POWER SYSTEM STABILITY BY USING FACTS DEVICES

D-STATCOM

DISSERTATION-II

Submitted in partial fulfillment of the requirement for the award of the degree

Of

MASTER OF TECHNOLOGY

IN

Power Systems

By

BALJINDER SINGH

Under the Esteemed Guidance of

Ms. Navita

School of Electrical & Electronics Engineering
Lovely Professional University
Punjab

MAY 2015

INDIA'S LARGEST UNIVERSITY*

LOVELY PROFESSIONAL UNIVERSITY

Transforming Education Transforming India

Discipline: ……………………………………………………………………….

PROJECT/DISSERTATION TOPIC APPROVAL PERFORMA

Name of student: Registration No.:

Batch: Roll no.:

Session: Parent section:

Details of Guide:

Name: ……………….... Qualification: …………….

U.ID………………….. Research Experience: ……….

PROPOSED TOPICS

1. ……………………………………………………………………………………………………

2. ……………………………………………………………………………………………………

3. ……………………………………………………………………………………………………

Signature of Guide

*Guide should finally encircle one topic out of three proposed topics & put up for approval before project approval committee (PAC).

*Original copy of this format after PAC approval will be retained by the student & must be attached in the project/dissertation synopsis & final report.

*One copy to be submitted to guide.

APPROVAL PAC CHAIRPERSON Signature:

CERTIFICATE

This is to certify that the Thesis titled "**POWER SYSTEM STABILITY BY USING FACTS DEVICES**" that is being submitted by "**BALJINDER SINGH** " is in partial fulfillment of the requirements for the award of **MASTER OF TECHNOLOGY DEGREE (POWER SYSTEMS)**, is a record of bonafide work done under my/our guidance. The content of this dissertation-II , in full or in parts, have neither taken from any other source nor have been submitted to any other Institute or university for award of and degree or diploma and the same is certified.

Ms. Navita
ASSISTANT PROFESSOR
(LOVELY PROFESSIONAL UNIVERSITY)

Objective of the Thesis is satisfactory /unsatisfactory

Examiner I **Examiner II**

ACKNOWLEDGEMENT

I would like to thank **LOVELY PROFESSIONAL UNIVERSITY** for giving me opportunity to use their resource and work in such a challenging environment. I am grateful to the individuals whom contributed their valuable time towards my thesis.

I wish to express my sincere and heart full gratitude to my guide "**Ms. Navita**" Assistant professor, who guides me to take up this thesis in sync with global trends in scientific approach.

I would also like to extend my gratitude to my friends and family who always encouraged and supported me in this thesis work.

Last but not the least; I would like to thank all the staff members of department of Electrical and Electronics engineering who have been very patient and co-operative with us.

BALJINDER SINGH
Reg. No. 11310397

CERTIFICATE

This is to certify that **BALJINDER SINGH** bearing Registration no. **11310397** has completed objective formulation of thesis title "**POWER SYSTEM STABILITY BY USING FACTS DEVICES"** under my guidance & supervision. To the best of my knowledge, the present work is the result of his original investigation & study. No part of the thesis has ever been submitted for any other degree at any University.

The dissertation-II is fit for submission and the partial fulfillment of the conditions for the award of **MASTER OF TECHNOLOGY (POWER SYSTEMS**).

Ms. Navita
Assistant professor
Lovely Professional University
Phagwara, Punjab.

Date:

DECLARATION

I, student of **MASTER OF TECHNOLOGY (POWER SYSTEM)** under **DEPARTMENT OF ELECTRICAL ENGINEERING** of lovely professional university, Punjab, hereby declare that all the information furnished in this pre dissertation reports based on my own intensive research and is genuine.

This dissertation-II does, to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university without proper citation.

Date:

BALJINDER SINGH
Registration No.11310397

TABLE OF CONTENTS
List of Figures and Tables
Abstract

LIST OF FIGURES AND TABLES

LIST OF TABLE

ABSTRACT

Power Quality problem in a system leads to various disturbances such as voltage fluctuations, transients and waveform distortions. Due to non linearity of load it leads to fluctuations in waveform. Modern industrial equipments produce distortion in load current and harmonic distortions. Present day power consumers are also aware enough regarding various Power Quality problems that lead to inconvenience. So engineers are also working in this field dedicatedly to improve the quality of power supply. One of the results of their research in this field is DSTATCOM (Distribution STATCOM) that performs various compensating functions in distribution systems.

A Distribution Static Compensator is a Voltage Source Converter based device. It is connected in parallel with the system to be compensated. This device injects compensating response at PCC into the system. Various Power Quality issues like voltage sag, swell, harmonics, power factor are compensated by this device. further its performance has been compared with VSI based DSTATCOM in a distribution network in MATLAB/SIMULINK environment. The performance of DSTATCOM to improve THD level in source current, Power Factor Improvement and load balancing has been demonstrated in this work.

CHAPTER 1

INTRODUCTION

1.1 Power system stability

Power system stability is the function of power system this condition the stability operation control the stability which occur by the disturbance in line. In the system constants and other variable error like fault it will make the system stability to increase the voltage level. Small and long disturbances are the part of the power system stability. , These classifications are shown in Fig (1.1).

1.1.1 Rotor angle stability

The function of the system is subjected when the disturbance in synchronous it make angle of rotor in generator depends on the control between the electromagnetic torques. The generator electrical power production and mechanical torque feedback through a prime mover. Few generators the balance between electromagnetic and mechanical torque is unbalanced in the system, then in the rotor angle oscillation will lead. .

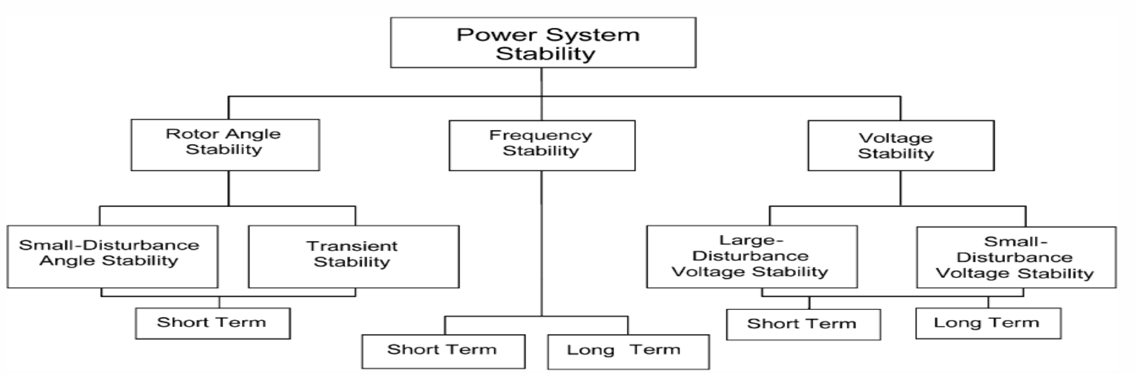

Fig.1.1: following classification of stability

1.1.2 Small-disturbance or small-signal angle stability

This is the function of the system which stable the synchronous generator disturbance .If a disturbance is less sufficient the nonlinear system will be estimated as a line system. In small disturbances can small load changes like switching on-off for small loads, line tripping and small generators tripping .Due to small disturbances there are two types of instability can be created: non-oscillatory instability and oscillatory instability. In non-oscillatory instability the rotor angle of a generator keeps on increasing due to a small disturbance and in case of oscillatory instability the rotor angle oscillates with increasing magnitude.

1.1.3 Large-disturbance or transient angle stability

The stability of the system is to stay on synchronism when in large disturbances. Large disturbance is due to switching on- off for high loads, faults and no of generators tripping. When in power system is subjected to more disturbances they will lead group of generator rotor angles. In the meantime more rotor angle changes the power system cannot be estimated by a linear representation in the case of less-disturbance stability. Time domain for large-disturbance as well as small-disturbance angle stability is 0.1- 10 s. Due to this reason small and large-disturbance angle stability are considered to be short term phenomenon. It has to be noted here that though in some literature “dynamic stability” is used in place of transient stability, according to IEEE task force committee report, only transient stability has to be used.

1.1.4 Voltage stability

This is the function of stability which stable the voltages and disturbances which occurs in the system. If the disturbance is more than it is called a long-disturbance voltage stability and if the disturbance is less it is called less-disturbance voltage stability. Dissimilar angle stability, voltage stability can also be a long term phenomenon. In case of voltage drop occur due to fast acting devices like induction motors, power electronic drive and HVDC then the time taken to understanding the stability is in the period of 10-20 s. then is called a short term phenomenon. On the other hand, if voltage drops there are slow changes in load, over loading of lines, generators hitting reactive power limits tap changing transformers and then time taken by the system for stability is 1 minute to several minutes.

1.2 Steady-State Stability

In the power systems in general and alternators particular have steady state stability limit beyond which is subjected to gradual load changes will loss steady state stability. Power system is capable for resist the changes that produce after the disturbance and that remain stable and is capable to maintain equilibrium.

1.3 Transient Stability

Power system stability is used to make the system stable up to when the actual position of the system can be shown is called the Transient stability. In the system when disturbance occur the components of the system removes the faults and other disturbances. In the line no off losses and other type of error disturb the line and cannot flow the power at the load side. That's way we use the transient stability to stable the system at the good condition.

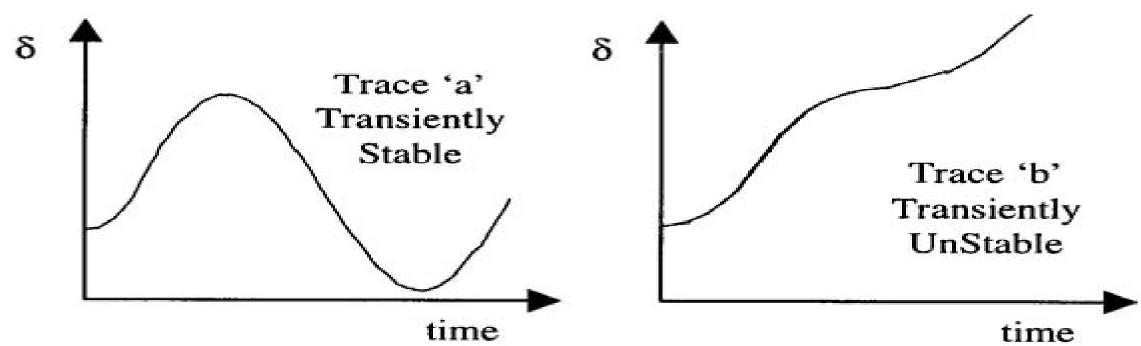

Figure 1.2: typical swing curve

1.3.1 The Equal Area Criterion

The dynamic performance of the generator that define the swing equation which make show the combination of angles. The possible equal area criterion. The mech. I/P of generator *Pm0*, $\delta = \delta 0$ an system works on point "a". However, the rotor speed is greater than the synchronous speed and the angle continues to increase. Beyond "b," $Pe > Pm$ and the rotor decelerates until reaching a maximum *m*ix at which point the rotor angle starts to return towards "b."

