Power Quality Improvement of Distribution System Using DSTATCOM

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Abstract-The causes of power quality problems are generally complex and difficult to detect. Technically speaking, the ideal AC line supply by the utility system should be a pure sine wave of fundamental frequency (50/60Hz).Different power quality problems, their characterization methods and possible causes are discussed above and which are responsible for the lack of quality power which affects the customer in many ways. We can therefore conclude that the lack of quality power can cause loss of production, damage of equipment or appliances or can even be detrimental to human health. It is therefore imperative that a high standard of power quality is maintained. This project demonstrates that the power electronic based power conditioning using custom power devices like DSTATCOM can be effectively utilized to improve the quality of power supplied to the customers. The aim of the project is to implement DSTATCOM with different control strategies in the MATLAB, simulink using Simpower systems tool box and to verify and compare the results through various case studies applying different loads and study them in detail.

Key words: DSTATCOM, Compensation, Power quality.

I. Introduction

In the early days of power transmission in the late 19th century problems like voltage deviation during load changes and power transfer limitation were observed due to reactive power unbalances. Today these Problems have even higher impact on reliable and secure power supply in the world of Globalization and Privatization of electrical systems and energy transfer. The development in fast and reliable semiconductors devices (GTO and IGBT) allowed new power electronic Configurations to be introduced to the tasks of power Transmission and load flow control. The FACTS devices offer a fast and reliable control over the transmission parameters, i.e. Voltage, line impedance, and phase angle between the sending end voltage and receiving end voltage. On the other hand the custom power is for low voltage distribution, and improving the poor quality and reliability of supply affecting sensitive loads. Custom power devices are very similar to the FACTS. Most widely known custom power devices are DSTATCOM, UPQC, DVR among them DSTATCOM is very well known and can provide cost effective solution for the compensation of reactive power and unbalance loading in distribution system [3].

The performance of the DSTATCOM depends on the control algorithm i.e. the extraction of the current components. For this purpose there are many control schemes which are reported in the literature and some of these are instantaneous reactive power (IRP) theory, instantaneous compensation, instantaneous symmetrical components, synchronous reference frame (SRF) theory, computation based on per phase basis, and scheme based on neural network [4- 11]. Among these control schemes instantaneous reactive power theory and synchronous rotating reference frame are most widely used. This paper focuses on the compensating the voltage sag, swells and momentary interruptions. The dynamic performance is analyzed and verified through simulation.

II. Distributed Static Compensator (DSTATCOM)

The Distribution Static Compensator (DSTATCOM) is a voltage source inverter based static compensator (similar in many respects to the DVR) that is used for the correction of bus voltage sags. Connection (shunt) to the distribution network is via a standard power distribution transformer. The DSTATCOM is capable of generating continuously variable inductive or capacitive shunt compensation at a level up its maximum MVA rating. The DSTATCOM continuously checks the line waveform with respect to a reference ac signal, and therefore, it can provide the correct amount of leading or lagging reactive current compensation to reduce the amount of voltage fluctuations. The major components of a DSTATCOM are shown in Fig. 1. It consists of a dc capacitor, one or more inverter modules, an ac filter, a transformer to match the inverter output to the line voltage, and a PWM control strategy. In this DSTATCOM implementation, a voltage-source inverter converts a dc voltage into a three-phase ac voltage that is synchronized with, and connected to, the ac line through a small tie reactor and capacitor (ac filter).

A. Basic Operating Principle

Basic operating principle of a DSATCOM is similar to that of synchronous machine. The synchronous machine will provide lagging current when under excited and leading current when over excited. DSTATCOM can generate and absorb reactive power similar to that of synchronous machine and it can also exchange real power if provided with an external device DC source.

