Power Quality Improvement by using DSTATCOM

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ABSTRACT: Maximum AC loads consumes reactive power, it causes poor power quality in power system. The DSTATCOM is a compensating device which is used to control the flow of reactive power in the distribution systems. The complete background of the compensating devices and power electronic application in compensating devices is presented in this paper and also the compensation using the DSTATCOM modeling is also discussed. The detailed modeling and simulations of different control strategies are presented and implemented along with the necessary equations in the MATLAB simulink using the simpower systems tool boxes. The PI controllers are used for the implementation of the models and are discussed. Simulation results are we discussed and various case studies applied depending on the various loads like resistive, inductive and capacitive on the DSTATCOM simulink models and the simulation results are studied.

Keywords : Reactive power compensation, DSTATCOM, dq-model, power control and power quality.

1. INTRODUCTION

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

The performance of the DSTATCOM depends on the control algorithm i.e. the extraction of the current components. For this purpose there are many control schemes which are reported in the literature and some of these are instantaneous reactive power (IRP) theory, instantaneous compensation, instantaneous symmetrical components, synchronous reference frame (SRF) theory, computation based on per phase basis, and scheme based on neural network. Among these control schemes instantaneous reactive power theory and synchronous rotating reference frame are most widely used. This paper focuses on the compensating the voltage sag, swells and momentary interruptions. The dynamic performance is analyzed and verified through simulation. It is a custom power device which is gaining a fast publicity during these days due to its exceptional features like it provides fast response, suitable for dynamic load response or voltage regulation and automation needs, Both leading and lagging VARS can be provided, to correct voltage surges or sags caused by reactive power demands DSTATCOM can be applied on wide range of distribution and transmission voltage, overload capability of this provides reserve energy for transients.

The causes of power quality problems are generally complex and difficult to detect. Technically speaking, the ideal AC line supply by the utility system should be a pure sine wave of fundamental frequency (50/60Hz).Different power quality problems, their characterization methods and possible causes are discussed above and which are responsible for the lack of quality power which affects the customer in many ways. We can therefore conclude that the lack of quality power can cause loss of production, damage of equipment or appliances or can even be detrimental to human health. It is therefore imperative that a high standard of power quality is maintained. This project demonstrates that the power electronic based power conditioning using custom power devices like DSTATCOM can be effectively utilized to improve the quality of power supplied to the customers.

The aim of the paper is shows to implement DSTATCOM with control strategies in the MATLAB, simulink using Simpower systems tool box and to verify the results through various case studies applying different loads and study them in detail.

2. POWER QUALITY AND RELIABILITY:

Power quality and reliability cost the industry large amounts due to mainly sags and short-term interruptions. Distorted and unwanted voltage wave forms, too. And the

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main concern for the consumers of electricity was the reliability of supply. Here we define the reliability as the continuity of supply. As shown in Fig.1, the problem of distribution lines is divided into two major categories. First group is power quality, second is power reliability. First group consists of harmonic distortions, impulses and swells. Second group consists of voltage sags and outages. Voltage sags is much more serious and can cause a large amount of damage. If exceeds a few cycle, motors, robots, servo drives and machine tools cannot maintain control of process.

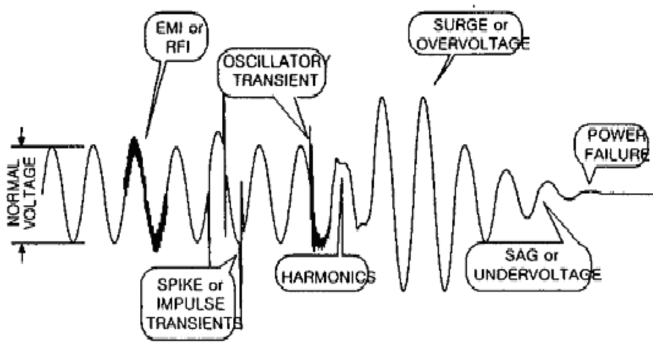


Fig.1. power quality and reliability

Both the reliability and quality of supply are equally important. For example, a consumer that is connected to the same bus that supplies a large motor load may have to face a severe dip in his supply voltage every time the motor load is switched on. In some extreme cases even we have to bear the black outs which is not acceptable to the consumers. There are also sensitive loads such as hospitals (life support, operation theatre, and patient database system), processing plants, air traffic control, financial institutions and numerous other data processing and service providers that require clean and uninterrupted power. In processing plants, a batch of product can be ruined by voltage dip of very short duration. Such customers are very wary of such dips since each dip can cost them a substantial amount of money. Even short dips are sufficient to cause contactors on motor drives to drop out. Stoppage in a portion of process can destroy the conditions for quality control of product and require restarting of production. Thus in this scenario in which consumers increasingly demand the quality power, the term power quality (PQ) attains increased significance.