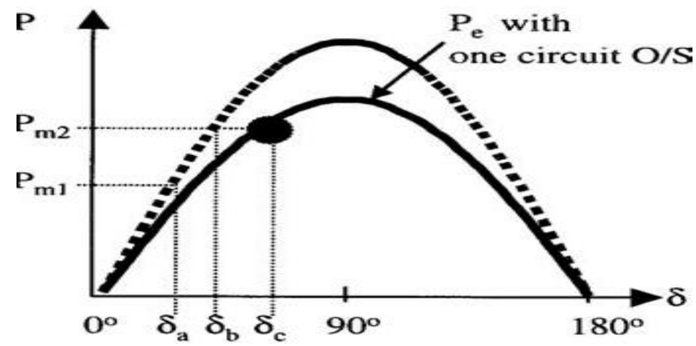

Fig 1.3: Power-angle relationship with one circuit out of service.

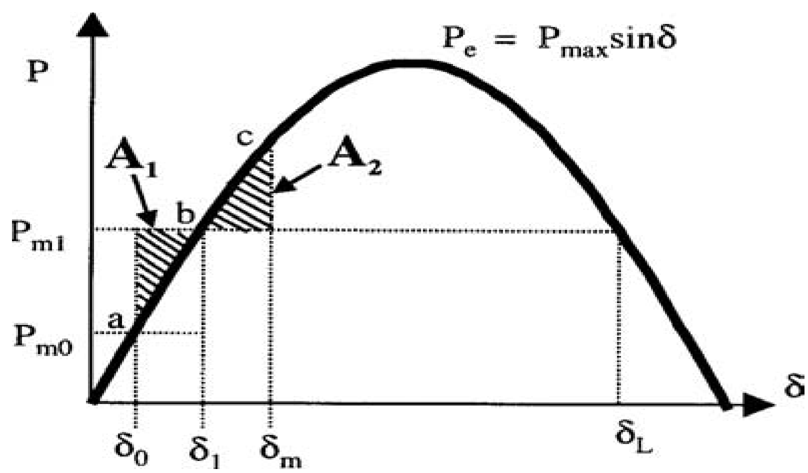

Fig 1.4: Equal area criterion for step change in mechanical power.

As we will see, for a single machine infinite bus system, it is not necessary to plot the swing curve to determine if the rotor angle of the machine increases indefinitely, or if it oscillates around an equilibrium point.

1.4 Voltage profile improvement

The function of voltage instability can be considered the proper plan it increment the load , which causing the system condition and voltage profile particular load. The voltage stability as well as sag and swell sensitive the load .The power quality of the system can be improve the time range and time limits which shows the variation and duration of the disturbance.

1.5 Introduction of FACTS Devices

Flexible AC T/M system is a system which composed the stable element which are used for AC T/M of electrical energy. It means to improve the docility which increase the power capacity of N/W. It is commonly power electronic system.

FACTS devices is following four dimensions:

- Series Controllers
- Shunt Controllers
- Combination of series-series Controllers
- Combination of series-shunt Controllers

1.5.1 Series Controllers: Series Controller have a on and off device. capacitor, reactor and power electronics. The voltage controller is a series controller with in line. The multiple impedance variable used to flow the current through in line. As well as possible voltage in line which along in the first quadrature. The basic components used for series connected system are SSSC, IPFC, TCSC, TSSC, and TCSR. The most useful controller to achieve sinusoidal voltage with variable amplitude is explained below:.

1.5.1.1 SSSC (Static Synchronous Series Compensator)

SSSC is the family of FACTS. Which represent the voltage and amplitude. Capacitive and inductive reactance in T/M line. In sssc supplied the voltage into two parts. In the line capacitive reactance cover the losses which produced in the line. When injective voltage produced then the line current will increase. The fig of SSSC and equivalent circuit SSSC is shown in fig (1.5).

1.5.1.1.1 SSSC is superior to other FACTS equipment and the benefits of using SSSC are:

- Remove the heavily positive element - capacitors and reactors.
- Symmetrical capacity of capacitive and inductive nodes.

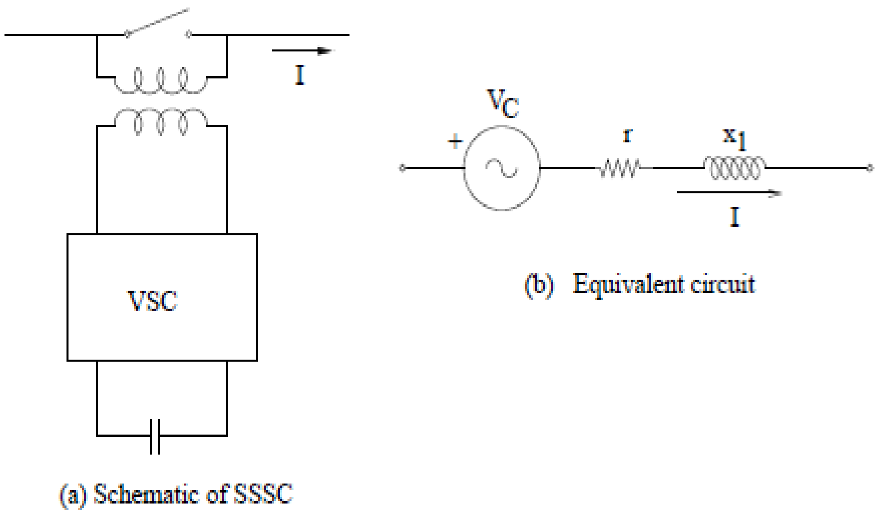

Fig 1.5: schematic and equivalent circuit of the SSSC

1.5.2 Shunt Controllers: In the shunt controller variable sources may be combine with the series controllers. The principle system is connected with shunt controller show the line impedance which causes the variable current flow in the line. Injected current of the line control the power as well as phase angle. The controlling of power with the help of shunt controller which is helpful to improve the real powers. The basic controller used for shunt connected system is STATCOM, SSG, BESS, SMES, SVC, TCR, and TSR .

1.5.3 Combination of series-series Controllers: When we combine the two series controller it will make the combination of series-series controller .the UPFC is also part of the series controller which represent the inductive and capacitive power . The line of power can be utilize the T/M line. In the UPFC all controller are fixed with the real powers.

1.5.4 Combination of series-shunt Controllers: When we combine the two series and shunt controller which make the series and shunt controller which will also power flow the unified power which is connected with series in the line. In the shunt controller is used to control the voltages as well as reactive and inductive power in line. The basic controller used for combined series-shunt connected is UPFC, TCPST, and IPC. In above controllers mentioned UPFC is used for better compensation.

1.6 D-FACTS Devices:

D-FACTS devices are the Distributed FACTS devices which are used to provide the capacitive or inductive power to the ac system. These devices attached directly to line. The FACTS devices following limitations as discussed below:

- **High Cost**: Converter complexity and semiconductor ratings make FACTS devices an expensive solution. Moreover, the maintenance and repair calls for skilled labor, which further increase the cost.
- **Low Reliability:** A single component failure can prove to be fatal in the overall performance of the module. Further, currently available power electronic components are not suitable for operation in the hostile utility environment.
- **Custom Engineering:** Most FACTS devices are custom-designed and have long build times. They further require additional infrastructure such as mounting platforms and isolation transformers.

The limitations listed above can be attributed to the lumped nature of FACTS devices. The Reliability of the technology can be increased and the cost can be decreased if the control Objective is served by replicating a lumped controller into small controllers and distributing them Over to the grid Which show in the fig 1.6.

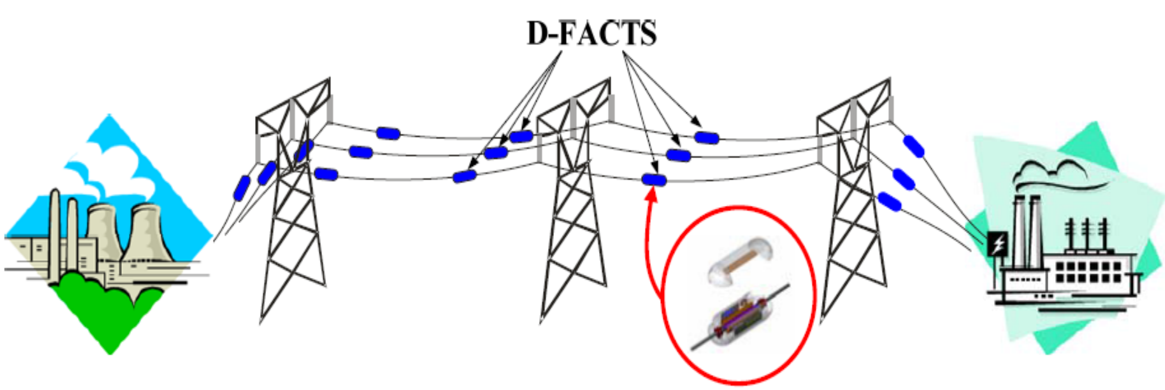

Fig 1.6: D-FACTS on Power line

1.6.1 D-STATCOM (Distribution Static Compensator)

D-STATCOM is one of the most powerful and fast controller from following power devices. It is used to control the voltage swell and sags, which occur in distribution system and used to improve the power quality of the system. In fig show the schematic of D-STATCOM which is build with 4 basic parts, VSC, DC ESD and coupling T/F connected in parallel with ac system. A DSTATCOM consists of a switching device such as GTO or IGBT along with storage device like capacitor, flywheel etc. and a controller to inject the controlled switching pulses for the semiconductor device and the whole system is connected to an AC system through a coupling transformer. Basic operating principle of a DSATCOM is resembles to that of synchronous machine.