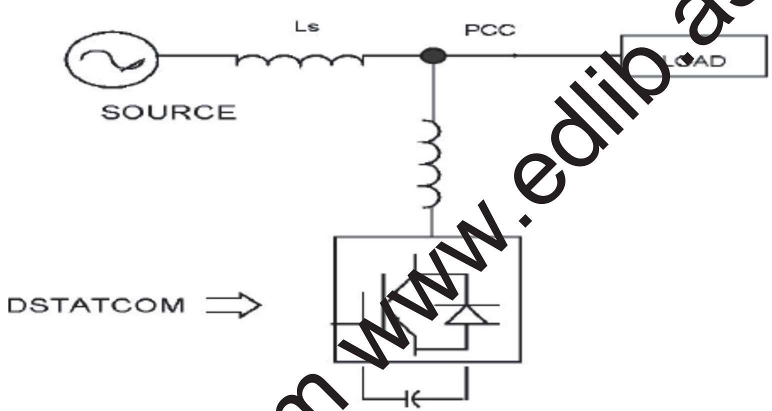

Fig.1 .block diagram of DSTATCOM circuit

1) Exchange of reactive power:- if the output voltage of the voltage source converter is greater than the system voltage then the DSATCOM will act as capacitor and generate reactive power(i.e.. provide lagging current to the system)
2) Exchange of real power: - as the switching devices are not loss less there is a need for the DC capacitor to provide the required real power to the switches. Hence there is a need for real power exchange with an AC system to make the capacitor voltage constant in case of direct voltage control. There is also a real power exchange with the AC system if DSTATCOM id provided with an external DC source to regulate the voltage in case of very low voltage in the distribution system or in case of faults. And if the VSC output voltage leads the system voltage then the real power from the capacitor or the DC source will be supplied to the AC system to regulate the system voltage to the $=1_{p.u}$ or to make the capacitor voltage constant. Hence the exchange of real power and reactive power of the voltage source converter with AC system is the major required phenomenon for the regulation in the transmission as well as in the distribution system.

III. Results and Analysis

In this work, the performance of VSC based power devices acting as a voltage controller is investigated. Moreover, it is assumed that the converter is directly controlled (i.e., both the angular position and the magnitude of the output voltage are controllable by appropriate on/off signals) for this it requires measurement of the rms voltage and current at the load point.The DSTATCOM is commonly used for voltage sags mitigation and harmonic elimination at the point of connection. The DSTATCOM employs the same blocks as the DVR, but in this application the coupling transformer is connected in shunt with the ac system, as illustrated in Fig.2.. The VSC generates a three-phase ac output current which is controllable in phase and magnitude. These currents are injected into the ac distribution system in order to maintain the load voltage at the desired voltage reference. Active and reactive power exchanges between the VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

1) Voltage regulation and compensation of reactive power; 2) Correction of power factor 3) Elimination of current harmonics.

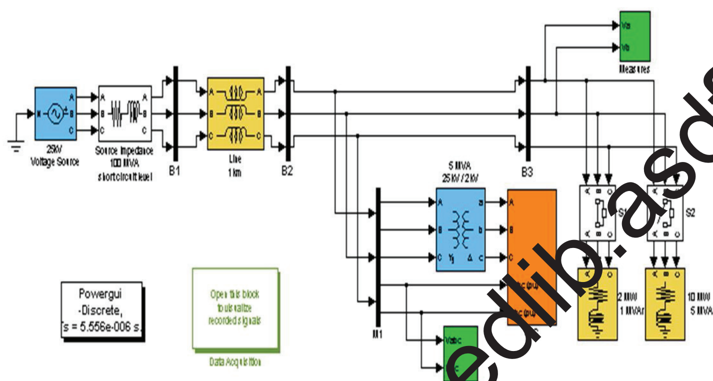

Fig.2. DSTATCOM connected to 25kVdistribution system

The DSTATCOM model developed using the mat lab is allowed to run for .5 seconds. A fixed inductive load is always connected to the source .the increase or decrease in voltage is performed by using circuit breakers with a delay of 0.2second from the start of the simulation.

(A) Balanced Loads:

Without Dstatcom Compensation:

Case: 1 (an inductive load is applied .2seconds after the start of the simulation)
Initially there is a fixed inductive load is connected to the line. After .2 second the circuit breaker .is closed and the terminal voltage is decreased to.8pu. The top window shows the change in the three phase voltage waveforms, the second window shows the changes in the currents when the inductive load is applied after .2seconds and the bottom window shows the magnitude of the voltage.

