS and HVDC technologies offers some effective schemes to meet these demands. An attempt is made in this paper to discuss the developments of FACT devices, different types of FACT devices and simulation of DSTATCOM, using SIMULINK is carried out for comparing various issues relating to power transmission.**

Keywords— FACT:,Voltage regulatio:,DSTATCOM

I. Introduction

Present day electrical power systems have a high rate of complexity and there is expansion in power transmission networks due to the increase in generation, loads, and also due to extensive interconnections among various power utilities. The present AC power transmission poses following key challenges. [1]:-

- Power flow in parallel paths is determined according to their reactance.
- Increase in load levels results in higher reactive power consumption in the line reactance.
- Power flow in AC lines is limited by system stability and thermal stability considerations.
- Lack of control in AC lines implies that normal power flow in a line is kept much below the peak value.
- AC transmission network requires dynamic reactive power control to maintain satisfactory profile under varying load conditions

Improved utilization of the existing power system is provided through the application of advanced control technologies that is Flexible AC Transmission systems (FACTS); provide solutions to address these new operating challenges. FACTS technologies allow for improved transmission system operation with minimal infrastructure investment, environmental impact, and implementation time of the existing transmission system compared to the construction of new transmission lines.[2]

Distribution Static compensator (DSTATCOM) is used for power factor correction, voltage regulation, load balancing, and harmonic elimination. A DSTATCOM cannot fulfill all these objectives simultaneously. A control algorithm for dual functional DSTATCOM that enables it to operate either in current control mode (CCM) or in voltage control mode (VCM) is proposed. This control demonstrated the DSTATCOM capability of mitigating voltage and current related power quality issues. [3]

An effective control technique for a DSTATCOM, as a custom power conditioner to mitigate the current fluctuation and voltage flicker in industrial distribution systems is studied. The proposed control is newly utilized for a single-phase DSTATCOM, and it depends on a current vector control technique for generating the required reactive power. This paper introduces a concept of implementing a current vector control on a single-phase DSTATCOM. The presented results prove that the propose development on the vector control of DSTATCOM is efficient since the current fluctuation is greatly reduced, and the voltage profile is drastically improved. [4]

The widespread application of DSTATCOM for filtering load harmonics is expected to occur in the near future. Although the requirement of DSTATCOM is universally accepted, equipment cost can still be an impediment for its wide usage. The use of DSTATCOM can be very well justified by incorporating multiple control functions on the same equipment. The performance evaluation of a single DSTATCOM which can perform the three major functions namely the elimination of harmonics, load balancing and reactive power compensation is investigated. When energy source is interfaced at the DC bus, DSTATCOM can be controlled to supply active power in addition to the primary objectives like harmonic compensation, load balancing and supply of fundamental reactive power. [5]

Rating of voltage source inverter (VSI) and size of the interfacing filter are two important issues while implementing DSTATCOM. A new DSTATCOM topology has been proposed which simultaneously reduces the rating of VSI as well as size of interfacing filter with enhanced current compensation capabilities. A new topology of DSTATCOM, comprising of a LCL filter at the front end of voltage source inverter followed by a series capacitor, has been proposed. It is shown that the proposed topology provides superior current compensation compared to traditional topology using a much lower value of dc link voltage as well as Interfacing filter inductor. [6]

The control of DSTATCOM for reactive power, harmonics and unbalanced load current compensation of a diesel generator set for an isolated system. The control of DSTATCOM is achieved using least mean square-based adaptive linear element. This scheme is simulated under MATLAB environment using Simulink and Power System Block set toolboxes for feeding linear and nonlinear loads. The modeling is performed for a three-phase, three-wire star connected synchronous generator coupled to a diesel engine, along with the three-leg voltage source convertor (VSC) working as a DSTATCOM.