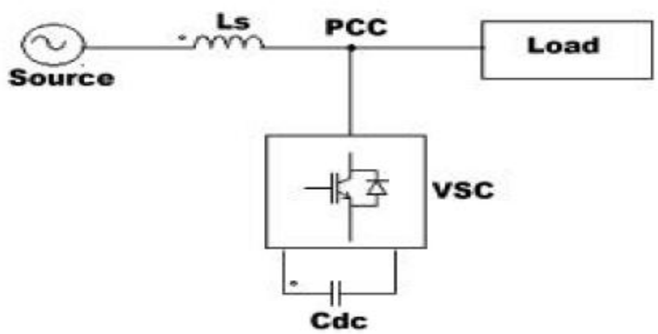

Fig 1.7: Basic Structure of D-STATCOM

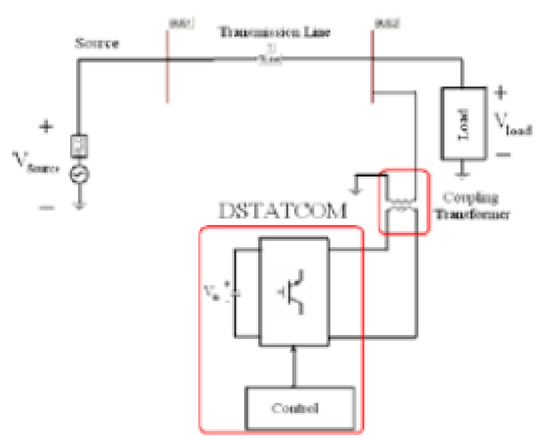

Fig 1.8:Basic configuration of D-STATCOM

The DC converter link which improve the ripple and error I/P which are storages in the element. The AC terminals of the reactive power which flow in the line can be delivered to the system. In the system capacitor mode is same as well as power flow of the two voltages. It is difference of two voltages. The parallel connected voltage source convertor is suitable technique which provide multi-functional topology can be used for three purpose.

- Voltage regulation and reactive power compensation .
- Use to remove the power factor error.
- Power quility improvement and reduce total harmonic distortion.

1.6.2 Exchange of Reactive Power

Amplitude regulation of the DSTATCOM output voltage controls the reactive power exchange of the DSTATCOM with the AC system. The reactive power supplied by the DSTATCOM is given by-

$$Q= \frac{(Vi-Vs)*Vs}{Vs}$$

Where,

Q is the reactive power.

V_i is the magnitude of DSTATCOM output voltage.

V_s is the magnitude of system voltage.

X is the equivalent impedance between DSTATCOM and the system.

Power exchange within DSTATCOM and AC system is given by-:

Case I: $V_i = V_s$,

The reactive current is zero and the DSTATCOM does not Generate /absorb reactive power.

Case II: $V_i > V_s$, (capacitive mode)

The lagging current flows through the transformer reactance from the DSTATCOM to the AC system by:

Case III: $V_i < V_s$, (inductive mode)

Then the leading current flows from the AC system to the DSTATCOM,

1.6.3 Exchange of Active Power

There is a requirement of a DC capacitor to provide real power to the switching devices used in the DSTATCOM. When direct voltage control is required, real power exchange is demanded by a AC system in order to maintain capacitor voltage constant. In case of distribution system with very low voltage or faults, external DC source is provided in DSTATCOM to regulate voltage when there is a real power exchange with the AC system. If the system voltage lags the VSC voltage then real power form the DC source will be injected to the AC system in order to regulate system voltage or to maintain constant capacitor voltage.

1.6.4 Basic Elements of DSTATCOM

The basic configuration of DSTATCOM consists of:

- Voltage Source Converter
- L-C Passive Filter
- Coupling Transformer
- Control Block
- Energy Storage Device

1.6.5 Characteristics and Design of D-STATCOM

D-STATCOM is device which is used in AC ditibution system. They manily used to reduce the harmonic current mitigation, reactive current compensation and load balancing.In the block of D-STATCOM VSC attached with self commutation semiconductor valves and capictor also connected with the dc bus. The device is parallel connected to the distribution sustem through coupling inductor which is used to control the T/F leakage reactance. D-STATCOM is used to provide THD compensation P.F correction and load balancing. The most popular advantages of D-STATCOM compare with static VAR compensation include the ability to genrate rated current at any voltage N/W. The dynamic response of D-STATCOM is good and used to relibale small size capacitor on the DC bus. The size of the capacitor is not important in steady state generation. In the schematic dig of the D-STATCOM connected with a 3-phase ac supply which also connected the 3-phase load. The 3-phase load may be lagging, unblancing or non-linear laods. In ac side VSC is used to reduce the ripple factor in compensating current. The small series connected capacitor and resistor represent the ripple filter which install at the PCC parallel with loads. In the fig dc bus voltage, ac inductor and ripple remove filter are given as:

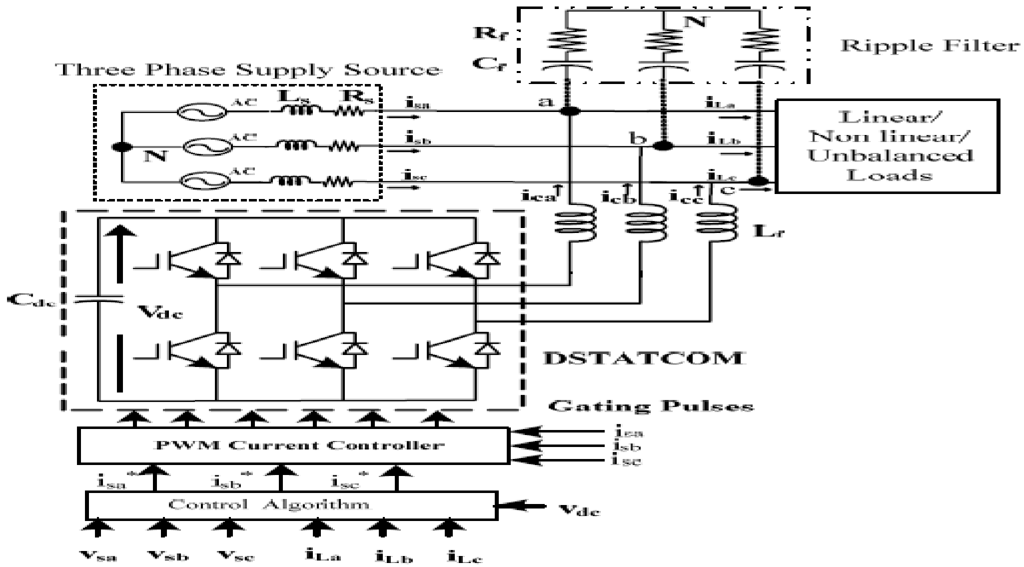

Fig 1.9: schematic dig of DSTATCOM

1.6.6 Application of D-STATCOM for reactive power compensation and voltage regulation

- The capacitor switching voltage is less.
- Improve the voltage sag for the both feeders.
- The voltage fluctuations were reduced from 1.5% to 0.1% with D-STATCOM.
- In the mathematical operation the mech. Switch operation improve the maintenance.
- The max. load will increase when the system is stable.
- Power factor correction.
- Elimination of harmonics present in source current.
- Regulation and compensation of voltage and reactive power respectively.

CHAPTER 2

REVIEWS OF LITERATURE

Saeed Mohammad [1] is represent a paper which show a power quality is a major issue in distribution system. In the distribution system problem will be occurs regarding reactive power due to the large power angle with voltage magnitude gradient. The D-STATCOM is used in FACTS devices to compensate the reactive power. D-STATCOM is 3-phase VSC used to compensate the voltage and make the system stable by absorbing and generating the reactive power. The model of D-STATCOM was analyzed and developed for use in Simulink. D-STATCOM also control reactive power and regulate voltage. D-STATCOM also improve power system performance.

Bhim Singh, Sabha Raj Arya[2] represent the paper in which –phase D-STATCOM design. The control algorithm based on correlation and cross correlation function approach the quality improvement during non-linear and linear distribution system. In this paper, the functional active and reactive power compensation on load current. The D-STATCOM is make under non-linear and linear loads. The performance of the system in MATLAB Simulink and SPS toolbox. The designed and control model of D-STATCOM is used in 3-phase distribution system. The control algorithm under correlation and cross correlation function. Which is used to generating switching signals for D-STATCOM in 3-phase system. D-STATCOM is used to reduce THD, reactive power compensation and also load balancing. The dc bus voltage of D-STATCOM can be regulate without overshoot.

Mr. Vaishali P Kuralkar[3] Doing in this paper the FACTS devices is a devices which is capable to control the voltage, transmission line, devices STATCOM and UPFC are analyzed in this paper. Analysis of the standard 5 bus system done static and dynamic with the help of MATLAB. Result of network using UPFC and STATCOM are compared in terms of active and reactive power flow in line. The performance of injected voltage, injected phase and phase distortion are show in dig and graph. This paper shows the simulation methods which are required for FACTS devices UPFC and STATCOM. UPFC is able to control voltage that affects the power flow in the transmission line.

Kyungsoo LEE, Hirotaka KOIZUMI and Kosuke KUROKAWA [4] Here, D-UPFC is used to control the distribution system voltage during voltage sages and swells. In the D-UPFC concepts single phase. Converters generate power which are using switching outline when voltage variation occurs. A transformer in series is used to compensate voltage to the load. In this paper simulation are used for testing the voltage sag and swell .

Zang Dongling, Li Guoxin [5] In this paper the circuit of D-STATCOM. The model of D-STATCOM is based on the 3-level voltage inverter. Which build by lead in switch function. In this research main focus on the control method of D-STATCOM. The main purpose of this dissertation to detect the reactive power. The PWM controller used to find the current technology achieve to direct control. The result of D-STATCOM shows in Matlab Simulink. The need of VAR compensation to improve the voltage regulation. That's by we study on the D-STATCOM. The switching functions build with the help of mathematical expression. The simulation is done with the help of Matlab Simulink. The result shows to compensating reactive power.

Kyungsoo LEE, Kenichiro Yamaguchi, Hirotaka KOIZUMI and Kosuke KUROKAW[6] Controlling over-voltage condition in the distribution system are the problems so far has been faced and it is discussed and eliminated in this paper. The voltage controller is also called the distribution-unified power flow controller (D-UPFC). At high voltage level and power consumption is feed into the system .

