RESEARCH ARTICLE OPEN ACCESS

Implementation of Control Strategies for Power Quality Improvement Using Distribution Static Compensator (D-Statcom)

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ABSTRACT
This present paper deals the enhancement of voltage sags, Harmonic distortion and low power factor using Distribution Static Compensator (D-STATCOM) in Distribution system. The present model is based on the Voltage Source Converter (VSC) principle. The D-STATCOM injects a current into the system to mitigate the voltage sags. The operation of the proposed control method is presented for D-STATCOM. Simulations and analysis are carried out in MATLAB/SIMULINK with this control method for the proposed systems. The reliability of the control scheme in the system response to the voltage instabilities due to system faults or load variations is proved obviously in the simulation results.
Keywords: D-STATCOM, VSC, MATLAB/ SIMULINK**.**

I. INTRODUCTION

An increasing demand for high quality, reliable electrical power and increasing number of distorting loads may leads to an increased awareness of power quality both by customers and utilities. The most common power quality problems today are voltage sags, harmonic distortion and low power factor. Voltage sags is a short time (10 ms to 1 minute) event during which a reduction in rms voltage magnitude occur. It is often set only by two parameters, depth/magnitude and duration. The voltage sags magnitude is ranged from 10% to 90% of nominal voltage and with duration from half a cycle to 1 min. Voltage sags is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing. Voltage sags are one of the most occurring power quality problems. For an industry voltage sags occur more often and cause severe problems and economical losses. Utilities often focus on disturbances from end-user equipment as the main power quality problems.

Harmonic currents in distribution system can cause harmonic distortion, low power factor and additional losses as well as heating in the electrical equipment. It also can cause vibration and noise in machines and malfunction of the sensitive equipment. The development of power electronics devices such as Flexible AC Transmission System (FACTS) and customs power devices have introduced and emerging branch of technology providing the power system with versatile new control capabilities. There are different ways to enhance power quality problems in transmission and distribution systems. Among these, the D-STATCOM is one of the most effective devices.

A new PWM-based control scheme has been implemented to control the electronic valves in the DSTATCOM. The D-STATCOM has additional capability to sustain reactive current at low voltage, and can be developed as a voltage and frequency support by replacing capacitors with batteries as energy storage. In this paper, the configuration and design of the DSTATCOM is analyzed. It is connected in shunt or parallel to the 11 kV test distribution system. The design is used to enhance the power quality such as voltage sags, harmonic distortion and low power factor in distribution system.

II. POWER QUALITY & IT'S PROBLEMS

For the purpose of this article, we shall define power quality problems as 'Any power problem that results in failure or mis-operation of customer equipment, manifests itself as an economic burden to the user, or produces negative impacts on the environment.' When applied to the container crane industry, the power issues which degrade power quality include, Power Factor, Harmonic Distortion, Voltage Transients, Voltage Sags or Dips, Voltage Swells.

The AC and DC variable speed drives utilized on board container cranes are significant contributors to total harmonic current and voltage distortion. Whereas SCR phase control creates the desirable average power factor, DC SCR drives operate at less than this. In addition, line notching occurs when SCR's commutate, creating transient peak recovery voltages that can be 3 to 4 times the nominal line voltage depending upon the system impedance and the size of the drives.

The frequency and severity of these power system disturbances varies with the speed of the drive. Harmonic current injection by AC and DC drives will be highest when the drives are operating at slow speeds. Power factor will be lowest when DC drives are operating at slow speeds or during initial acceleration and deceleration periods, increasing to its maximum value when the SCR's are phased on to produce rated or base speed. Above base speed, the power factor essentially remains constant.

Low power factor loads can also affect the voltage stability which can ultimately result in detrimental effects on the life of sensitive electronic equipment or even intermittent malfunction. Voltage transients created by DC drive SCR line notching, AC drive voltage chopping, and high frequency harmonic voltages and currents are all significant sources of noise and disturbance to sensitive electronic equipment.

It has been our experience that end users often do not associate power quality problems with Container cranes, either because they are totally unaware of such issues or there was no economic Consequence if power quality was not addressed. Before the advent of solid-state power supplies, Power factor was reasonable, and harmonic current injection was minimal.