The proposed control algorithm of the DSTATCOM has been found to improve the performance of the isolated DG system. The DSTATOM has compensated the variety of loads on the DG set and it has sinusoidal voltages at PCC and currents with compensated and equivalent linear balanced unity power factor loads. [7]

Aiming at potential interaction between power grid and DSTATCOM, the paper firstly derives and analyzes the harmonic impedance of DSTATCOM, which is not only related to phase locked loop (PLL) control, but also deeply affected by the voltage control of DSTATCOM's DC bus and reactive power compensated by DSTATCOM. Then the paper illustrates harmonic resonance between power grid and DSTATCOM through impedance model. Finally, two solutions are proposed to suppress harmonic resonance, including the selection of control strategy and design of control parameters. Simulation results verify the effectiveness of interaction analysis. (1)Unlike the grid-connected inverter, the harmonic impedance of DSTATCOM is not only affected by the PLL control, but also closely correlated to the DC voltage control and reactive power demanded. (2) Resonance may occur when the harmonic impedance of DSTATCOM and grid equivalent impedance have approximately the same magnitude, but the opposite polarity at some frequency. (3) Resonance between DSTATCOM and grid can be suppressed by focusing on the selection of control strategy and design of control parameters. The approach of impedance analysis has excellent applicability. [8]

An improved Synchronous Reference Frame based control technique or algorithm for time varying power flow control and optimum load compensation of non-linear loading under abnormal or disturbed source voltage by DSTATCOM designed for three-phase three wire systems is analysed. The simulation results also show which algorithm can accurately detect the harmonics and reactive component of load current even under the asymmetric and distorted source voltage condition. [9]

This paper proposes an improved performance interactive distribution static compensator (DSTATCOM) to address the limitations of conventional current control mode (CCM) and voltage control mode (VCM) operations. The principle of operation and control for both operating modes is analyzed. The detailed process of the flexible transfer between the two modes is derived. Deadbeat predictive control algorithms for CCM as well as VCM operation are developed for fast operation during mode transfers. The performance of the proposed scheme is validated by both simulation and experimental results.[10]

This paper presents the modelling and implementation of a three-phase DSTATCOM using an efficient control algorithm for power conditioning. This is one of an effective way for harmonic suppression, load balancing and reactive power compensation at distorted Point of Common Coupling voltages under nonlinear loads. Simulation studies are showing the better performance of three-phase DSTATCOM using MATLAB SIMULINK & power system toolboxes [11].

The impact of DTATCOM size and location on the voltage regulation of a distribution system is investigated in this research work. Possibility of coordination between DSTATCOM units at different locations in the system is investigated. This study is conducted on the IEEE 14 bus system (69 KV/13.8kv) without any compensation. The results show the effectiveness of using the DSTATCOM on the system voltage regulation during normal operating conditions as well as in cases when the system is subjected to abnormal conditions. System improved performance is depicted. [12]

II TYPES OF FACT CONTROLLERS

FACTS Controllers can be classified into- (1)Series Controllers (2) Shunt Controllers (3) Combined Series-Series controllers (4) Combined Series-Shunt Controllers

(1) Series Controllers

Series controllers may be variable impedance as capacitor; reactor etc., or power electronics based variable source of main frequency, sub-synchronous frequency and harmonic frequency or any combination of these. The basic principle of series controller is to inject voltage in series with the line. If the injected voltage is in phase with line current, real power is not consumed or supplied.

(2)Shunt Controller:

Series controller element can be used as a shunt controller by connecting it in parallel with the line. In principle, all shunt controllers inject current into the system at the point of connection. Even variable shunt impedance connected to the line voltage causes a variable current flow and hence represents injection of current into the line. Types of Shunt connected controllers:

(a) Static Synchronous Compensator (STATCOM):A static synchronous generator operated as a shunt-connected static var compensator whose capacitive or inductive output current can be controlled independent of the ac system voltage.

(b) Static Var Compensator (SVC): A shunt-connected static var generator or absorber whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific parameters of the electrical power system.

(c) Thyristor Controlled Reactor (TCR): A shunt-connected, thyristor-controlled inductor whose effective reactance is varied in a continuous manner by partial-conduction control of the thyristor valve.