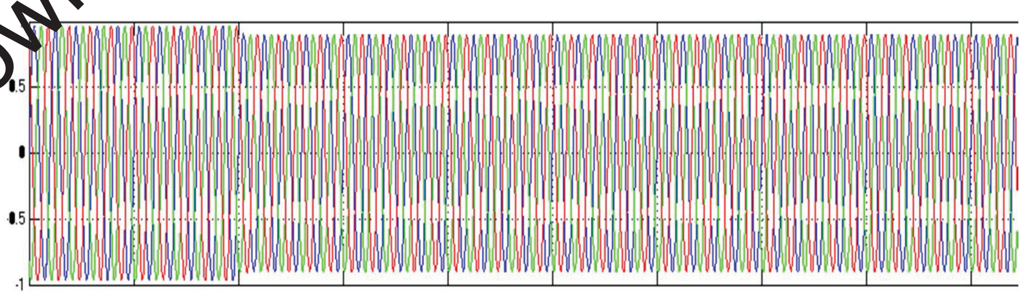

Fig 3.load voltage with inductive load in the uncompensated line

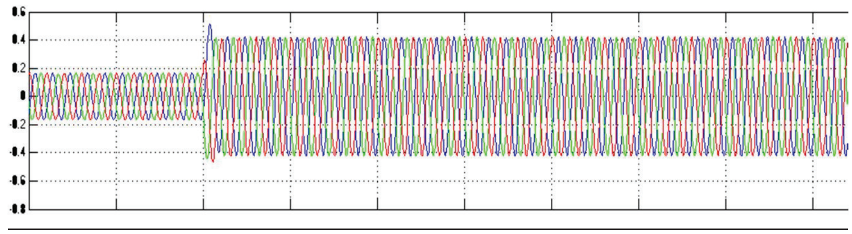

Fig 4. Load current with inductive load in the uncompensated line

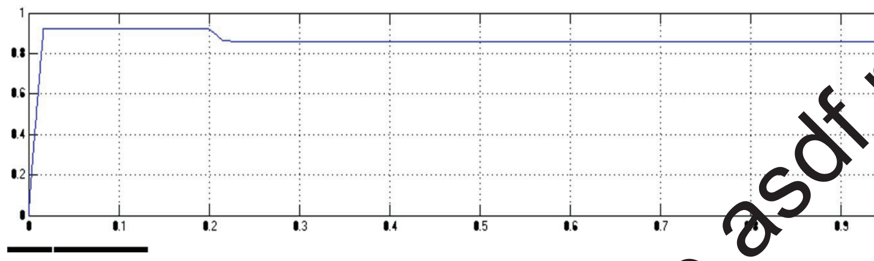

Fig 5. Load voltage magnitude with inductive load in the uncompensated line

Compensation Using Decoupled Current Control

6.2 With DSTATCOM Compensation:

Case: 1 (an inductive load is applied .2seconds after the start of the simulation)
Considering that the DSTATCOM is connected in shunt with the line. Initially there is a fixed inductive load is connected to the line. After 0.2 seconds the circuit breaker is closed an inductive load is applied, but in both the cases we observe that there is no drop in the terminal voltage due to the injection of reactive power by the DSTATCOM .Therefore the load is maintained at unity power factor. The top window shows that there is no change in the voltage waveform and it is maintained at unity power factor. The second window shows the variations in the currents when inductive loads are applied at different instances of the simulation.