Transmission lines are exposed to the forces of nature. Furthermore, each transmission line has its load ability limit that is often determined by either stability constraints or by thermal limits or by the dielectric limits. Even though the power quality problem is distribution side problem, transmission lines are often having an impact on the quality of the power supplied. It is however to be noted that while most problems associated with the transmission systems arise due to the forces of nature or due to the interconnection of power systems, individual customers are responsible for more substantial fraction of the problems of power distribution systems.

3. DISTRIBUTED STATIC COMPENSATOR (DSTATCOM)

The Distribution Static Compensator (DSTATCOM) is a voltage source inverter based static compensator (similar in many respects to the DVR) that is used for the correction of bus voltage sags. Connection (shunt) to the distribution network is via a standard power distribution transformer. The DSTATCOM is capable of generating continuously variable inductive or capacitive shunt compensation at a level up its maximum MVA rating. The DSTATCOM continuously checks the line waveform with respect to a reference ac signal, and therefore, it can provide the correct amount of leading or lagging reactive current compensation to reduce the amount of voltage fluctuations. The major components of a DSTATCOM are shown in Fig. 2. It consists of a dc capacitor, one or more inverter modules, an ac filter, a transformer to match the inverter output to the line voltage, and a PWM control strategy. In this DSTATCOM implementation, a voltage-source inverter converts a dc voltage into a three-phase ac voltage that is synchronized with, and connected to, the ac line through a small tie reactor and capacitor (ac filter).

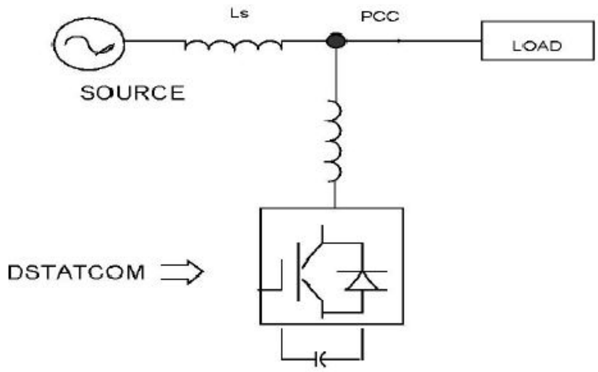


Fig.2.block diagram of DSTATCOM circuit

DSTATCOM components: DSTATCOM involves mainly three parts

IGBT or GTO based dc-to-ac inverters:

These inverters are used which create an output voltage wave that's controlled in magnitude and phase angle to produce either leading or lagging reactive current, depending on the compensation required.

L-C filter:

The LC filter is used which reduces harmonics and matches inverter output impedance to enable multiple parallel inverters to share current. The LC filter is chosen in accordance with the type of the system and the harmonics present at the output of the inverter.

Control block:

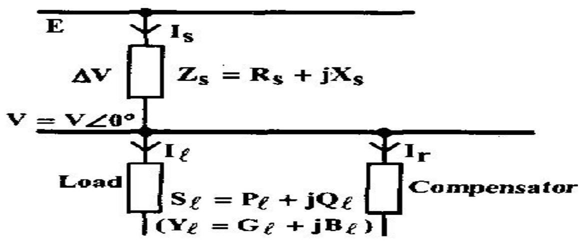
Control block is used which switch Pure Wave DSTATCOM modules as required. They can control external devices such as mechanically switched capacitor banks too. These control blocks are designed based on the various control theories and algorithms like instantaneous PQ theory, synchronous frame theory etc.. All these different algorithms are discussed in the next chapter.