(d) Thyristor Switched Capacitor (TSC): A shunt-connected thyristor- switched capacitor whose effective reactance is varied in a stepwise manner by full or zero conduction operation of the thyristor valve.

(3) Combined Series - Series Controllers

This could be any combination of series controllers, controlled in coordinated manner or it can be a unified controller. Unified controller provides independent series reactive compensation for each line. The term "unified" implies that DC terminals of all converters are connected. Transfer of real power between the lines takes place through this link, called power link. Unified controller provides independent series reactive compensation for each line.

(4)Combined Series - Shunt Connected Controller

Unified Power Flow Controller (UPFC): A combination of STATCOM and SSSC are coupled via a common dc link, to allow bidirectional flow of real power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM, and are controlled to provide concurrent real and reactive series line compensation without an external electric energy source. The UPFC, by means of angularly unconstrained series voltage injection, is able to control, concurrently or selectively, the transmission line voltage, impedance, and angle or, alternatively, the real and reactive power flow in the line. The UPFC may also provide independently controllable shunt reactive compensation.

(5)Combined Series-Series Controller

Interline Power Flow controller (IPFC): Conventionally, series capacitive compensation is employed to increase the transmittable real power over a given line and also to balance the loading of a normally encountered multi-line transmission system. However, independent of their implementation, series reactive compensators are unable to control the reactive power flow in, and thus the proper load balancing of, the lines. This problem becomes particularly evident in those cases where the ratio of reactive to resistive line impedance (Xm) is relatively low. Series reactive compensation reduces only the effective reactive impedance X and, thus, significantly decreases the effective X/R ratio and thereby increases the reactive power flow and losses in the line.

III BASIC PRINCIPLE OF DSTATCOM

Distributed Static Compensator (DSTATCOM) is a fast-compensating reactive power source that's applied on the transmission or distribution system to reduce voltage variations such as sags, surges, and flicker, along with instability caused by rapidly varying reactive power demand. The DSTATCOM is used in distribution system for reactive power compensation and to reduce harmonics. It is connected in parallel with transmission lines. For example if we are transmitting sum of power through transmission lines and at receiver end we are receiving it with some noise or any other interruption that means losses are there. These may be reactive power, voltage sag and harmonics. So we use DSTATCOM for reactive power compensation and also mitigate the voltage fluctuations.[2] For the faster control Voltage Source Converter (VSC) can be used with Pulse Width Modulation (PWM) to mitigate the voltage fluctuations and other modulation techniques or other converter can be also used with DSTATCOM. DSTATCOM is used to mitigate harmonics, power quality improvement and reactive power compensation in distribution system. A DSTATCOM is a controlled reactive source, which includes a Voltage Source Converter (VSC) and a DC link capacitor connected in shunt, capable of generating and/or absorbing reactive power. The operating principles of a DSTATCOM are based on the exact equivalence of the conventional rotating synchronous compensator. (Figure 1)

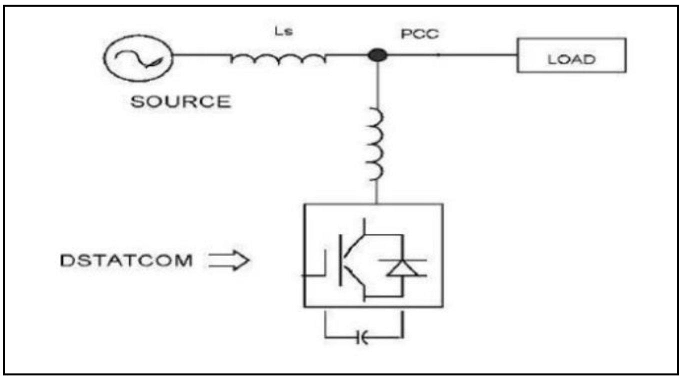

Figure 1.Basic DSTATCOM diagram

There are the two stages, overexcited and under-excited in synchronous machine that provides leading current and lagging currents respectively in two stages. Thus DSTATCOM's working principle is quite similar to synchronous machine. DSTATCOM can exchange the active power and as well as the reactive power with an external DC source. There are two stages of exchanging of active power and reactive power. For generating reactive power there are two conditions;

(i) The system voltage should not be same as that of voltage source converter's output voltage.

