A Review on Power Quality Improvement by using D-STATCOM in Dynamic Load of Distributed Power System

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Abstract:- This thesis addresses the D-STATCOM which is a major custom power solutions capable for load balancing, power factor-correction, voltage regulation, voltage and current harmonics mitigation in a three-phase three-wire distribution system for different combinations of linear, non-linear and dynamic loads. The unit template technique (UTT) is used to get the reference signals for series active power filter and shunt active power filter which utilizes two closed loop PI controllers. The design of three- phase three-wire D-STATCOM includes the design of shunt controller (SHUC) and series controller (SERC). This thesis investigated the development of D-STATCOM control schemes and algorithms for power quality improvement and implementation of a versatile control strategy to enhance the performance of D-STATCOM. The proposed control scheme gives better steady state and dynamic response MATLAB/Simulink based simulation results are presented, which support the functionality of the D-STATCOM. This thesis also presents a comprehensive review on the D-STATCOM to enhance the electric power quality at distribution levels. This is intended to present a broad overview on the different possible D-STATCOM system configurations for three-phase (three-wire and four-wire) networks, different compensation approaches, and recent developments in the field. It is noticed that several researchers have used different names for the D-STATCOM based on the unique function, task, application, or topology under consideration.

Keywords: Inter-IC,Master,Slave,Concatenating sensor, Machine Learning, Xilinx Vivado HLx Editions suite.

I. INTRODUCTION

For reduction of cost and improved reliability, most of the world's electric power systems continue to be interconnected. Interconnections take advantage of diversity of loads, availability of sources and fuel price for supplying power to the loads at minimum cost and pollution with a required reliability. In a deregulated electric service environment, an effective electric grid is essential to the competitive environment of reliable electric service. Now a day's greater demands have been placed on the transmission network, and these demands will continue to rise because of the increasing number of nonutility generators and greater competition among utilities themselves. The aims of the electric power system are to supply electrical energy to terminals of electrical equipment, and to maintain the voltage at the equipment terminals within certain limits. Quality of supply and reliability are essential for proper operation of industrial processes which involve critical and sensitive loads. In coming decades, electrical energy storage is expected to be widely used in power systems as capacitor, battery, and superconducting magnet technologies move forward. In distribution area, an exciting opportunity called custom power enables at-the-fence solution for delivery to industrial and commercial customers, value added reliable electric service (which is free from significant voltage reduction) distortions, and over voltage. It is now well known that voltage reduction of greater than 15% or 20% and of duration greater than few cycles (resulting from lightning faults and switching events on the transmission and distribution system) lead to significant losses for the increasingly automated processing and manufacturing industry. The custom power concept incorporates power electronics controller and switching equipment, one or more of which can be used to provide a value-added service to the customers. In general, these custom power applications represent power electronics in the range of a few tens of kilowatts of conversion or switching equipment between the utility supply and the customer. It is not easy to acquire new rights of way. Increased demands on transmission, absence of long term planning, and the need to provide open access to generating companies and customers have resulted in less security and reduced quality of supply.

1.2 Requirement for Compensation

Compensation in power systems is, therefore, essential to alleviate some of these problems. Series /shunt compensation has been in use for past many years to achieve this objective. In a power system, given the insignificant electrical storage, the power generation and load must balance at all times. To some extent the electrical system is self – regulating. If generation is less then load, voltage and frequency drop, and thereby reducing the load. In an ideal ac power system, the voltage and frequency at every supply point would be constant and free from harmonics, and the power factor would be unity. These parameters would be independent of the size and

characteristics of consumers load. In an ideal ac power system, each load would be designed for optimum performance at the given supply voltage, rather than for merely adequate performance over an unpredictable range of voltage. The characteristics of power systems and their loads which can deteriorate the quality of supply, concentrating on those which can be corrected by compensation, that is by supply or absorption of an appropriately variable quality of reactive power. Short-duration power disturbances, such as Voltage sags, swells and short interruptions, are major concerns for industrial customers. Due to the wide usage of sensitive electronic equipment in process automation, even voltage sags which last for only few tenths of a second may cause production stops with considerable associated costs, these costs include production losses, equipment restarting and Damaged or lower-quality product and reduced customer satisfaction.