Even as harmonic distortion and power Factor issues surfaced, no one was really prepared. Rather than focus on Awareness and understanding of the potential issues, the power quality issue is intentionally or unintentionally ignored. Power quality problem solutions are available. Although the solutions are not free, in most cases, they do represent a good return on investment. However, if power quality is not specified, it most likely will not be delivered.

III. DESIGN OF MULTI LEVEL BASED DSTATCOM

3.1 Principle of DSTATCOM

A D-STATCOM (Distribution Static Compensator), which is schematically depicted in Fig 3.1, 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. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. 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. Such configuration allows the device to absorb or generate controllable active and reactive power.

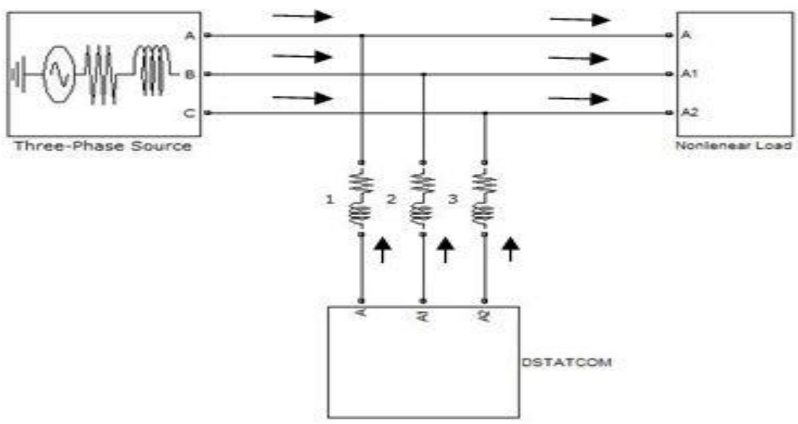


Fig 3.1 Basic Schematic Diagram of D-STATCOM

The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

(i) Voltage regulation and compensation of reactive power;
(ii) Correction of power factor; and
(iii) Elimination of current harmonics.

3.2 Cascade H-Bridge Multilevel Inverter

The circuit is a model of a single CHB inverter Configuration. By using H-Bridge we can get 3 voltage levels. The number of output voltage levels of CHB is given by 2n-1 and voltage step of each level is given by Vdc/2n. where n is number of H- Bridges connected in cascade. The switching table is given in Table1.

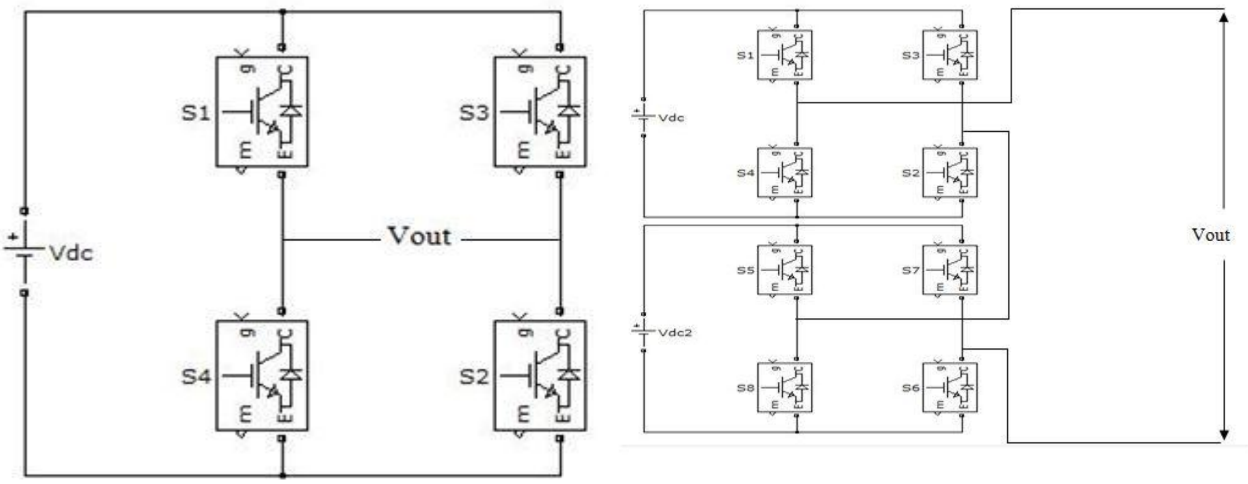


Fig 3.3 Single cascaded H-Bridge Inverter

Table 3.1 Switching table of single CHB inverter levels HB inverter

Switches TURN ON	Voltage Level
S1,S2	**Vdc**
S3,S4	**-Vdc**
S4,S2	**0**

IV. MATLAB MODELLING AND SIMULATION RESULTS

The D-STATCOM model is done based on Mat lab Simulink. Here simulation is carried out in different cases such as