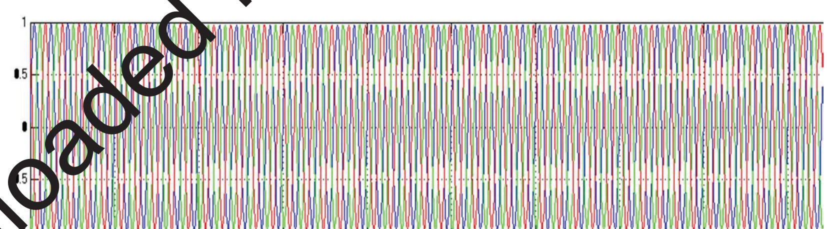

Fig 6..load voltage with inductive load in the compensated line

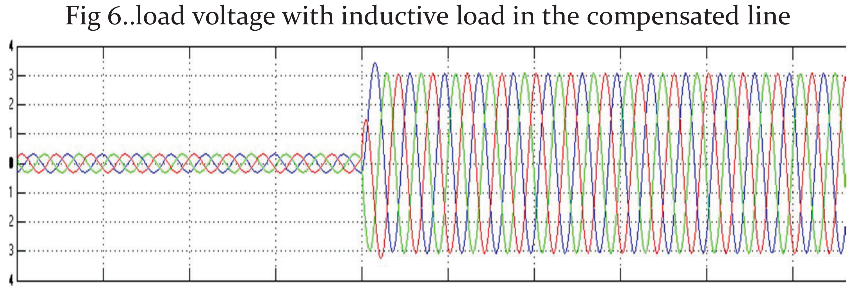

Fig 7.load current with inductive load in the compensated line

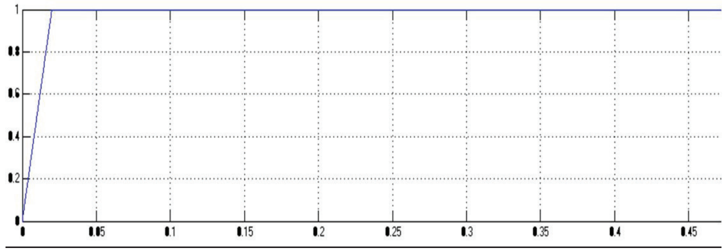

Fig 8.load voltage magnitude with inductive load in the compensated line

(B) Un-Balanced Loads:

6.3 With Out Dstatcom Compensation.

Case: 1 (an inductive load is applied .2seconds after the start of the simulation)
Initially there is a fixed inductive load is connected to the line. After .2 second the circuit breaker is closed and the terminal voltage is decreased to.8pu due to the unbalanced inductive load. The top window shows the change in the three phase voltage waveforms, the second window shows the changes in the currents when the inductive load is applied after .2seconds and the bottom window shows the magnitude of the voltage.

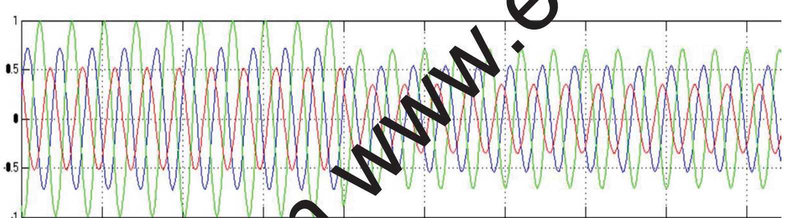

Fig 9.load voltage waveform with unbalanced inductive load in the uncompensated line

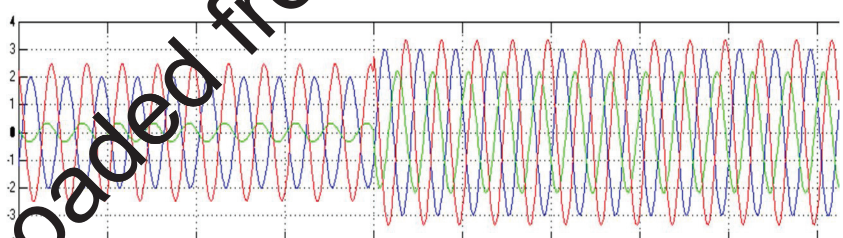

Fig 10 .load current waveform with unbalanced inductive load in the uncompensated

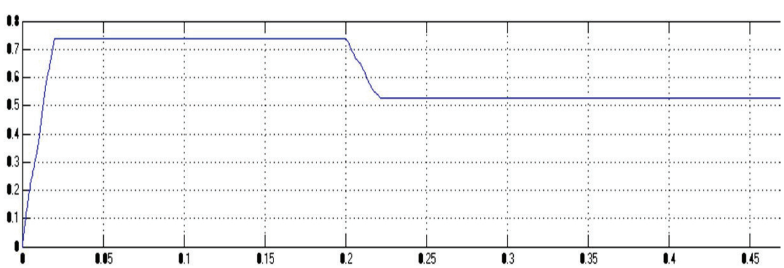

Fig 11 .load voltage magnitude waveform with unbalanced inductive load in the uncompensated line

Compensation Using Decoupled Current Control:

6.4 With Dstatcom Compensation

Case: 1 (an inductive load is applied .2seconds after the start of the simulation)
Considering that the DSTATCOM is connected in shunt with the line. Initially there is a fixed inductive load is connected to the line. After 0.2 seconds the circuit breaker is closed an inductive load is applied, but in both the cases we observe that there is no drop in the terminal voltage due to the injection of reactive power by the DSTATCOM .Therefore the load is maintained at unity power factor. The top window shows that there is no change in the voltage waveform and it is maintained at unity power factor. The second window shows the variations in the currents when inductive loads are applied at different instances of the simulation.