II. LITERATURE REVIEW

Wesam Rohouma [1] with the increased use of power electronic for ac-to-dc converters, electrical distributions systems are experiencing an increased in non-linear loads. These non-linear loads, such as the classical rectifier, draw non-sinusoidal currents which tend to have a deleterious impact on the power quality of the modern AC distribution systems. The interaction of non-sinusoidal currents with the grid impedance leads to distorted system voltage which can adversely impact other devices connected to the grid. The integration of distributed energy resources (DERs) with the distribution power grid can further exacerbate the harmonic power issues. The traditional methods of compensation are no longer adequate and hence it is necessary to develop a means to provide local reactive and harmonic compensation at the source of the power quality problem within the low-voltage distribution network. This article investigates the use of a capacitor-less distribution static synchronous compensator (D-STATCOM) for power quality compensation in modern distribution systems. The proposed topology is based on a matrix converter (MC), controlled by finite control set model predictive control (FCS-MPC) which makes possible the use of inductive energy storage rather than electrolytic capacitors, which have been proven to be the most failure-prone components in a power electronic circuit. Simulation and experimental results are presented to validate the effectiveness of the approach.

Hingorani [2] has introduced the custom power concept. This concept has been proposed to ensure high quality of power supply in distribution networks using power electronic devices. The evolution of power controller for improvement in the distribution system is discussed. Series and shunt topologies and their operating principles are discussed. Some power quality problems and their effects also described in short.

Timothy J.E. Miller [3] addresses a through and unified account of the most recent advance in the technologies of ac power transmission. It presents the fundamental principles & applications of all types of modern equipment, hence solve the problem in power factor correction, voltage control and stabilization, phase balancing, and the handling of harmonics. The author describe about the principle of all types of modern compensating equipments –including thyristor control reactor(TCR), thyristor switched capacitor (TSC) and saturated reactor (SR). In the control of adjustable speed drives, the performance of inexpensive digital integrated circuits is approaching the stage where traditional control algorithms may be displaced by new algorithms that better exploit their speed and the functional capabilities of their software.

Arindam Ghosh &Gerard ledwich [4] represent about custom power devices, concept of power quality, power electronics controller and compensation devices which include SSB, SSTS, DSTATCOM, DVR, and UPQC. It include practical structure of series and shunt compensator, DSTATCOM used in a distribution system for load compensation when the supply voltage is stiff and non-stiff, while series device DVR can regulate voltage at load terminal against sag/swell or distortion in supply side .

W.Freitas and A. morelato [5] discuss a comparative study between two commercial programs considering transient analysis of custom power devices based on voltage source converter. The program investigated were the Power System Blockset for use with Matlab/Simulink, which employs state variable analysis, and PSCAD/EMTDC, which is based on nodal analysis. The objective is to determine the main difference between them considering computation time, easiness of implementation of the necessary models, evaluation of the existent libraries and accurateness of results. In all studies presented, such device were simulated by using detailed models, i.e. the switching element IGBT/diodes and PWM signal generator were explicitly represented. Both programs were suited for transient analyses of custom power device and very easy to use. The main advantage of the PSB is it be developed into Matlab/Simulink environment, such fact become possible to utilize it together with several other control design tools. On the other hand, the main advantage of PSCAD/EMTDC is computing time. In this software simulations run very fast.

Olimpo Anaya-Lara and E.Acha [6] describe the timely issued of modeling and analysis of custom power controller, a new generation of power electronics-based equipment aimed at enhancing the reliability and quality of power flow in low voltage distribution networks. Graphical-based model suitable for electromagnetic transient studies are presented for the following three custom controllers: the distribution static compensator (D-

STATCOM) is are based on VSC and the solid state transfer switch (SSTS). Comprehensive results are presented to assess the performance of each device as a potential custom power solution. PSCAD/EMTDC's highly developed graphical interface has proved instrumental in implementing the graphics based PWM control the D-STATCOM. It relies on voltage measurements for its operation, i.e. it does not require power measurements. A sensitive analysis is carried out to determine the impact of the dc capacitor size on D-STATCOM performance.

S.V Ravi Kumar and S. Siva Nagaraju [7] describes the techniques of correcting the supply voltage sag, swell and interruption in a distributed system. A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or a mis-operation of end user equipments. Utility distribution networks, sensitive industrial loads and critical commercial operations suffer from various types of outages and service interruptions which can cost significant financial losses. In developing countries like India, where the variation of power frequency and many such other determinants of power quality are themselves a serious question, it is very vital to take positive steps in this direction .The present work is to identify the prominent concerns in this area and hence the measures that can enhance the quality of the power are recommended. the distribution static compensator and the dynamic voltage restorer are most effective devices, both of them based on the VSC principle. A D-STATCOM injects a current into the system to correct the voltage sag, swell and interruption. It was also observed that the capacity for power compensation and voltage regulation of D-STATCOM depends on the rating of the dc storage device.