Table 3.2 Switching table for 5

Switches TURN ON	Voltage Level
S1,S2	Vdc
,S5,S6	2Vdc
S4,S2,S8,S6	0
S3,S4	-Vdc
S3,S4,S7,S8	-2Vdc

1) Implementation of D-STATCOM using level Shifted Modulation Technique.
2) Implementation of D-STATCOM using Phase Shifted Modulation Technique

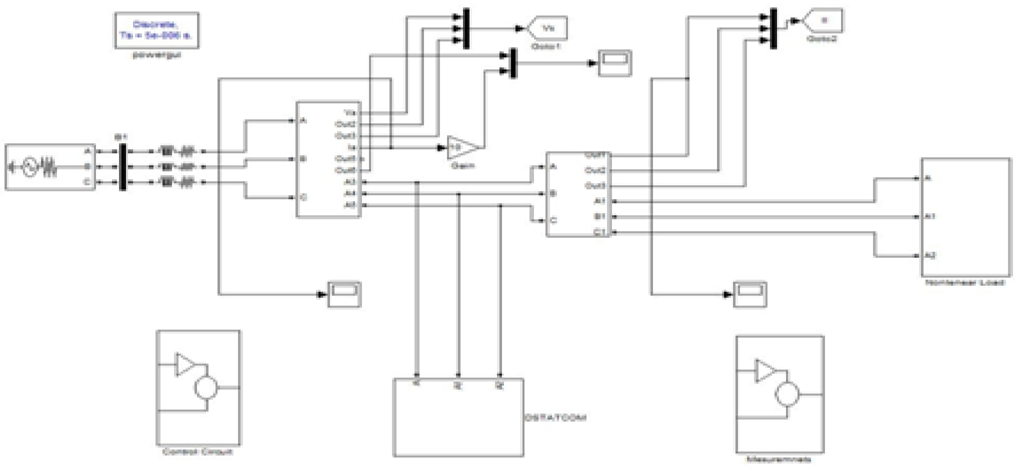
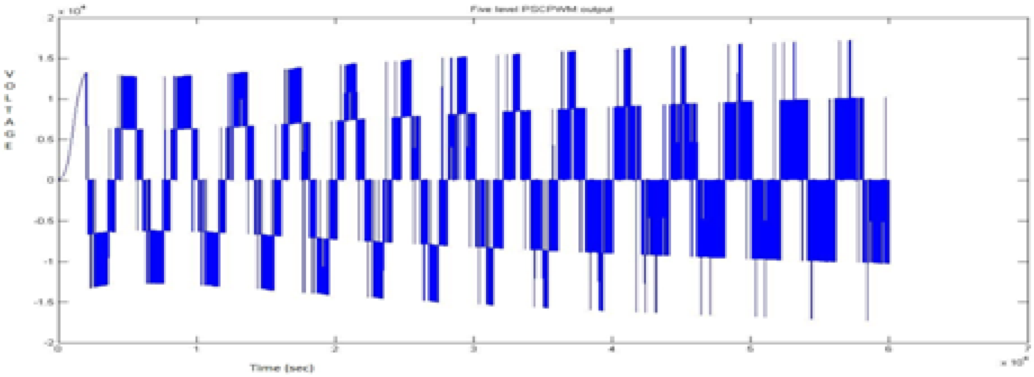


Fig 4.1 MATLAB Simulink model of proposed compensator using Level shifted modulation Technique based CHB D-STATCOM



D-STATCOM

Fig 4.2 Phase A voltage of five level output of level shifted carrier PWM inverter