Sourabh Kothari, Rahul Agrawal, Dr. Surendra Kumar Bharadwaj [7] Is done in this paper presents a review on the enhancement of voltage stability margin by employing FACTS controllers. Due to the sharp increase in power demand, voltage instability & line overloading has become challenging problems for the power engineers. In case of heavily loaded transmission line, reactive power may be insufficient causing voltage drops at various buses. This results in voltage collapse, unexpected line & generator outages which lead to total blackouts of the whole systems. Reactive power unbalancing is the major cause of voltage instability. Therefore to improve & enhance the voltage profile & the stability margin of a power system, FACTS controllers are the alternative solution. Under the contingency conditions, the conventional methods and artificial intelligent techniques are required for handling the complex problems in power system. The authors strongly believe that this paper will be helpful to the researchers.

Chintan R Patel, Sanjay N Patel and Dr. Axay J Mehta[8] Done in this paper a transmission line needs controllable compensation for power flow control and voltage regulation. This can be achieved by FACTS controllers. Static Synchronous Series Compensator (SSSC) is a series connected FACTS controller, which is capable of providing reactive power compensation to a power system. The output of an SSSC is series injected voltage, which leads or lags line current by 90°, thus emulating a controllable inductive or capacitive reactance. SSSC can be used to reduce the equivalent line impedance and enhance the active power transfer capability of the line. In this paper, series compensation provided by an SSSC is considered. It can also inject fast changing voltage in series with the line irrespective of the magnitude and phase of the line current. The SSSC can also damp out the oscillations of the system .

B.Sharath Kumar and MD.Yaseen [9] Dynamic voltage restorer (DVR) and a unified power flow controller (UPFC) for the compensation of voltage sag is discussed in this paper. A Unified Power Flow Controller (UPFC) is an electrical device for providing fast-acting reactive power compensation on voltage electricity networks. The modeling of Z-source based dynamic voltage restorer and UPFC is carried out component wise and their performances are analyzed using MATLAB software. Control of the flow of power over the transmission line has been investigated and simulated on the control circuits.

Ismail musirin, nur dianah mohd. radzi, Muhammad murtadha Othman, Mohammad khanate idris and titik khawa abdul rahman [10] The voltage drops cause voltage profile decay that can be accomplished by the system when system is subjected to load increment or disturbances. Load variation with accessions at unscheduled rate that is directed the system to be not easy and leading to possible cascading trip on the entire system. In this way, close monitoring of load variation can assist to change the system operating close to its maximal capability. In addressing this aspect, special strategy can be implemented for instance reactive power compensation; installation of flexible AC transmission system (FACTs) devices and placing capacitor. .

M.G Molina [11] discuss in this paper the performance of D-STATCOM coupled with ESS to improve the power quality of distribution system. The presence of D-STATCOM and ESS compensator to analyzed a voltage controller. A multi-level control techniques purpose is depends upon the power theory model and control. Result shows in Matlab. The performance of multilevel inverter improve the power quality a distribution system. To simulate the dynamic system study demonstrate effect of multi-level control. In multi-level control synchronous rotating dq frames and model detailed presented. D-STATCOM control reactive and active power on distribution system. It is very fast device which shows the result quickly and control the disturbance, voltage control, power factor and also reduce the THD distortion.

Akhilesh A. Nimje, Chinmoy Kumar Panigrahi and Ajaya Kumar Mohanty [12] Static Synchronous Series Compensator (SSSC) is a voltage sourced converter based series FACTS device. It provides capacitive as well as inductive compensation and making it separate of line current. The achievement of the required active and reactive power flow into the line for the reason of compensation as well as affirmation of enhancement of the power transfer capability of a transmission line when Interline Power Flow Controller acts as standalone as SSSC. The changing effects of the phase angle which injects the voltage parameters and overall power factor along SSSC have also been assimilated. The mathematical results for the test case have been presented to determine performance and its appropriateness on a line. SSSC operates to reduce the reactive power flow over the line by compensating the reactive power expected by the line inductance. The numerical results for the test case presents and demonstrate the performance as well as its applicability on a transmission line .

Saidi Amara and Hadj Abdullah Hsan [13] The rate of change of dissipated transient power. It is usually tool which used to measure system damping. Control strategy for suppressing undesirable electromechanical oscillations in power system is discussed in this paper along with STATCOM, SSSC and UPFC. 1- Machine infinite bus power system was several disturbances. The effectiveness and robustness of all these devices on power system stability is obtained after the analysis .

Shalini Bajpai, . [14] proposed a scheme in this paper in which a pulse width modulation ac-ac converter along with auto transformer is used. Over the occurrence of disturbances this scheme supplies the missing voltage and helps to maintain rated voltage at terminal of critical load. Here 4 step switching technique is used that derives the ac-ac converter to realise snubber less operation. In this paper design is presented for 440V, 50 Hz system. This technique identifies and mitigates the disturbance to a desired magnitude. Simulation analysis is performed for the 27% voltage sag for 3 phase system and simulation results presents the effectiveness of device in compensation of voltage sag disturbances.

Prafull A. Desale, . [15] presents a review paper on Custom Power Devices for the improvement of Power Quality. This paper presents a comprehensive survey of these devices in distribution system to eliminate various Power Quality disturbances like voltage sag/swell, dip, flicker, lower power factor etc according to this paper shunt connected DSTATCOM provides better Power Quality in both transmission and distribution system, UPQC can compensate both voltage and current related problems at same instant.

Vijayakumar.R, . [16] discussed here regarding Dynamic Voltage Restorer (DVR) as most efficient and effective custom device to be used in distribution system. It is main features apart from Power Quality improvement, described are low cost, fast response and small size. In this paper the design and applications of DVR are presented.

M. Anuj Gargeya, [17] proposed a PWM based control technique, that requires only voltage measurement for DSTATCOM. This paper presents the voltage regulation in parallel distribution feeders using multi converter DVR (MC-DVR). It is connected in shunt between 2 parallel feeders originating from different substations, supplying 2 non-linear loads. It has been concluded that bi-directional power flow between 2 feeders is possible i.e. in case of voltage sag in supply of one feeder can be accomplished by supplying power from another feeder.

Alka Singh, [18] presented the performance of DSTATCOM for the load compensation of linear and non-linear loads in steady and dynamic conditions. In this paper DSTATCOM and BESS have been simulated using MATLAB. Performance of DSTATCOM has been analysed to regulate voltage at PCC under unbalanced load conditions. BESS performance with equal load sharing and constant current has been found to be satisfactory. According to this paper both devices has enough scope in improving Power Quality in distribution system.

Wei-Neng Chang [19] discussed the design and implementation of DSTATCOM for load compensation of unbalanced loads. In this paper new feed forward compensation scheme is derived and employed with symmetrical components method and accordingly a hardware prototype is built. Simulation results as compared to existing SVC, DSTATCOM has less space demand, higher response time and generates lower noise. This concludes that DSTATCOM will gradually replace SVC in near future.

D.Masand, . [20] compares the linear and non linear methods of current regulation referring DSTATCOM performance using synchronous reference frame through this paper. In this paper merits and demerits of each regulation method are stated. Here it is concluded that when the PWM with carrier technique in reference frame is implemented, fixed switching of VSC results in overshoot of about 2.5 times more as compared to hysteresis current controller. In case of non linear load the THD in fixed switching frame is far higher than that in variable switching frame. Here it is concluded that hysteresis based DSTATCOM in SRF frame is feasible for load compensation at distribution level.

M.G. Molina,. [21] describes the modeling and control design of DSTATCOM coupled with Ultra-Capacitor Energy Storage (UCES) for improving Power Quality of system. In this the control technique employed is instantaneous power theory based, synchronous-rotating *dq* reference frame. This fast response device proved to be very effective in improving quality of power. Power Quality problems like voltage sag, swell, flicker and power factor are lessened with this device.

CHAPTER 3

PRESENT WORK

3.1 Problem Formulation

Power system stability is the major issue in the power system. Today in the power system or power n/w no of faults, distortion and voltage drops will occur. Due these variation no of problems produce in the load side because in the generation side energy cannot transfer same on load side following errors are:-

- Voltage sag and swell
- Reactive and active power
- Harmonics

3.2 Objectives

The main objective of my research work is to improve the power quality in distribution System by using FACTS devices.

- To damp out power oscillation in distribution system using FACTS devices.
- To compare the simulation results for above cited objectives in distribution system using Matlab/Simulink environment for

1. D-STATCOM

,

CHAPTER 4

POWER QUALITY

4.1 Power Quality

In earlier times generating and transmitting power to farther areas used to be the matter of concern. But with changing times challenges has changed to the reliability of the power delivered, as well as the quality of power supplied to various industries, commercial establishments and residences.. Power Quality these days have very serious affects for the power consumers utilities and electrical equipment manufacturers.

4.2 Requirement of Power Quality

These day's electrical and electronic equipments are more prone to malfunction or even failure when faced one or more Power Quality problems. Due to intolerance of various equipments towards Power Quality problems has lead to increased importance of Power Quality improvement.

- Increased focus on improved overall efficiency that lead to growth in device applications like capacitors for power factor correction to reduce losses and adjustable speed motor drives. This lead to increased harmonic levels in power systems.
- Nowadays network contains interconnections i.e. integrated networks. So failure to even single equipment is a relevant issue.
- Consumers are becoming more aware regarding Power Quality issues and are looking forward to get improved power delivery.

4.3 Various Power Quality Problems

Ideal power supply would always have a steady magnitude and a sinusoidal wave shape without any Disruption. But any condition that cause change in this ideal situation is known as disturbance. Due to inherent non- linearity of power electronic devices, they draw harmonics and reactive power from the supply.

Various Power Quality Problems are as listed below-

- Voltage swell / over voltage

- Voltage dip / under voltage
- Harmonic distortion in Voltage and current signals
- Voltage and current transients
- Voltage flicker
- Power frequency variation
- Electrical noise
- Interruptions

4.3.1 Voltage Swell

The instantaneous increase in RMS voltage supplied by mains beyond normal tolerance for the duration more than one cycle up to few seconds as shown in Fig 4.1.