Dr. Gareth A Taylor [8] in his paper he describes the effort made to develop and demonstrate new technologies which will allow distribution utilities significant improve power quality. Custom power is a technology driven product and service solution which embrace a family of devices which will provide power quality function at distribution voltages. It has been made possible by the now widespread availability of cost effective high power solid state switches such as GTO and IGBT. The rapid response of these devices enables them to operate in the real time, providing continuous and dynamic control of the supply including: sub-cycle transfer of critical load, voltage and reactive power regulation, harmonics mitigation and elimination of voltage dips.

Michael, Gerald and Fredericks [9] describe about new technologies, using power electronics-based concepts, have been developed to provide protection for commercial and industrial customers from power quality problems on electrical distribution system known as custom power products, the technology describe in this paper provides protection against sag, swell, voltage flicker, harmonics, and other power quality concerns. The custom power product increases the availability of sensitive load and reduces cost associated with process interruptions. These custom power devices provide solution to power quality at the medium voltage distribution network level. In many cases depending on the frequency of events and the cost associated with lost production, the custom power can provide pay back in less than two year. This paper cover two custom products they are: the Dynamic voltage restorer (DVR), which is a series connected power electronics based device, quickly compensates for power system sag and swell. The DSTATCOM, Which is a shunt connected power based device, protect the electrical system from a polluting (flicker- producing) load. It has the ability to (1) regulate voltage (2) correct power factor (3) to some degree reduce line harmonic voltage with sample, wide area applied solution.

Vijayan Immanuel† and Gurunath Yankanch [10] in there paper presents the development of a novel waveform synthesis technique for effective voltage sag compensation for multilevel inverter based DSTATCOM. An effective control algorithm for calculation of reference compensating voltages based on PQR power theory together with Space Vector Modulation (SVM) technique is implemented using a three-level Diode Clamped Voltage Source Inverter (VSI) configuration. Extensive Simulations are carried out under various test conditions and the results show that the proposed scheme for voltage sag compensation is seamless with negligible THD. In this paper a method for waveform synthesis is developed Such that the DSTATCOM response is in the sub cycle region. The reference compensation voltages are calculated using an algorithm based on PQR power theory. The Space Vector Modulation (SVM) technique is developed to drive a three- level diode clamped inverter to generate the required compensation voltages. A DSTSCOM using three level diode clamped topology is well suited for medium and high voltage applications.

III. THEORY OF PROPOSED WORK

3.1 Electrical Power Quality

Electrical power is perhaps the most essential raw material used by commerce and industry today. It is unusual commodity because it is required as a continuous flow – it cannot be conveniently stored in quantity – and it cannot be subject to quality assurance checks before it is used. The situation with electricity is similar, the reliability of the supply must be known and the resilience of the process to variations must be understood. The most obvious power defects are complete interruption and voltage dips where the voltage drops to a lower value for a short duration. Naturally, long power interruptions are a problem for all users. The main concern of customers of electricity was the

reliability of supply. The reliability means the continuity of electric supply. The transmission systems compound the problem further as they are exposed to the vagaries of Mother Nature. It is however not only reliability that the consumer wants these days, quality too is very important to them. If a consumer that is connected to the same bus that supplies a large motor load may have to face a sever dip in his supply voltage every time the motor load is switched on. In some cases may have to bear with blackouts. This may be quite unacceptable to consumers.

3.2 Impact of Power Quality Problems

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 Hz. In addition, the peak of the voltage should be rated value. Unfortunately the actual ac line supply that we receive everyday departs from the ideal specifications. There are many ways in which the lack of quality power affects customers. The table (3.1) below lists various power quality problems, their characterization methods and possible causes.

3.3 Power Quality Terms and Definitions

The power quality standards vary between countries. However, it is needless to say that poor quality power affects almost all consumers. It is therefore important to list the terms and definition that are used with power quality.

3.4.1 Transients these are sub cycle disturbances with a very fast voltage change. They typically have frequencies often up to hundreds of kilohertz and sometimes megahertz. The voltage excursions range from hundreds to thousands of volts. Transients are also called spikes, impulses and surges. Two categories of transients are describe as.