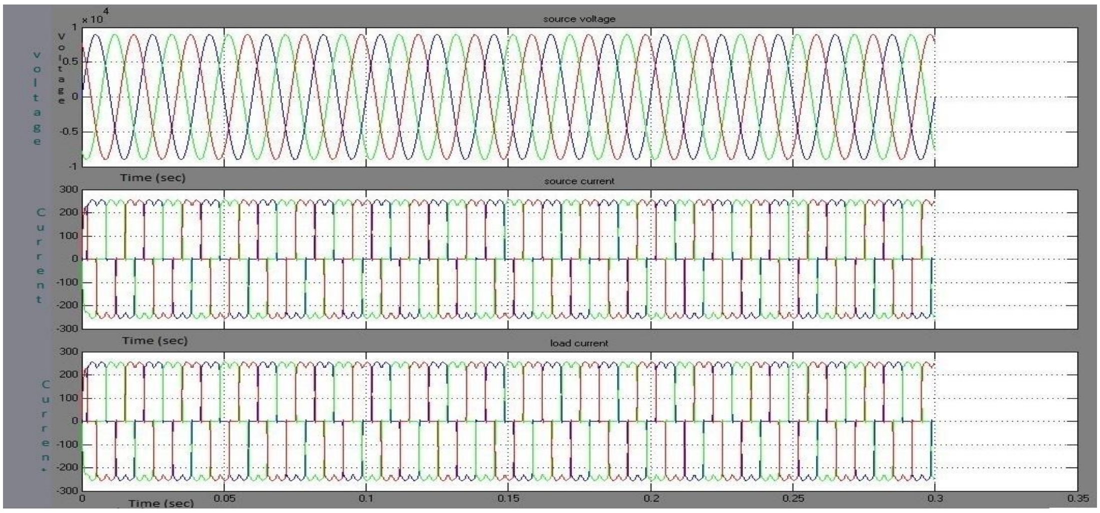


Fig 4.3 Three phase source voltage, three phase source currents and load currents respectively without D-STATCOM.

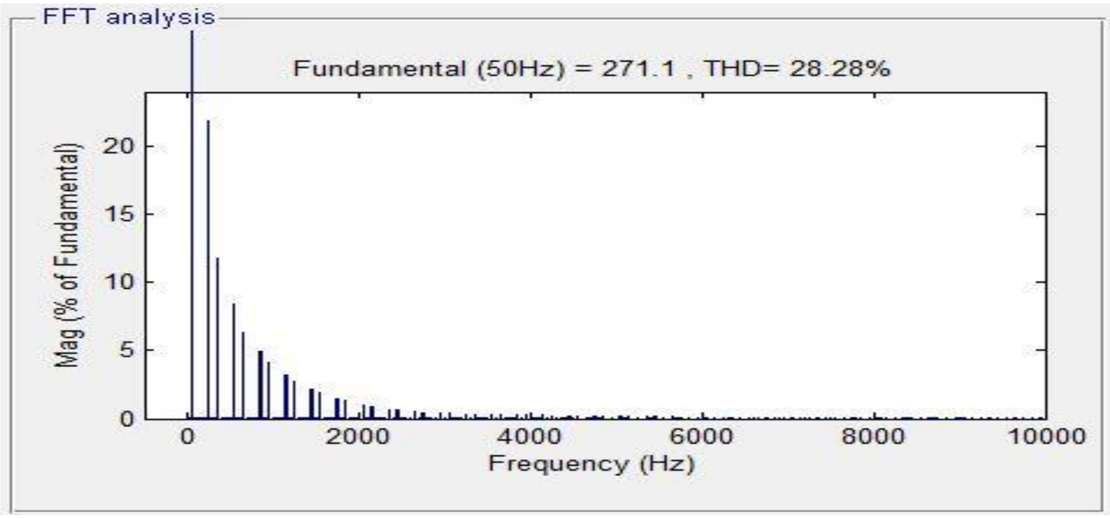


Fig 4.4 Harmonic spectrum of phase source current without DSTATCOM.