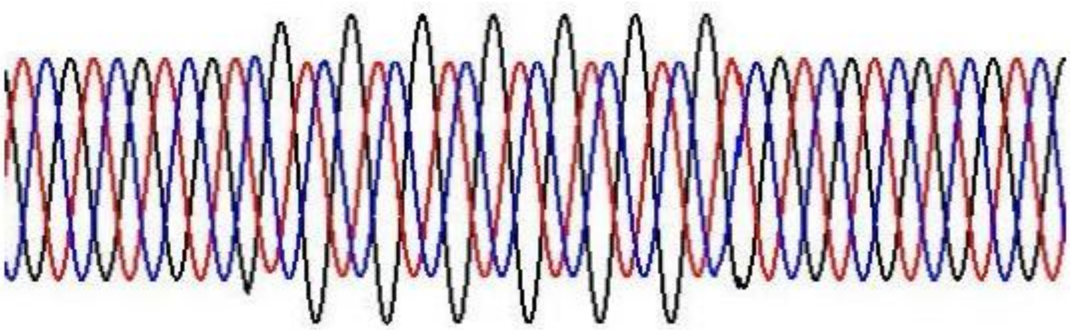

Fig 4.1: Voltage swells

4.3.2 Voltage Sag or dip

A brief drop in the rms voltage, about 10- 90 % of nominal line voltage. It lasts for 0.5 cycles to 1 minute as shown in Fig 4.2.

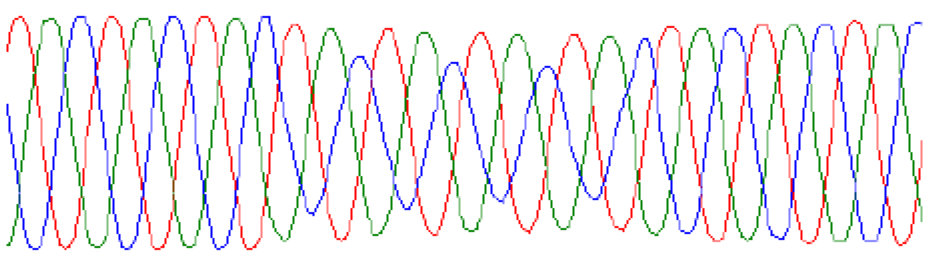

Fig4.2: Voltage sag

4.3.3 Harmonic Distortions

These are Sinusoidal voltages or currents with frequencies that are integer multiples of the frequency at which the system is designed to operate i.e. termed as fundamental frequency up to 50-60 Hz as shown in Fig 4.3. These harmonics rise due to non linear characteristics of devices and loads connected to the system.

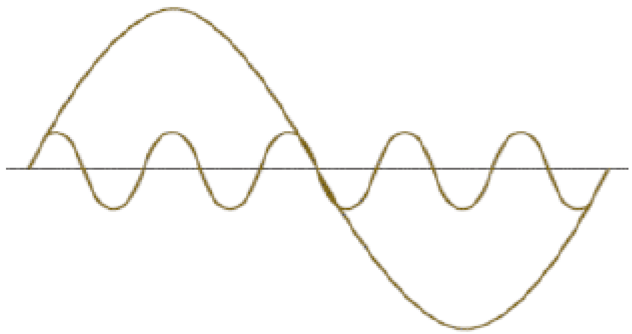

Fig4.3 Harmonic Distortions

4.3.4 Voltage Flicker

In this voltage exhibits alterations in magnitude or/and phase angle in a time scale of seconds or less.

4.3.5Power Frequency Variation

Any deviation of the fundamental frequency (60-Hz) is power frequency deviation as shown below in Fig 4.4.

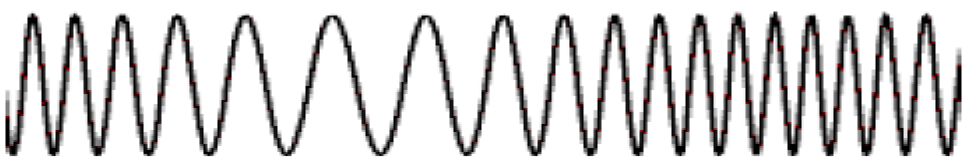

Fig 4.4 Frequency Variation

4.4 Poor Power Quality leads to:-

Load device may draw non-sinusoidal current from the source on distortion of power supply. This also leads to various technical problems like extra heating, malfunctions, before time maturation of the devices etc., to the customer's devices at his installation. The current with non- sinusoidal waveform also causes extra losses and other problems to various components.

Apart from above listed problems are also included-

- Unexpected power supply failures

- Equipment overheating leading reduction in its lifetime.
- Increase of system losses.

4.5 Custom Power

4.5.1 Introduction

In order to improve the performance of the distribution system the concept of Custom Power Devices was introduced. Custom Power Devices have taken place at very fast space due to rise in demand and speedy development. A custom power specification includes provision for:-

- Tight Voltage regulation along with short duration sags or swells,
- Low harmonic Voltages,
- No power interruption,
- Handling of fluctuating and non-linear loads without effect on terminal voltage.

4.6 Custom Power Devices

These schemes compensate the effect of imbalance and distortion in current and also rectify the power factor at the load bus. The FACTS devices provide steady, rapid and reliable control across the transmission parameters like voltage, line impedance and phase angle between the sending and receiving end. On contrary the custom power is Applicable for low voltage distribution, melioration of poor quality and reliability of supply affects the sensitive loads.

There are various Custom Power Devices. These devices include Surge Arrester, Solid State Transfer Switch, Active Power Filter, Static Electronic Tap Changer, Super Conducting Magnetic Energy Systems (SCMES), and distribution series capacitor, Solid State Fault Current Limiter, Static Var Compensator (SVC), Distribution Static Compensator, Dynamic Voltage Restorer (DVR) and Unified Power Quality Conditioner (UPQC) [11]. Categorization of Custom Power Devices is grounded on their controller working on power electronic devices. There is further categorization of these controllers as network reconfiguration devices also called switchgear devices, that consists of the solid state or current limiting, current transferring, and current breaking components and other type is the compensating type devices that are used for active filtering, correction of power factor, balancing load, and voltage regulation. They are connected in shunt or in series or both. These are designed to modify or improve the quality of power at the point of installation of the power distribution system. They are not mainly contrived to enhance the Power Quality of the entire system. The classification of CPDs is given in following sections.

4.6.1 Distribution STATCOM (DSTATCOM)

A DSTATCOM is a compensating device that operates with VSC that is connected in parallel with the distribution system to compensate reactive power. In order to compensate irrelevant components of current DSTATCOM injects compensated current at the point of common coupling. In distribution system the power exchange between this device and the AC system is primarily reactive. Applicable adjustment of the phase and magnitude of the DSTATCOM output voltages permits effective control of active and reactive power exchanges between the DSTATCOM and the AC system. Fig 4.5 below shows the DSTATCOM.

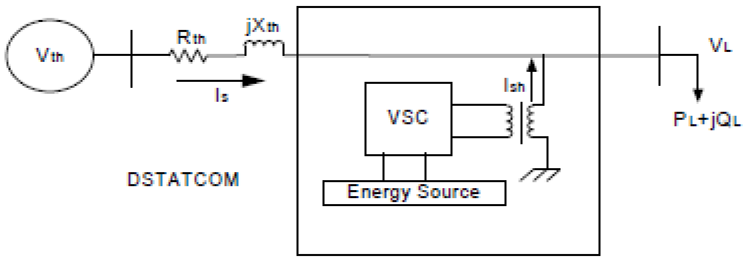

Fig4.5: DSTATCOM

The Voltage Source Converter connected in parallel with the system offers three different functions:

- Elimination of harmonics in source current;
- Regulation of Voltage and reactive power compensation;
- Power factor correction.

4.6.2 Dynamic Voltage Restorer (DVR)

The DVR is an effective controller that is generally applied for voltage sags mitigation at the point of connection. The DVR resembles in terms of blocks used the DSTATCOM, but here the coupling transformer is connected in series with the ac system. The primary function of DVR is compensation for reactive power, voltage regulation; voltage sags and swells compensation and imbalanced voltage compensation. It operates as harmonic isolator in order to avoid harmonics travelling in the source voltage that reaches load and also the voltage balancing and regulation. Fig 4.6 illustrates the DVR device.

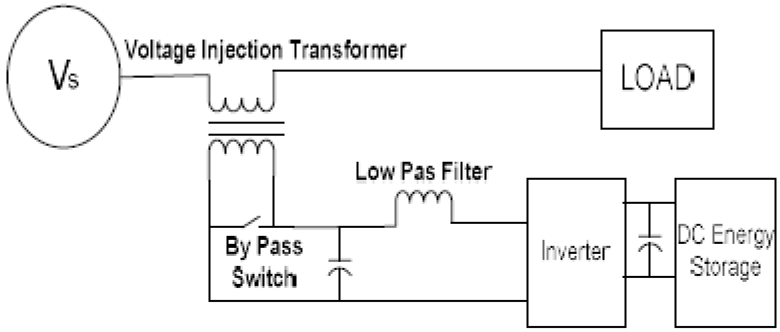
Vs
Voltage Injection Transformer
LOAD
Low Pas Filter
By Pass
Switch
Inverter
DC Energy
Storage

Fig4.6: DVR

CHAPTER 5

SIMULATION OF D-STATCOM

5.1 Introduction

As in this thesis work Power Quality problems faced Power Systems are confronted by DSTATCOM in order to compare its performance without DSTATCOM and fault, with fault and uncompensated system.

5.2 Simulation Diagrams

▪Test system without D-STATCOM shown in Fig 5.1.