4. PRINCIPLE OF DSTATCOM OF VOLTAGE REGULATION

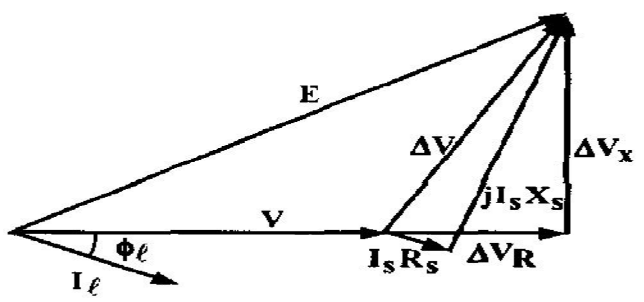
A. voltage regulation without compensator

Voltage E and V mean source voltage and PCC voltage respectively. Without a voltage compensator, the PCC voltage drop caused by the load current, I_L is as shown in Fig.3 (b) as ΔV

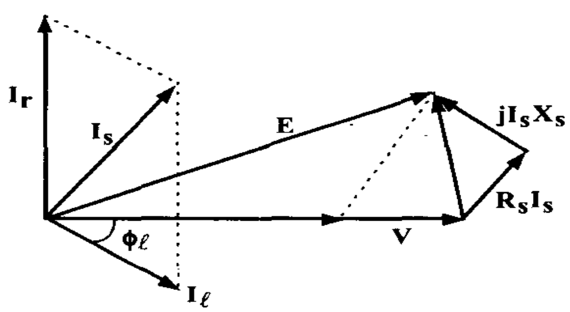
$I_S = I_L + I_R$ Where IR is the compensating current



(a)



(b)



(c)

Fig.3. (a) the equivalent circuit of load and supply system; (b) Phasor of uncompensated line; (c) Phasor of the compensated line

ΔV = E -V = ZSIL

S = VI*, S_= V*I

From above equation

$$I_L = \left(\frac{P_L - jQ_L}{V}\right)$$

So that

$$\Delta V = \left(R_S + jX_S\right)\left(\frac{P_L - jQ_L}{V}\right)$$

$$= \left(\frac{R_S P_L - X_S Q_L}{V}\right) + J\left(\frac{X_S P_L + R_S Q_L}{V}\right)$$

$$= \Delta V_R + \Delta V_X$$

The voltage change has a component ΔVR in phase with V and a component ΔVx , in quadrature with V, which are illustrated in Fig.3(b). it is clear that both magnitude and phase of V , relative to the supply voltage E, are the functions magnitude and phase of load current, namely voltage drop depends on the both the real and reactive power of the load. The component ΔV can be written as

$$\Delta V = I_S R_s - jI_S X_s$$

B: voltage regulation using the DSTATCOM

Fig.3(c) shows the vector diagram with voltage compensation. By adding a compensator in parallel with the load, it is possible to make $|E| = |V|$ by controlling the current of the compensator.

$$I_S = I_L + I_R$$

Where I_R is compensator current

BASIC OPERATING PRINCIPLE

Basic operating principle of a DSATCOM is similar to that of synchronous machine. The synchronous machine will provide lagging current when under excited and leading current when over excited.

DSTATCOM can generate and absorb reactive power similar to that of synchronous machine and it can also exchange real power if provided with an external device DC source.

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

system voltage to the =1p.u or to make the capacitor voltage constant.

Hence the exchange of real power and reactive power of the voltage source converter with AC system is the major required phenomenon for the regulation in the transmission as well as in the distribution system. For reactive power compensation, DSTATCOM provides reactive power as needed by the load and therefore the source current remains at unity power factor (UPF). Since only real power is being supplied by the source, load balancing is achieved by making the source reference current balanced. The reference source current used to decide the switching of the DSTATCOM has real fundamental frequency component of the load current which is being extracted by these techniques.

A STATCOM at the transmission level handles only fundamental reactive power and provides voltage support while as a DSTATCOM is employed at the distribution level or at the load end for power factor improvement and voltage regulation. DSTATCOM can be one of the viable alternatives to SVC in a distribution network. Additionally, a DSTATCOM can also behave as a shunt active filter, to eliminate unbalance or distortions in the source current or the supply voltage as per the IEEE-519 standard limits. Since a DSTATCOM is such a multifunctional device, the main objective of any control algorithm should be to make it flexible and easy to implement in addition to exploiting its multi functionality to the maximum.

The main objective of any compensation scheme is that it should have a fast response, flexible and easy to implement. The control algorithms of a DSTATCOM are mainly implemented in the following steps:

- Measurements of system voltages and current and
- signal conditioning
- Calculation of compensating signals
- Generation of firing angles of switching devices

Generation of proper PWM firing is the most important part of DSTATCOM control and has a great impact on the compensation objectives, transient as well as steady state performance. Since a DSTATCOM shares many concepts to that of a STATCOM at transmission level, a few control algorithms have been directly implemented to a DSTATCOM, incorporating Pulse Width Modulation (PWM) switching, rather than Fundamental Frequency switching (FFS) methods. This project makes attempt to compare the following schemes of a DSTATCOM for reactive power compensation and power factor correction based on:

1. Phase Shift Control

2. Decoupled Current Control (p-q theory)

3. Regulation of ac bus and dc link voltage

4. Synchronous Reference Frame (SRF) Method

5. Adaline Based Control Algorithm (in this paper we are not discussing about this controller)

The performance of DSTATCOM with different control schemes have been tested through digital simulations with the different system parameters. The switch on time of the DSTATCOM and the load change time are also mentioned.