Case 1. Implementation of D-STATCOM using Level Shifted Modulation Technique (LSMT)

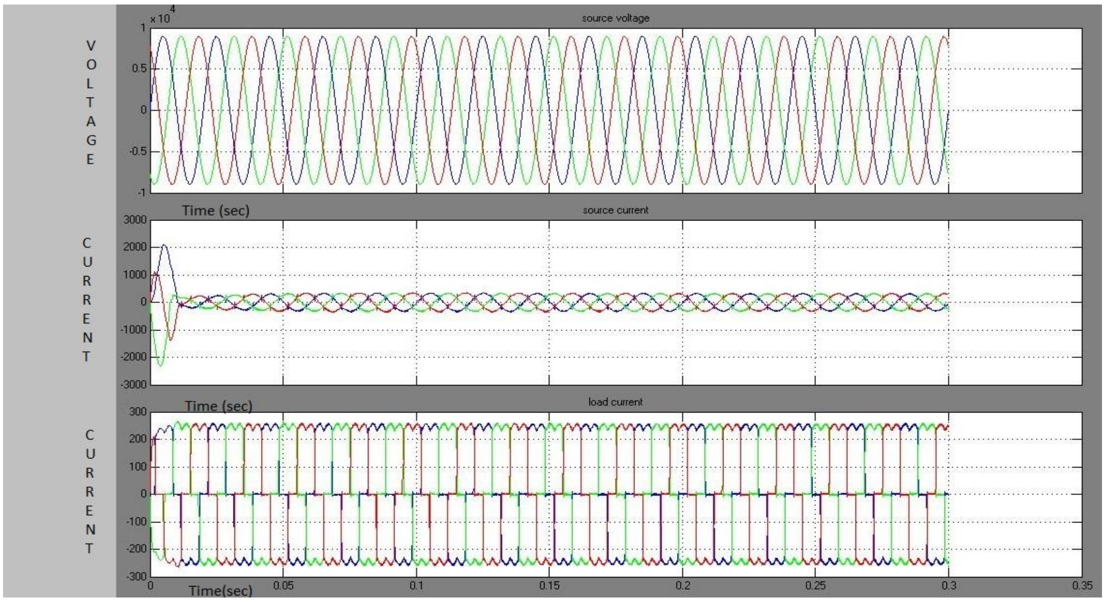


Fig 4.5 Source voltage, source current, load current with DSTATCOM

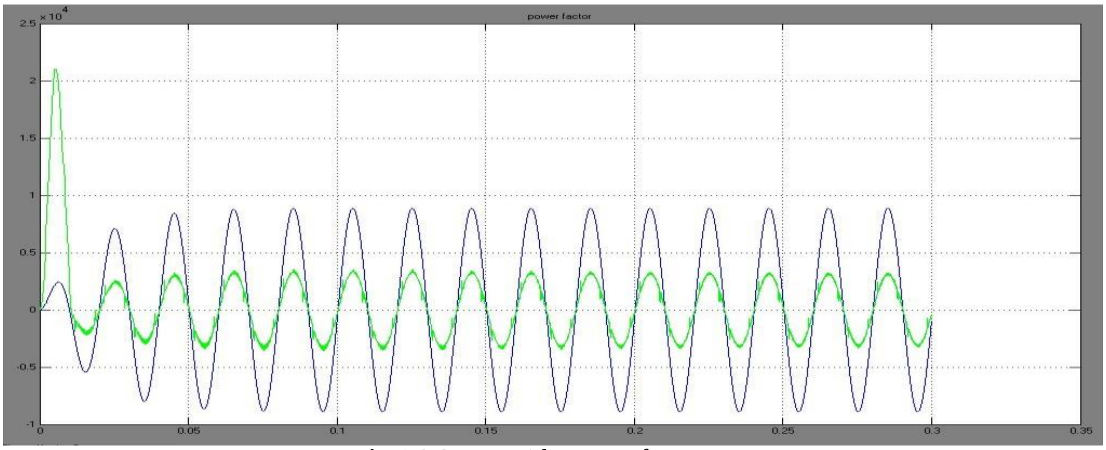