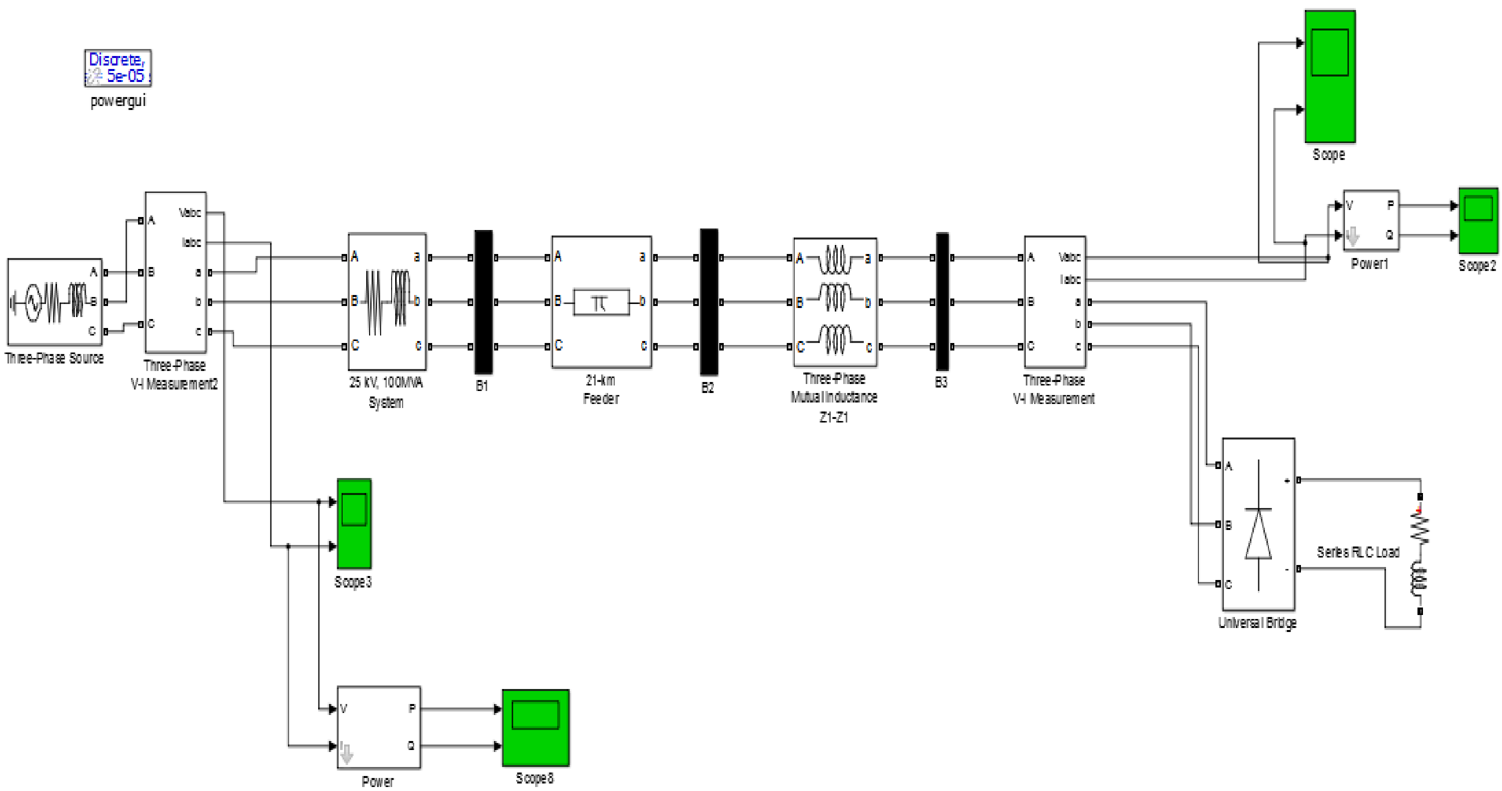

Fig 5.1: SIMULINK Model of test system without D-STATCOM

- Test system with D-STATCOM shown in Fig 5.2.

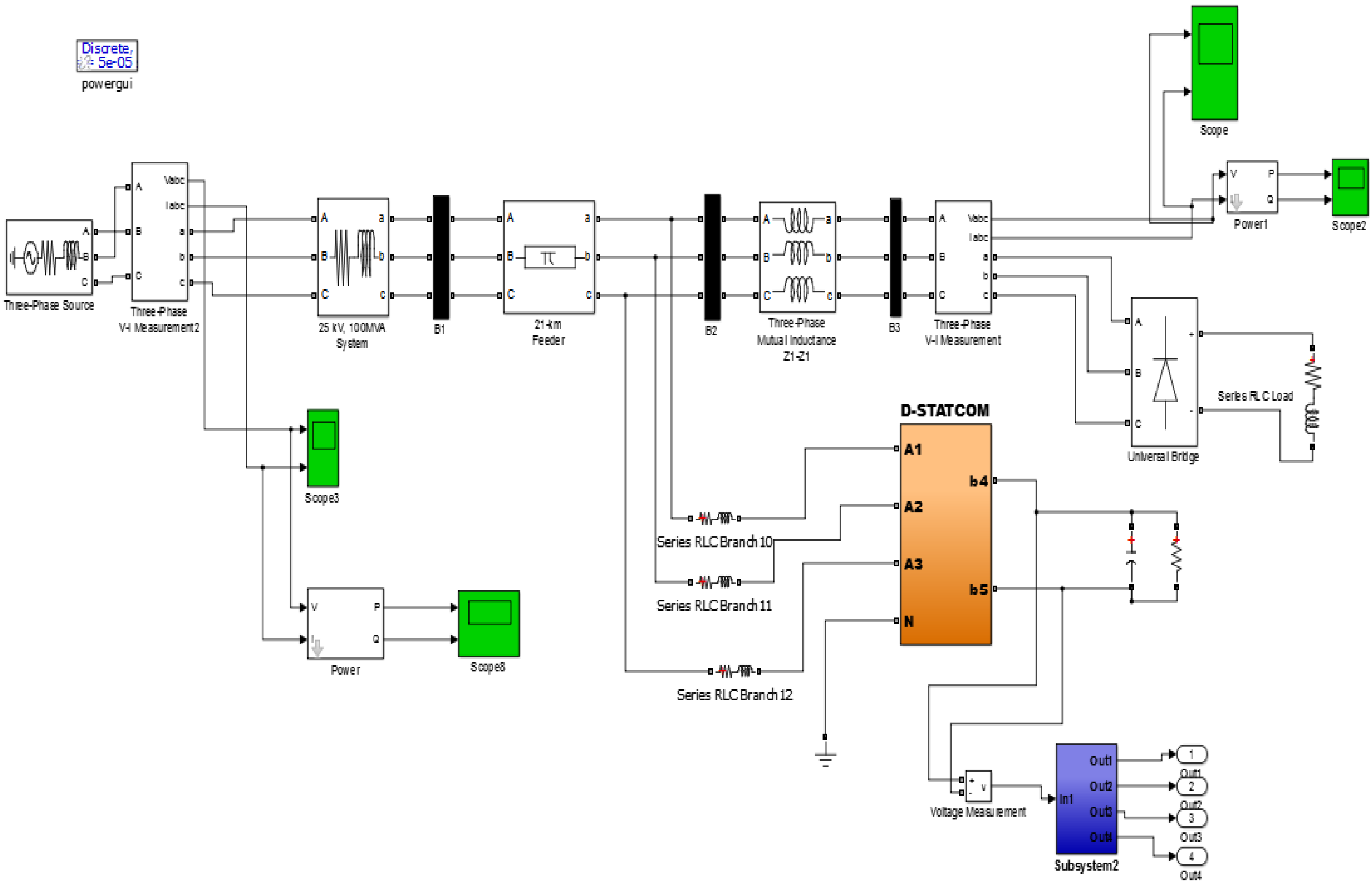

Fig5.2: SIMULINK Model of test System with D-STATCOM

CHAPTER 6
RESULTS AND DISCUSSIONS

6.1 Introduction

Here various Power Quality problems are discussed as Power Factor, THD and load balancing. Reactive and Active power Performance of DSTATCOM is analyzed in such situations to note its Power Quality improvement function. Without D-STATCOM and with D-STATCOM are employed in SIMULINK model of the system.

Here three cases as follows:

- Reduction in THD LEVEL
- Load Balancing
- Reactive and Active power

6.2 System Parameter without D-STATCOM

Table 6.1 System parameter

S. no	Component	Units
1.	Voltage	25Kv
2.	Frequency	60Hz
3.	Source Impedance	0.625+0.0165j
4.	Non linear load	Universal Bridge

6.3 Block Diagrams

Fig 6.1 below illustrates the system without DSTATCOM.

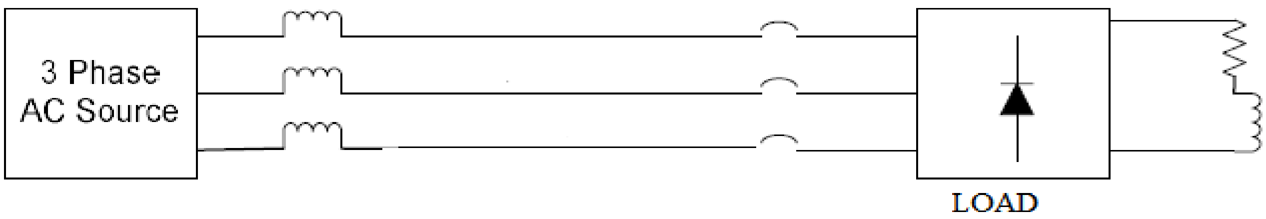

Fig 6.1: 3phase system without D-STATCOM

Fig 6.2 below illustrates the system with DSTATCOM.

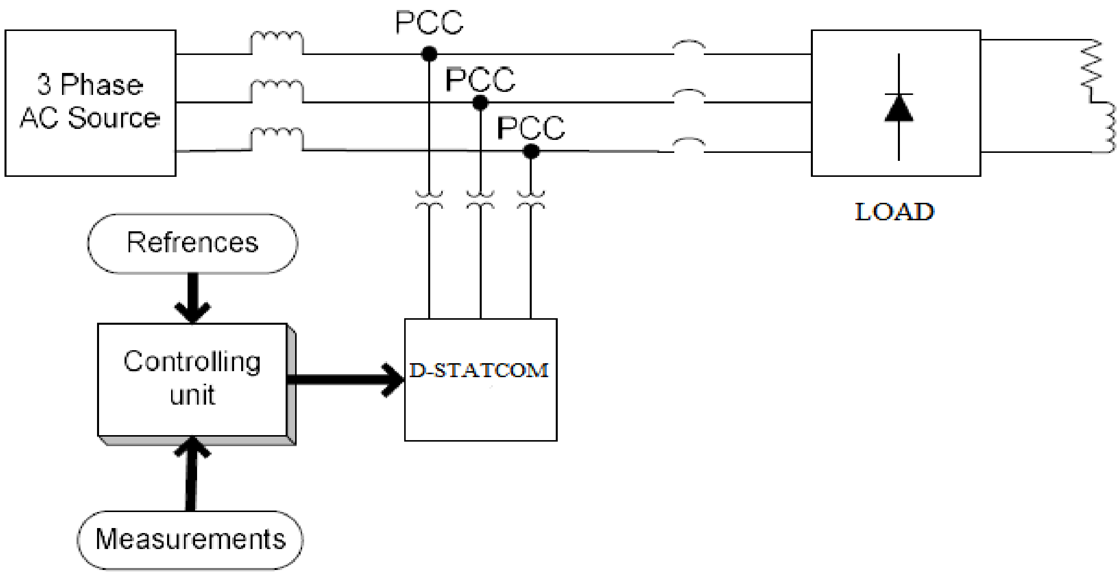

Fig 6.2: 3phase system with D-STATCOM

6.4 Results and Discussions

Case I: Reduction in THD level.