(ii) DSTATCOM should act as a capacitor and in this case the current is lagging.

For the switches DC capacitor provides the active power. To maintain constant capacitor voltage for AC system the active power interchange is needed. And to make the constant capacitor voltage this active power of DC source will be given to AC system but for that case the system voltage will be guided by output voltage of VSC. This interchange of active power and reactive provides voltage regulation in distribution network. DSTATCOM provides reactive power for reactive power compensation and power factor unity. For load balance the active power is provided from the input. Applications of DSTATCOM are to improve voltage regulation in distribution line, to improve power factor and also for load balancing.

IV SIMULINK MODEL

The DSTATCOM model is simulated using SIMULINK and the results are as shown for varying length of distribution line from 400km to 1400km. (Figure 2 to Figure 6 and Table I to Table III)

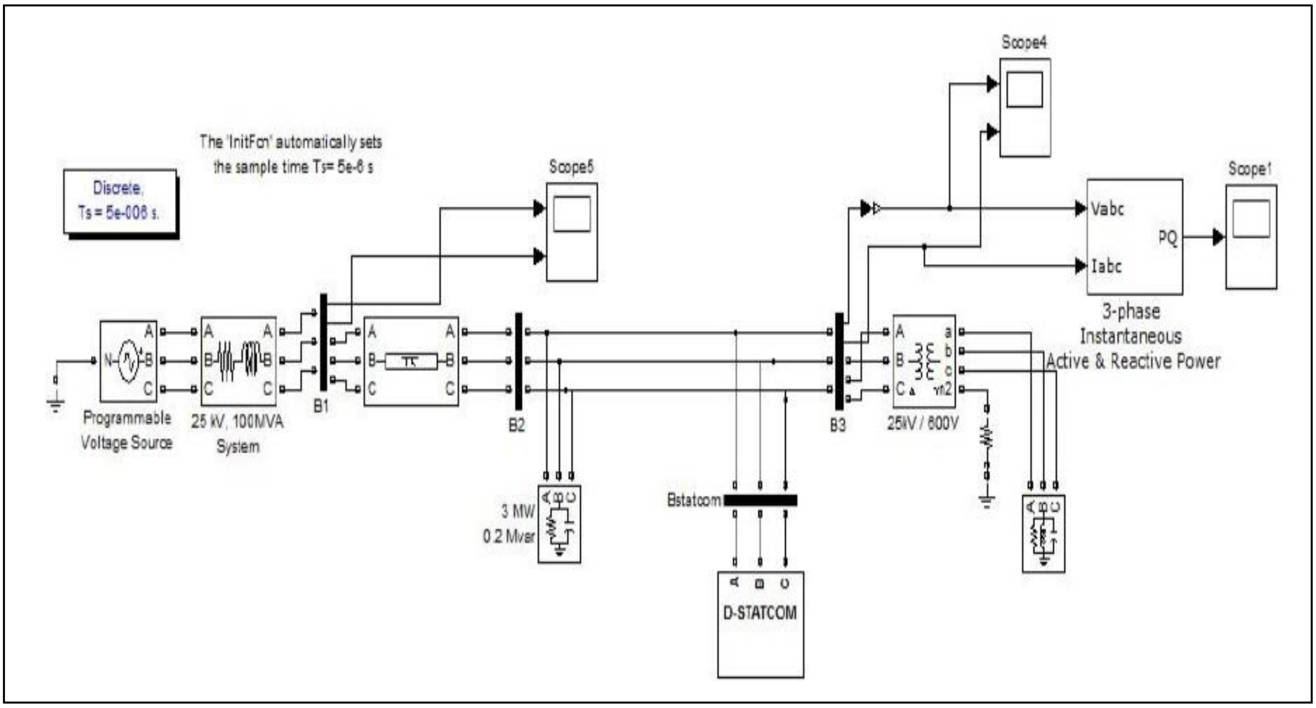

Figure 2.Simulation of DSTATCOM

TABLE I RESULTS OF DSTATCOM

Line length km	Without DSTATCOM				With DSTATCOM			
	Vs(pu)	Vr(pu)	%VR	Q(pu)	Vs(pu)	Vr(pu)	%VR	Q(pu)
400	1.0433	0.936	10.28	0.0537	1.0427	0.9985	04.24	5.3837
500	1.0512	0.78942	25.39	0.0373	1.051	0.8602	18.135	3.7409
600	1.0572	0.6822	35.47	0.0282	1.0571	0.7755	26.686	2.8305
700	1.0618	0.6127	42.29	0.0228	1.0617	0.6587	38.18	2.2833
800	1.0657	0.5646	47.02	0.0193	1.0656	0.6587	38.18	1.939
900	1.069	0.5314	50.28	0.0172	1.069	0.6648	37.81	1.7198
1000	1.0722	0.5096	52.47	0.0158	1.0721	0.6551	38.89	1.5849
1100	1.075	0.4987	53.60	0.0151	1.075	0.661	38.51	1.5127
1200	1.0775	0.4953	54.03	0.0149	1.07771	0.6849	36.41	1.4923
1300	1.0806	0.4999	53.73	0.0152	1.0806	0.7118	34.12	1.5203
1400	1.0835	0.5127	52.68	0.016	1.0835	0.7412	31.59	1.5993

Table II Line and Load parameters

Line Parameters /km	Values	Load Parameters
Resistance ohm	0.1153 & 0.3963	Active Power -400MW
Inductance mH	1.048 & 2.730	Inductive Power -125Mvar
Capacitance nF	11.33 & 5.338	Capacitive Power -75Mvar