Fig 4.6 Source side power factor

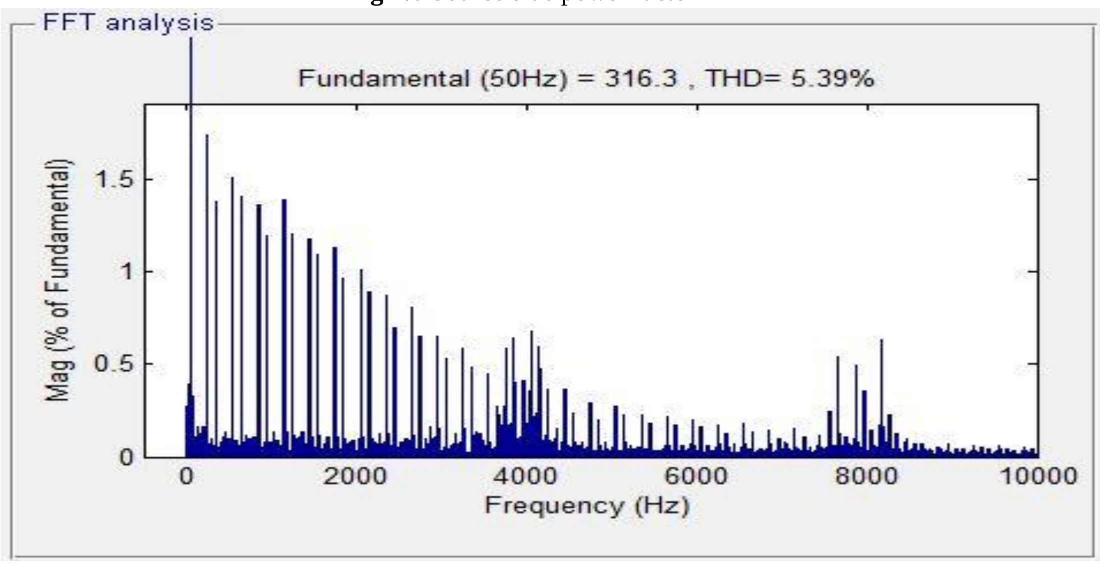


Fig 4.7 FET Analysis of source current with compensator using LS Modulation Technique

Case 2. Implementation of D-STATCOM using Phase Shifted Modulation Technique (PSMT)