System Harmonic Distortion levels are compared and presented below to compare the reduction in THD levels without employing DSTATCOM.

Source

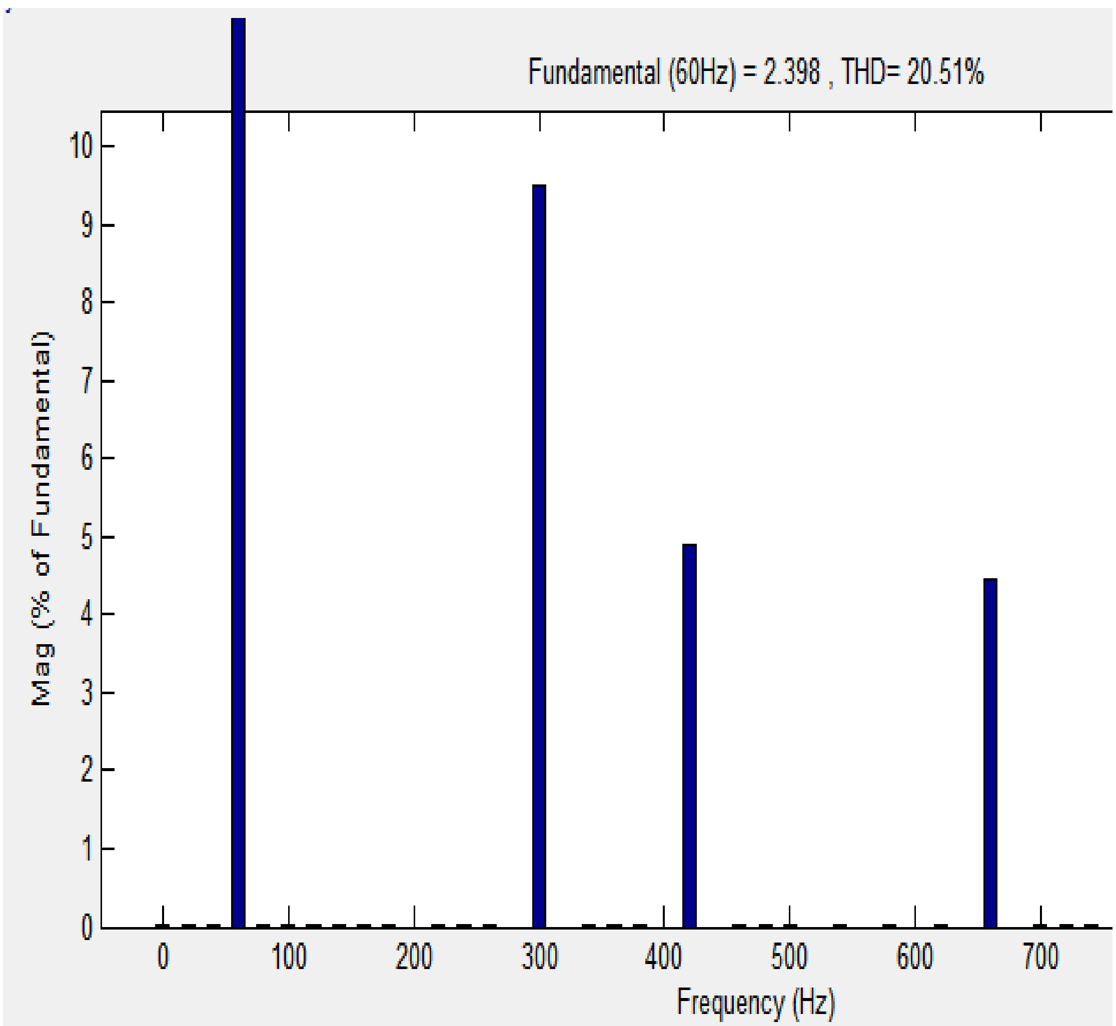

Fig 6.3: THD source side

Load

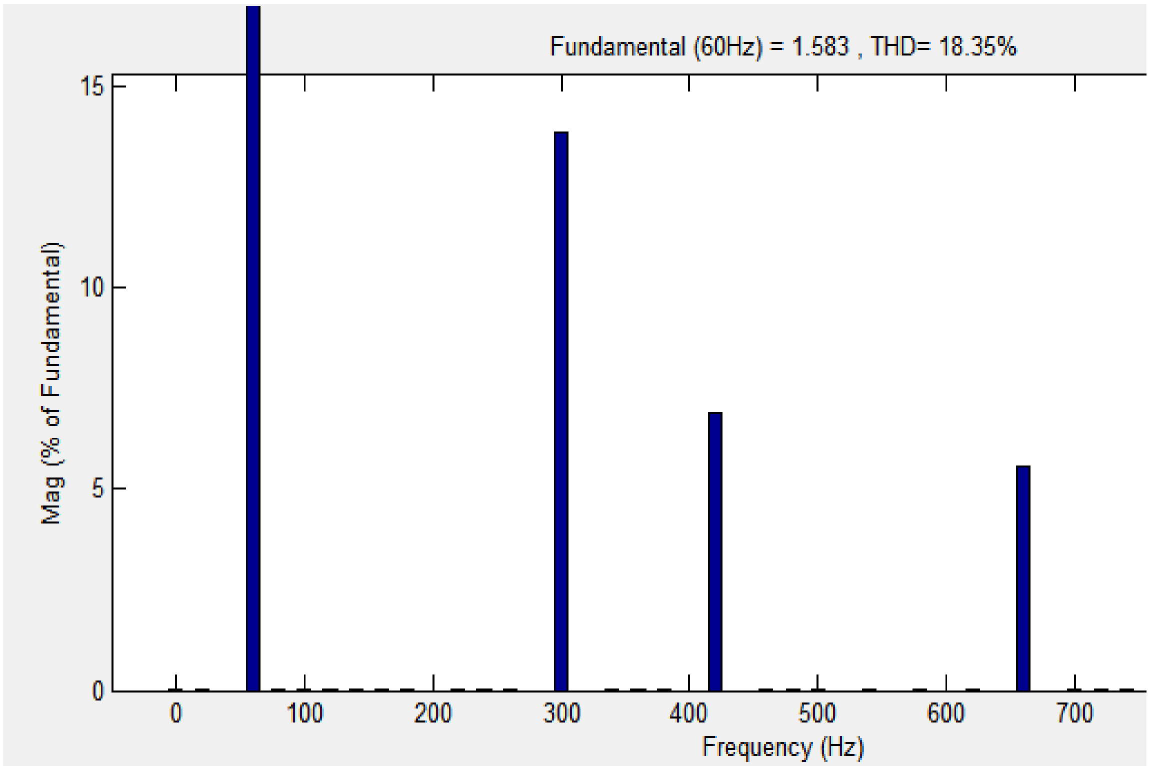

Fig 6.4: THD load side

With D-STATCOM

Source

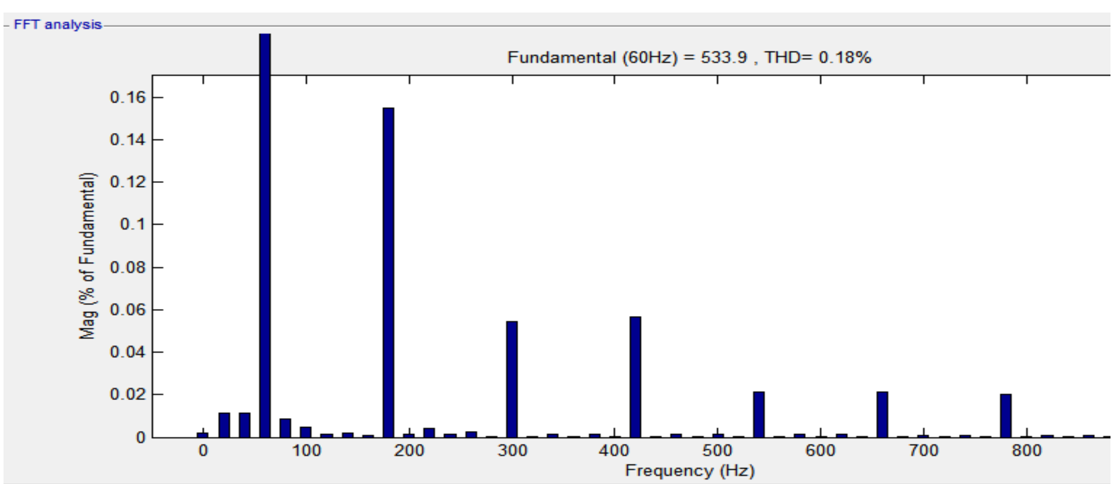

Fig 6.5: THD source side

Load

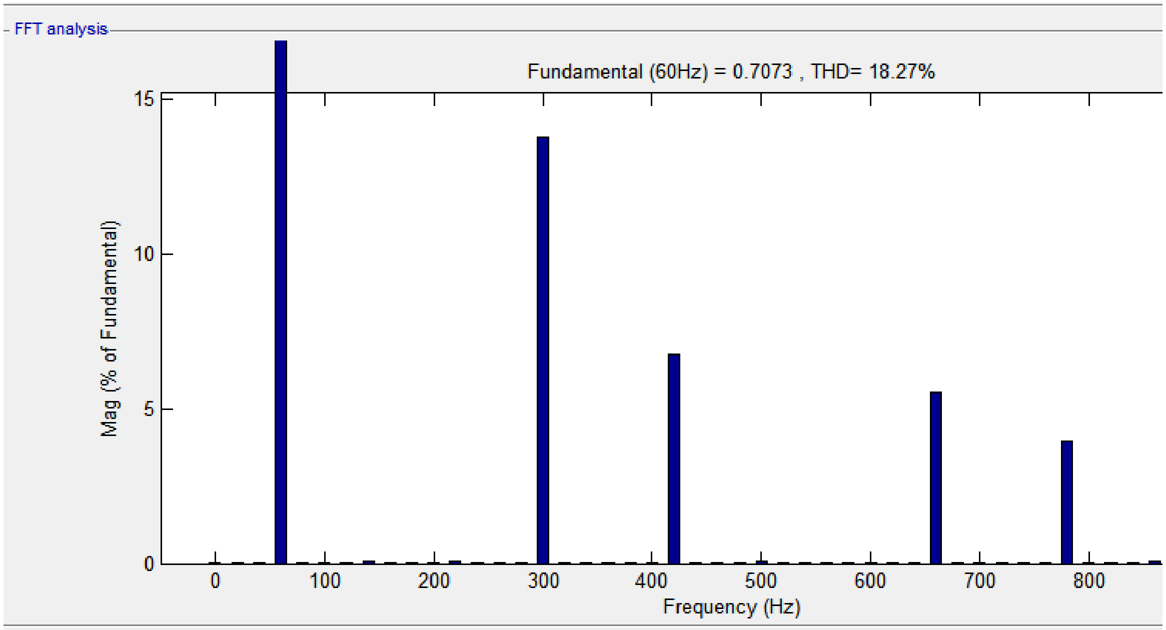

Fig 6.6: THD load side

Case II. Load Balancing

The performance of 3phase system with and without DSTATCOM is compared for load balancing. The supply currents are balanced and in phase at all conditions.