Phase Shift Control

In this control algorithm the voltage regulation is achieved in a DSTATCOM by the measurement of the rms voltage at the load point and no reactive power measurements are required. Fig.4 shows the block diagram of the implemented scheme.

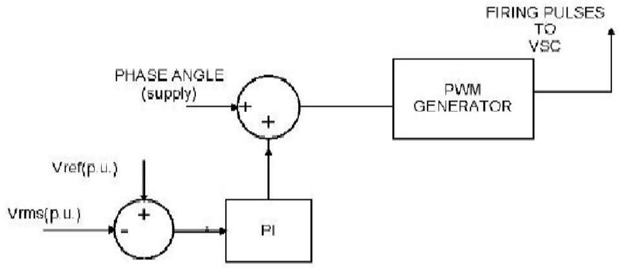


Fig.4. Block diagram of phase shift control

Sinusoidal PWM technique is used which is simple and gives a good response. The error signal obtained by comparing the measured system rms voltage and the reference voltage, is fed to a PI controller which generates the angle which decides the necessary phase shift between the output voltage of the VSC and the AC terminal voltage. This angle is summed with the phase angle of the balanced supply voltages, assumed to be equally spaced at 120 degrees, to produce the desired synchronizing signal required to operate the PWM generator. In this algorithm the D.C. voltage is maintained constant using a separate dc source.

Decoupled Current Control p-q theory

This algorithm requires the measurement of instantaneous values of three phase voltage and current. Fig.5. shows the block diagram representation of the control scheme. The compensation is achieved by the control of id and iq. Using the definition of the instantaneous reactive power theory for a balanced three phase three wire system, the quadrature component of the voltage is always zero, the real (p) and the reactive power (q) injected into the system by the DSTATCOM can be expressed under the dq reference frame as:

$$p = v_d i_d + v_q i_q$$
$$q = v_q i_d - v_d i_q$$

Since vq=0, id and iq completely describe the instantaneous value of real and reactive powers produced by the DSTATCOM when the system voltage remains constant. Therefore the instantaneous three phase current measured is transformed by abc to dqo transformation. The decoupled d-axis component id and q axis component iq are regulated by two separate PI regulators. The instantaneous id reference and the instantaneous iq reference are obtained by the control of the dc voltage and the ac terminal voltage measured. Thus, instantaneous current tracking control is achieved using four PI regulators. A Phase Locked Loop (PLL) is used to synchronize the control loop to the ac supply so as to operate in the abc to dqo reference frame. The instantaneous active and reactive powers p and q can be decomposed into an average and an oscillatory component.

$$p = \bar{p} + \tilde{p} \quad \text{and} \quad q = \bar{q} + \tilde{q}$$

Where $\bar{p}$ and q are the average part and $\tilde{p}$ and $\tilde{q}$ are oscillatory part of real and reactive instantaneous powers. The compensating currents are calculated to compensate the instantaneous reactive power and the oscillatory component of the instantaneous active power. In this case the source transmits only the non-oscillating component of active power.

Therefore the reference source currents $i_{s\alpha}^*$ and $i_{s\beta}^*$ in α-β coordinate are expressed as:

$$\begin{bmatrix} i_{s\alpha}^* \\ i_{s\beta}^* \end{bmatrix} = \frac{1}{\Delta}\begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix}\begin{bmatrix} \bar{p} \\ 0 \end{bmatrix}$$

These currents can be transformed in a-b-c quantities to find the reference currents in a-b-c coordinate.

$$\begin{bmatrix} i_{sa}^* \\ i_{sb}^* \\ i_{sc}^* \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1/\sqrt{2} & 1 & 0 \\ 1/\sqrt{2} & -1/2 & \sqrt{3}/2 \\ 1/\sqrt{2} & -1/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} i_o \\ i_\alpha \\ i_\beta \end{bmatrix}$$