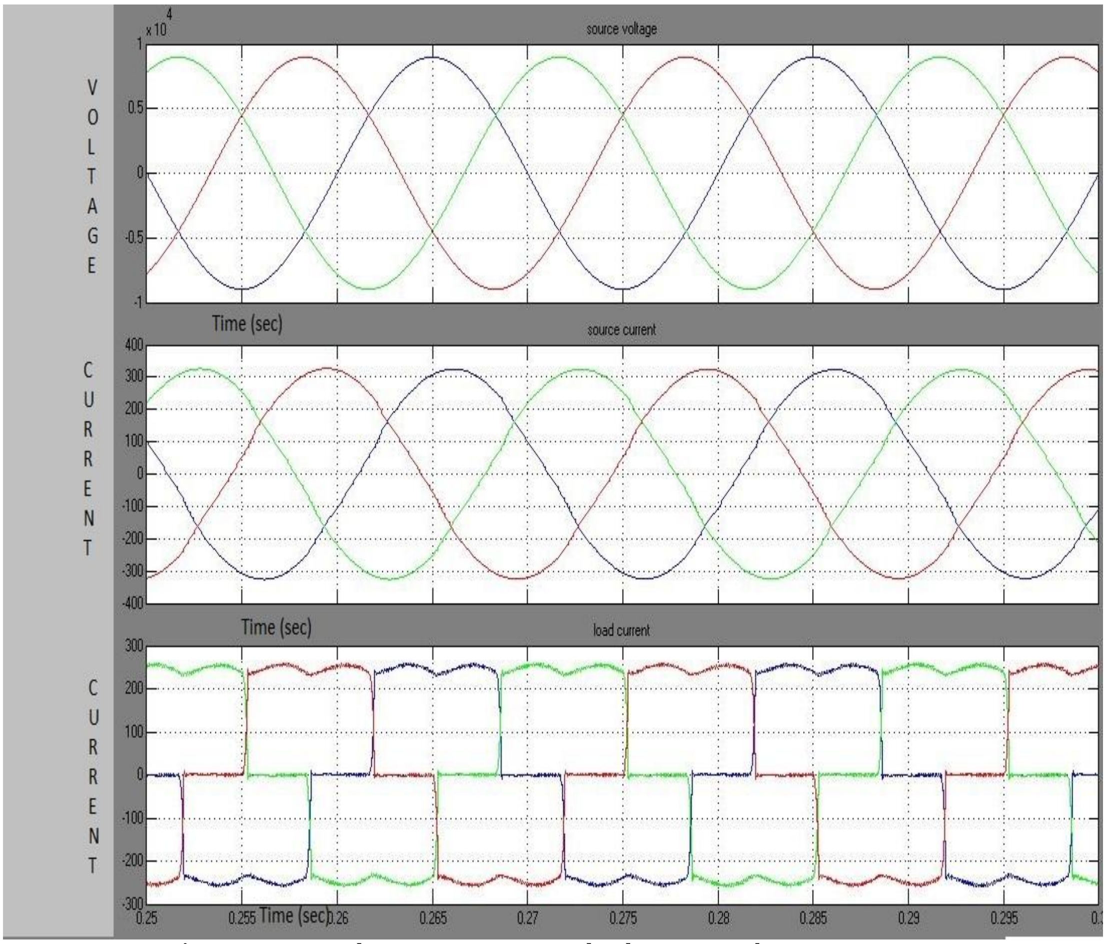


Fig 4.8 Source voltage, source current, load current with DSTATCOM.

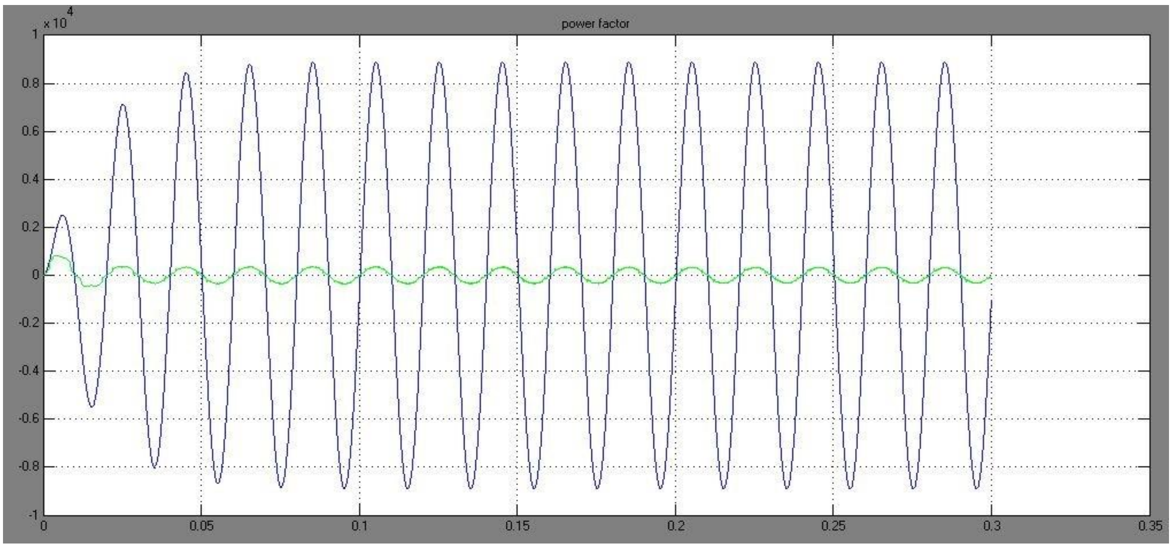


Fig 4.9 Source side power factor, both voltage and current are maintained sinusoidal and in phase condition