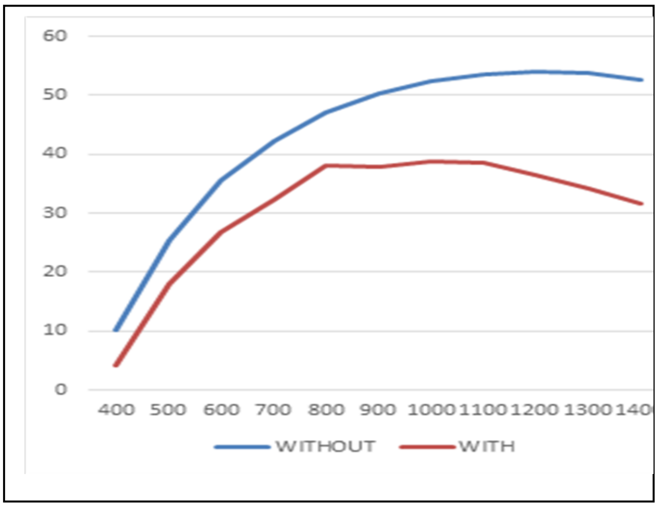

Figure 3 Variation of Voltage regulation with line length

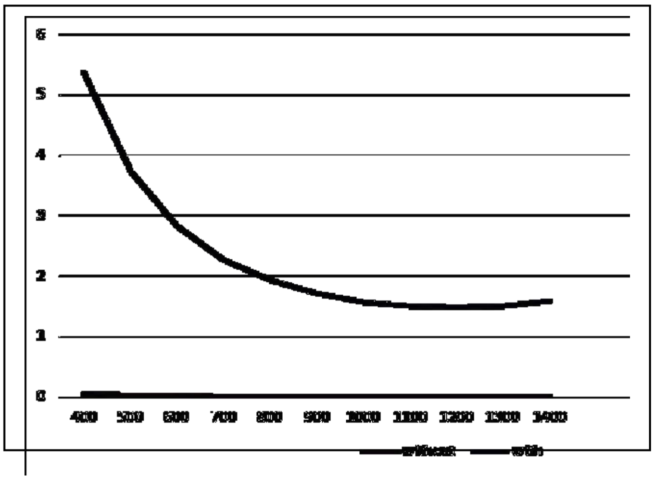

Figure 4 Variation of reactive power with line length

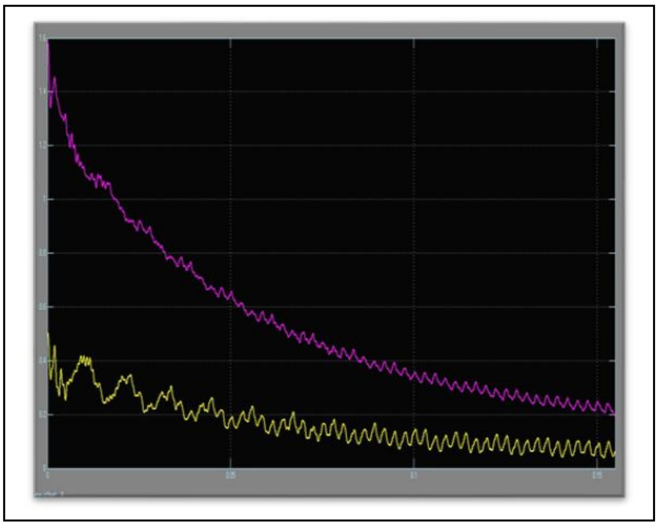

Figure 5 Variation of reactive and reactive power

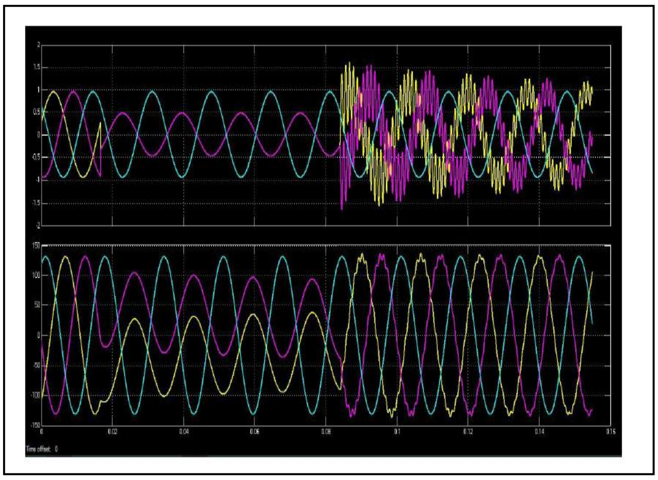

Figure 7 LL Fault current and voltage waveforms with DSTATCOM

Table III. Different fault currents with and without DSTATCOM

Type of fault	Fault current (A)	
	Without	With DSTACOM
L-G fault	If=92.277	If=41.372
L-L-G fault	Ifr=46.3 Ify=46.1665	Ifr=21.475 Ify=41.371
L-L fault	Ifr=47.2539 Ify=45.54	Ifr=18.767 Ify=17.643
3-phase fault	Ifr=9.812 Ify=-92.796 Ifb=83.534	Ifr=9.256 Ify=-40.496 Ifb=29.345

CONCLUSIONS

The control scheme is tested under a wide range of operating conditions and it is observed to be very robust in every case.

- Introducing the DSTATCOM improves the voltage regulation in the power system and also helps in reducing the fault current during fault conditions.
- The results show the effectiveness of using the DSTATCOM on the system voltage regulation during normal operating conditions as well as in cases when the system is subjected to abnormal conditions.
- The performance evaluation of a Single DSTATCOM which can perform the two major functions namely, load balancing and reactive power compensation is investigated.
- DSTATCOM balances the required reactive power in the power system and also act as controlled reactive source. Thus System improved performance is depicted.

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