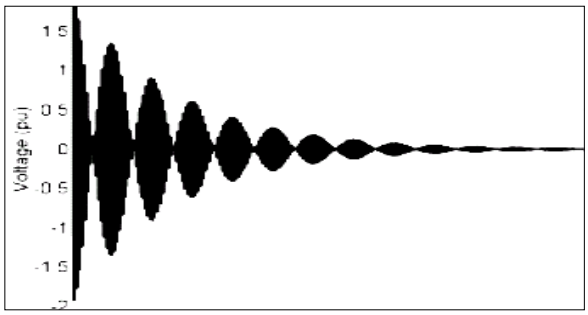


Figure 3.1 A typically oscillatory voltage transient

3.4.2 Short- Duration Voltage Variations:- Short-duration variations encompass the voltage dips and short interruptions. Each type of variations can be designated as instantaneous, momentary, or temporary, depending on its duration these variations can be categorized as:

3.4.3 Long- Duration Voltage Variations:- Long-duration variations encompass root-mean-square (rms) deviations at power frequencies for longer than 1 min. A voltage variation is considered to be long-duration when the limits are exceeded for greater than 1 min. These variations are categorized below.

3.4.4 Voltage and Current Imbalance:- Unbalance, or three-phase unbalance, is the phenomenon in a three-phase system, in which the rms values of the voltages or the phase angles between consecutive phases are not equal. Examples include unbalanced load, large single- phase load, blown fuse in one phase of a three-phase capacitor bank, etc.

IV CUSTOM POWER DEVICES AND D- STATCOM

4.1 INTRODUCTION:- The custom power term was proposed to designate a new generation of semiconductor devices based on power electronics , designed to operate at medium and low voltage levels , and whose main objective is to improve the service quality of distribution networks. Recent advantages in controllable semiconductors, microcontrollers, signal processors, and energy storage technology

The flexible ac transmission technology allows a greater control of power flow. Since these devices provide very fast power swing damping, the power transmission lines can be securely loaded up to their thermal limits.

4.2 NETWORK RECONFIGURING TYPE:- The reconfiguring equipment can be GTO based or thyristor based. They are usually used for fast current limiting and current breaking during the fault. They can also prompt a fast load transfer to an alternate feeder to protect a load from voltage sag/swell or fault in the supply feeder. These devices are:

- Solid state current limiter (SSCL): This is GTO base device that insert a fault current limiting inductor in series with the faulted circuit as soon the fault is detected. The inductor is removed from the circuit once the fault is cleared.
- Solid state circuit breaker (SSCB): This device can interrupt a fault current very rapidly and can also perform auto-reclosing function. This device, based on a combination of GTO and thyristor switches, is much faster than its mechanical counter part and is therefore an ideal device for custom power application.
- Solid state transfer switch (SSTS): This is usually a thyristor based device that is used to protect sensitive load from sag/swell. It can perform a sub-cycle transfer of the sensitive load from supplying feeder to an alternate feeder when a voltage sag/swell is detected in the supplying feeder. An SSTS can also be connected as a bus coupler between two incoming feeders.

4.3 DSTATCOM VOLTAGE CONTROLLER:- The Voltage controller analyzed in this section and its block diagram exhibited in figure

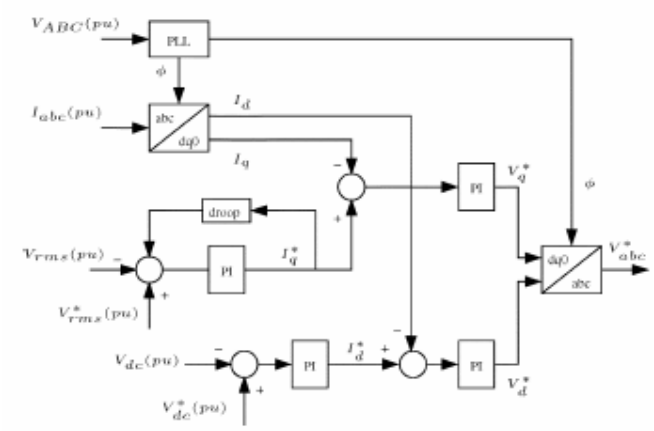


Fig.5.3. DSTATCOM Voltage Controller

Such controller consist of a phase locked loop (PLL) which synchronize the output three phase voltage of the converter with the zero crossing of the fundamental component of the phase –A voltage . Therefore the PLL provides the _ angle to abc –dq0 (dq0-abc) transformation .There are four proportional integral PI regulations.