Fig 4.9 Source side power factor

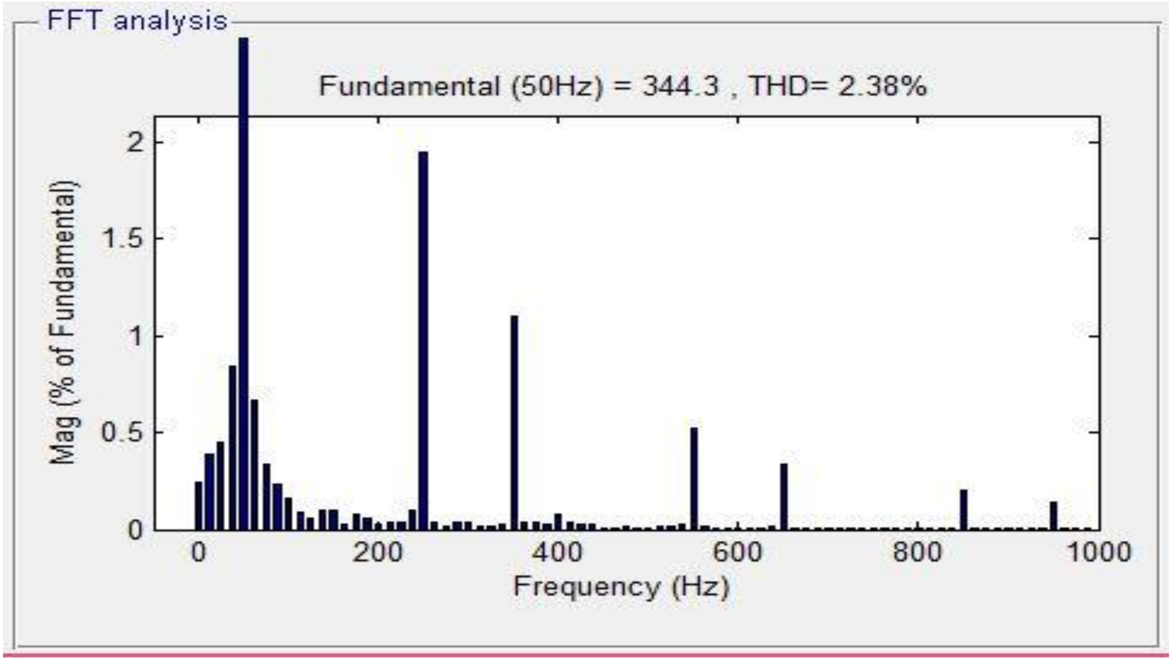


Fig 4.10 FET Analysis of source current with compensator using PS Modulation Technique

V. THE BENEFITS OF POWER QUALITY

Power quality in the container terminal environment impacts the economics of the terminal operation, affects reliability of the terminal equipment, and affects other consumers served by the same utility service. Each of these concerns is explored in the following paragraphs.

(i). Economic Impact

The economic impact of power quality is the foremost incentive to container terminal operators. Economic impact can be significant and manifest itself in several ways. Many utility companies invoke penalties for low power factor on monthly billings. There is no industry standard followed by utility companies. Methods of metering and calculating power factor penalties vary from one utility company to the next. Some utility companies actually meter kVAR usage and establish a fixed rate times the number of kVAR-hours consumed. Other utility companies monitor kVAR demands and calculate power factor. If the power factor falls below a fixed limit value over a demand period, a penalty is billed in the form of an adjustment to the peak demand charges. A number of utility companies servicing container terminal equipment do not yet invoke power factor penalties. However, their service contract with the Port may still require that a minimum power factor over a defined demand period be met. The utility company may not continuously monitor power factor or kVAR usage and reflect them in the monthly utility billings; however, they do reserve the right to monitor the Port service at any time. If the power factor criteria set forth in the service contract are not met, the user may be penalized, or required to take corrective actions at the user's expense.

(ii). Equipment Reliability

Poor power quality can affect machine or equipment reliability and reduce the life of components. Harmonics, voltage transients, and voltage system sags and swells are all power quality problems and are all interdependent. Harmonics affect power factor, voltage transients can induce harmonics, the same phenomena which create harmonic current injection in DC SCR variable speed drives are responsible for poor power factor, and dynamically varying power factor of the same drives can create voltage sags and swells.

(iii). Environment

No issue might be as important as the effect of power quality on our environment. Reduction in system losses and lower demands equate to a reduction in the consumption of our natural 'resources and reduction in power plant emissions. It is our responsibility as occupants of this planet to encourage conservation of our natural resources and support measures which improve our air quality.

VI. CONCLUSIONS

By comparing all the THD parameters of the DSTATCOM by using Level Shift Modulation Technique and Phase Shift Modulation Techniques leads to reduction in harmonics and provides reactive power compensation due to non- linear load currents.

Parameter	Without D-STATCOM	With DSTATCOM with Level Shifted Modulation Technique(LSMT)	With DSTATCOM with Phase Shifted Modulation Technique(PSMT)
THD	28.28%	5.39%	2.38%

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