I_{Load} v/s Time waveform for the uncompensated system is presented as below in Fig 6.6

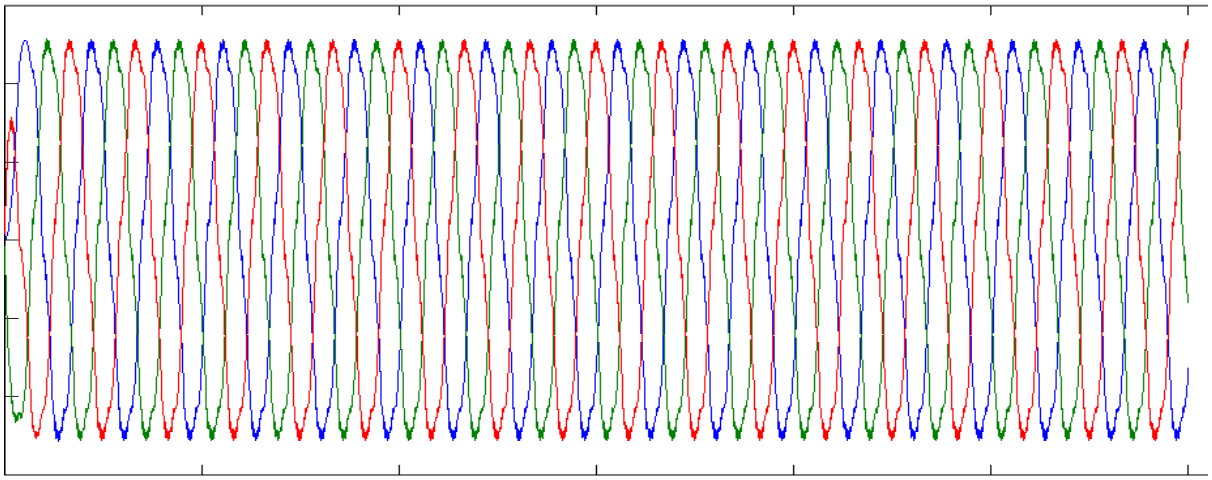

Fig6.7: Load Current (I_{load}) v/s Time Waveforms

I $_{Source}$ v/s Time Waveform for uncompensated system is shown as below Fig 6.7

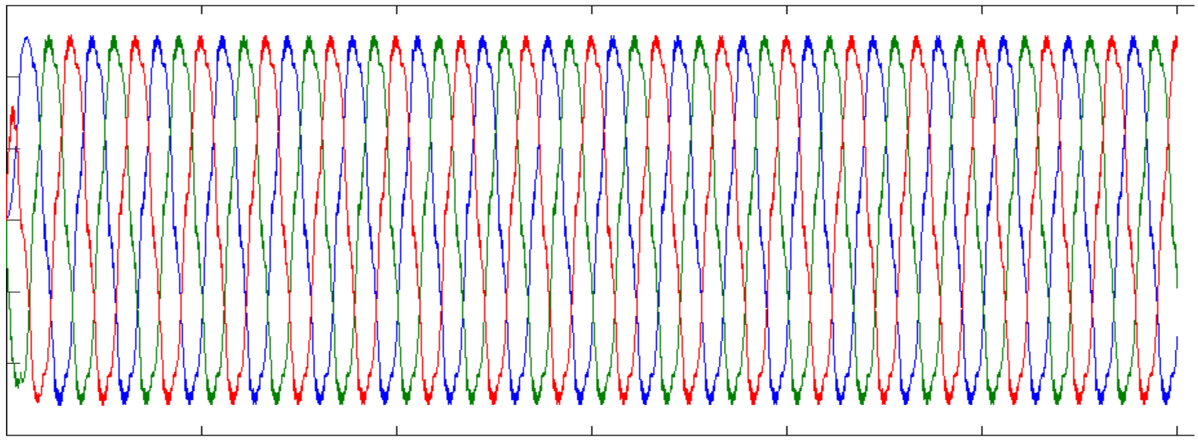

Fig6.8: Source Current (I $_{source}$) v/s Time Waveforms

Chapter 7

CONCLUSIONS AND FUTURE SCOPE OF WORK

7.1 Conclusion

- The level of voltage causes the events of large disturbances which do not ensure the stability of the power systems.
- D-STATCOM for reactive power, voltages and power transfer capability for power systems.
- Similarly, compensate reactive power, voltage injected and increased power transfer capability.
- The THD reduction in source current is more in the case of DSTATCOM.
- Power factor improvement is comparatively better in DSTATCOM system.

7.2 Future scope of work:

- To develop better control techniques for ZSI.
- To show ZSI based DSTATCOM performance in distribution system for power quality Improvement.

REFERENCES

[1] Saeed Mohammad (Impacts of D-STATCOM on voltage stability) Indian J. Edu. Inf. Manage., Vol. 1, No. 9 (Sep 2012)

[2] Bhim Singh, Sabha Raj Arya(Design and control of a DSTATCOM for power quality improvement using cross correlation function approach) International Journal of Engineering, Science and TechnologyVol. 4, No. 1, 2012, pp. 74-86

[3] Vaishali P Kuralkar(Power system control through statcom and upfc) International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 2, Issue 12, December 2012)

[4] Kyungsoo Lee, Kenichiro Yamaguchi, Hirotaka Koizumi, and Kosuke Kurokawa(D-UPFC as a Voltage Regulator in the Distribution System) Tokyo University of Agriculture and Technology, 2-24-16 Naka-cho, Koganei, Tokyo, 184-8588 Japan

[5] GYUGYI, "Static Synchronous Series Compensator: A solid state approach to the series compensation of the transmission line", IEEE Trans., 1997, PD-12.

[6] Kyungsoo Lee, Kenichiro Yamaguchi, Hirotaka Koizumi, and Kosuke Kurokawa, "D-UPFC as a Voltage Regulator in the Distribution System", RENEWABLE ENERGY 2006 Proceedings 2012.

[7] Sourabh Kothari, Rahul Agrawal, Dr. Surendra Kumar Bharadwaj, "Contributions to Security of Electric Power Systems", 2011.

[8] Chintan R Patel, Sanjay N Patel and Dr. Axay J Mehta," Introduction to FACTS Controllers: A Technological Literature Survey", International Journal of Automation and Power Engineering Volume 1 Issue 9, 2011.

[9] B.Sharath Kumar and MD.Yaseen,"Voltage Quality Improvement by using Facts Devices", International Journal of Current Engineering and Technology, 2012.

[10] ISMAIL MUSIRIN, NUR DIANAH MOHD. RADZI, MUHAMMAD MURTADHA OTHMAN, MOHAMAD KHAYAT IDRIS and TITIK KHAWA ABDUL RAHMAN, "Voltage Profile Improvement Using Unified Power Flow Controller via Artificial Immune System", 2010.

[11] Akhilesh A. Nimje, Chinmoy Kumar Panigrahi and Ajaya Kumar Mohanty, "Enhanced power transfer capability by using SSSC", 2011.

[12] Saidi Amara and Hadj Abdallah Hsan,"Power system stability improvement by FACTS devices:

[13] A comparison between STATCOM, SSSC and UPFC", 2012. Shalini Bajpai, "Power Quality Improvement using AC to AC PWM Converter for Distribution Line", International Journal of Engineering Inventions, Vol. 2, Issue No. 11, pp. 60-66, July 2013.

[14] Prafull A. Desale, Vishvadeep J. Dhawale and Ranjeet M. Bandgar, "Brief Review Paper on the Custom Power Devices for Power Quality Improvement", International Journal of Electrical Engineering, Vol. 7, Issue No. 7, pp. 723-733, 2014.

[15] Vijayakumar. R and Thangaraj. R, "Distribution System Voltage Regulation using Multifunctional DVR Implementation for Emergency Control and Protect Consumers System", Internationa Science And Research Journals, Vol. 2, Issue No. 2, pp. 59-67, April 2014.

[16]M. Anuj Gargeya, "A New Proposal for Mitigation of Power Quality Problems using DSTATCOM", International Journal of Scientific Engineering and Technology, Vol. 2, Issue No. 5, pp. 317-321, May 2013.

[17] Alka Singh, Suman Bhowmick and Kapil Shukla, "Load Compensation with DSTATCOM an BESS" IEEE 5th International Conference on Power Electronics, December 2012.

[18] Wei- Neng Chang and Kuan- Dih Yeh, "Design and Implementation of DSTATCOM for Fast Load Compensation of Unbalanced Loads", Journal of Marine Science and Technology, Vol. 17, Issue No. 4, pp. 257-263, 2009.

[19] D.Masand, S.Jain and G.Agnihotri, "DSTATCOM Performance Under Linear and Nonlinear Current Regulation Methods", J.Electrical Systems, pp. 91-105, 2008.

[20] M.G.Molina, "Dynamic Modeling and Control Design of DSTATCOM with Ultra-Capacitor Energy Storage for Power Quality Improvements", IEEE Conference on Transmission and Distribution: Latin America, pp. 1-8, August 2008.

APPENDICES

Appendix: - Simulation Data

- Three-Phase Source
  Voltage : 25Kv
  Frequency: 60 Hz
- Source Impendence: 0.625+0.0165j
- Three phase RLC branch
  R:0.625 ohm
  L: 0.165 H
- Feeder
  Length: 21km
- Load

  Nonlinear load