4.4 D-STATCOM Power Factor Controller

The power factor controller for this section is adopted here is shown figure –

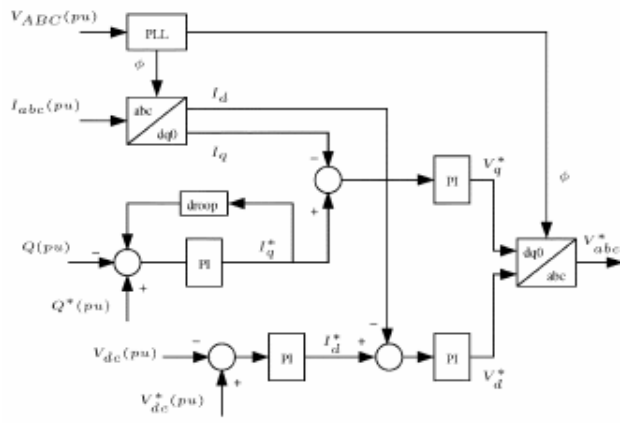


Fig. 5.4 DSTATCOM Power Factor Controller

This DSTATCOM power factor is very similar to the DSTATCOM voltage controller presented by previous section. The main difference found from the reactive power exchange controller, which is generally adjusted to provide all reactive power consumption at the facility. (i.e. unitary power factor operation .

V. DESIGN & CONTROL SCHEME OF STATCOM

6.1 System Configuration:- The system under consideration is shown in Fig.6.1.The D-STATCOM is connected before the load to protect the load from any voltage based distortions and at the same time, to make the source currents sinusoidal, balanced and in phase with the source voltages. Provisions are made to realize voltage imbalance and harmonics by switching on/off the three-phase dynamic load, R-L load. In order to create a voltage dip in source voltage an induction motor is connected suddenly on the load side. Fig.1 shows three-phase three-wire DSTATCOM, which is connected in shunt with distribution system DSTATCOM is most widely used for power factor correction, to eliminate current based distortion and load balancing, when connected at the load terminals. It can also perform voltage regulation when connected to a distribution bus.. Shunt APF is realized by using six Insulated Gate Bipolar Transistors (IGBT) switches. The (isa, isb, isc) ,(ila, ilb , ilc) and (ifa, ifb , ifc,),represent the source currents, load currents and shunt APF currents in phase a, b and c respectively. To evaluate the performance of DSTATCOM, the load under consideration is a combination of R-L linear. The values of the circuit parameters and load under consideration are given in Appendix.

VI. RESULT & DISCUSSION

The developed model of three-phase DSTATCOM system and the proposed control scheme in the MATLAB/ SIMULINK environment is shown in Fig.7.1 and Fig.7.2. The performance of D-STATCOM is evaluated in terms of voltage and current harmonics mitigation, load balancing and power-factor correction under different load conditions. The load under consideration is a combination of balanced linear lagging power factor loads and a three-phase diode bridge rectifier with resistive load on dc side. The unbalance has been created by opening the circuit breaker of phase ‘b’. The performance of the proposed control scheme of three-phase three-wire D-STATCOM-L is evaluated for sinusoidal supply voltages as well as distorted supply mains.