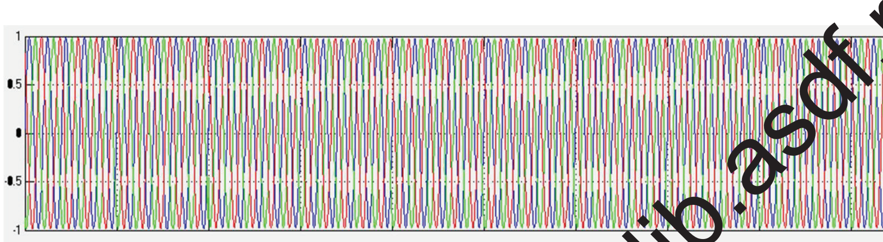

Fig 12 .load voltage magnitude waveform with unbalanced inductive load in the compensated line

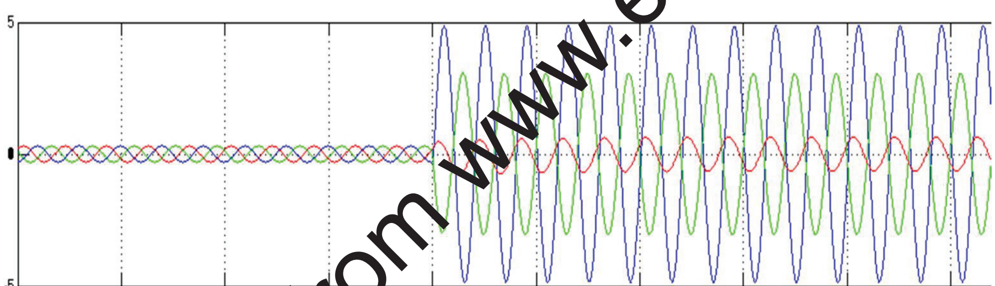

Fig 13..load current waveform with unbalanced inductive load in the compensated line

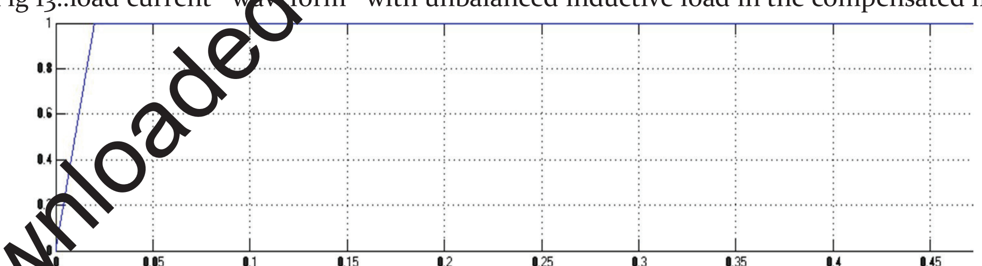

Fig 14 .load voltage magnitude waveform with unbalanced inductive load in the compensated line

IV. Conclusions

CUSTOM POWER (CP) devices can be used, at reasonable cost, to provide high power quality and improved power service. These Custom Power devices provide solutions to power quality at the medium voltage distribution network level. This project presents the detailed modeling of one of the custom power products, DSTATCOM is presented and also a comparative study of two control algorithms, phase shift control and instantaneous P-Q theory, used for the control of DSTATCOM are discussed with their relative merits and demerits. These control algorithms are described with the help of simulation results under linear loads. The control scheme maintains the power balance at the PCC to regulate the dc capacitor voltages. PWM control scheme only requires voltage measurements. This characteristic makes it ideally suitable for low-voltage custom power applications. The control scheme was tested under a wide range of operating conditions, and it was observed to be very robust in every case. Extensive simulations were conducted to gain insight into the impact of capacitor size on DSTATCOM harmonic generation, speed of response of the PWM control and transient overshooting. It was observed that an undersized capacitor degrades all three aspects. On the other hand, an oversized capacitor may also lead to a PWM control with a sluggish response but it will reduce D-STATCOM harmonic generation and transient overshooting. It is concluded that a DSTATCOM though is conceptually similar to a STATCOM at the transmission level; its control scheme should be such that in addition to complete reactive power compensation, power factor correction and voltage regulation the harmonics are also checked, and for achieving improved power quality levels at the distribution end.

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