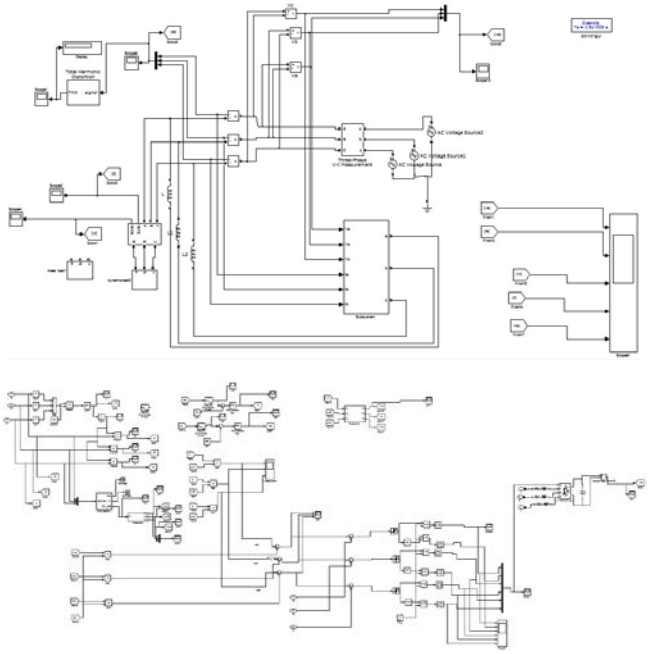
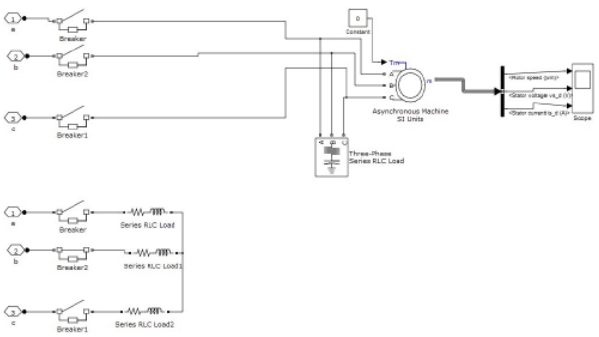


Fig.6.1 MATLAB model of D-STSTCOM Controller

Load Consider



6.1 Performance of D-STATCOM for Power Factor Correction:- Fig.6.3 and fig.6.4 shows the response of D-STATCOM without and with controller for linear lagging power-factor load respectively. The Dstatcom Controller was put into operation at 0.5 sec. Fig.6.3 shows that the source current lags the source voltage for R-L load but fig.7.4 shows that after connecting the R-L load with the DSTATCOM, the source voltage and source current in phase 'a' are exactly in phase.

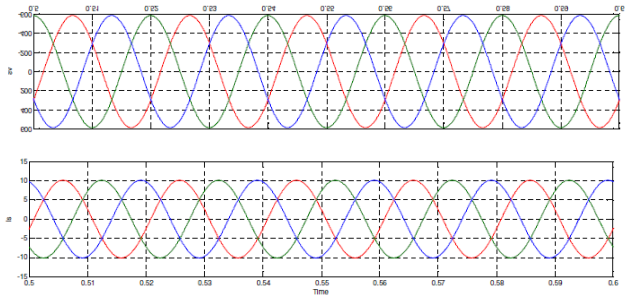


Fig.6.2 Result of Linear Load without DSTATCOM

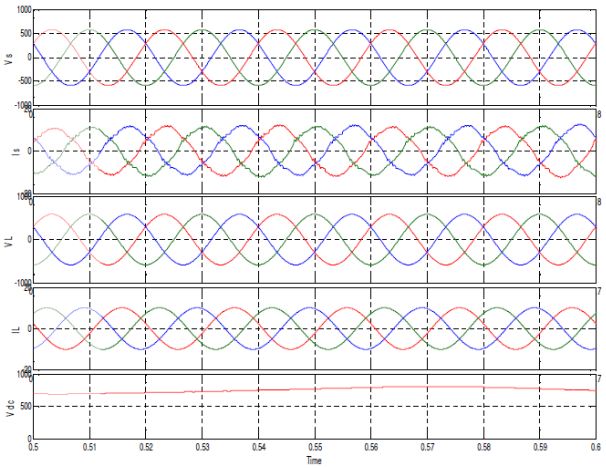


Fig.6.3 Performance of D-STATCOM for Power Factor Correction

VII. CONCLUSION & FUTURE SCOPE

The main objective of this work was to develop a versatile D-STATCOM control scheme for power quality improvement. This thesis investigates the development of D-STATCOM control schemes and algorithms for power quality improvement and implementation of a flexible control strategy to enhance the performance of DSTATCOM.

The objectives laid down have been successfully realized through software implementation in MATLAB/SIMULINK. The performance of D-STATCOM has been investigated under various practical situations. A configuration of DSTATCOM using UTT based control has demonstrated satisfactory working. The performance of the D-STATCOM has been evaluated in terms of various power quality improvements like load balancing, power-factor correction, voltage and current harmonics mitigation, voltage dip and dc voltage gets regulated. The source current THD is improved form 29.26 % to 4.69 %, while load voltage THD is improved form 2.16 % to 1.94 %.In addition to this the performance of DSTATCOM was found satisfactory during transient conditions.

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