Where i_o is the zero sequence components which is zero in 3-phase 3-wire system

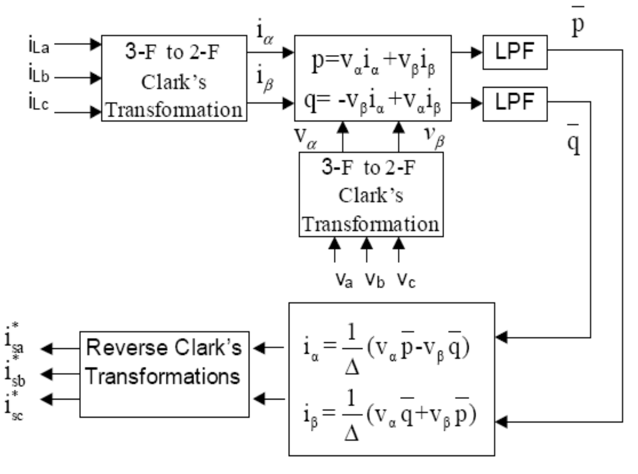


Fig.5. block diagram of decoupled theory based control of DSTATCOM

Synchronous rotating frame theory

The synchronous reference frame theory is based on the transformation of the currents in synchronously rotating d-q frame. Fig.6 explains the basic building blocks of the theory. If θ is the transformation angle, then the currents transformation from α-β to d-q frame is defined as:

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}$$

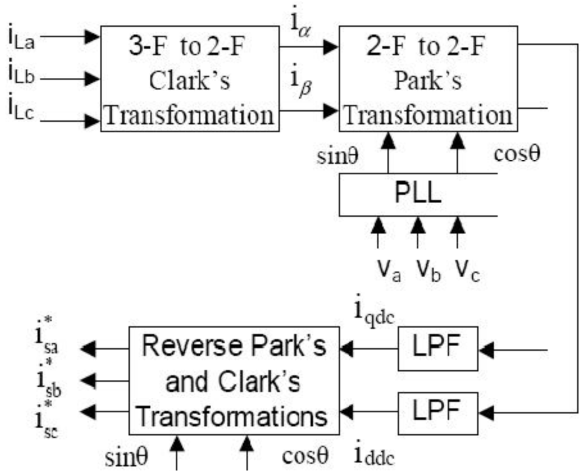


Fig.6. block diagram for synchronous frame theory

SRF isolator extracts the dc component by low pass filters (LPF) for each id and iq realized by moving averager at 100Hz. The extracted DC components iddc and iqdc are transformed back into α-β frame as shown below:

$$\begin{bmatrix} i_{\alpha dc} \\ i_{\beta dc} \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}\begin{bmatrix} i_{ddc} \\ i_{qdc} \end{bmatrix}$$

From here the transformation can be made to obtain three phase reference currents in a-b-c coordinates using. The reactive power compensation can also be provided by keeping iq component zero for calculating reference currents.

Regulation of bus and DC link voltage

This compensation scheme is multifunctional and can be effectively used for load balancing and harmonic suppression in addition to power factor correction and dynamic voltage regulation. Three phase ac supply voltages and DC link voltage is sensed and fed r two PI controller , the outputs of which decide the amplitude of the reference reactive and active current to be generated by the DSTATCOM. Fig.7. shows the block diagram of the implemented scheme.

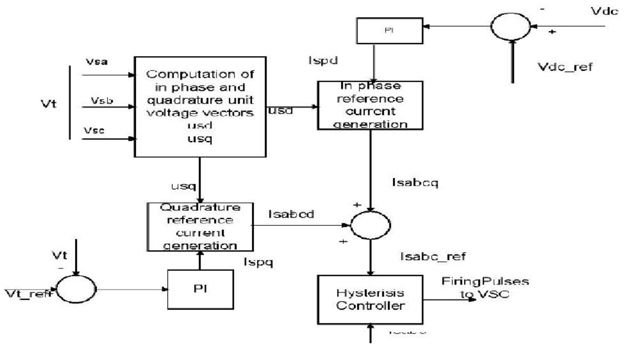


Fig. 7. Block diagram of regulation of bus and DC link voltage control

Multiplication of these amplitudes with the in phase and quadrature voltage unit vectors yields the respective component of reference currents. When applying the algorithm for power factor correction and harmonic elimination the quadrature component of the reference current is made zero. The summed direct and quadrature axis reference currents and the sensed line currents are fed to carrier less hysteresis controller which is used for tracking control. The converter switching actions are generated from a hysteresis controller which adds a hysteresis band +/-h around the calculated reference current. The pulses are generated for the lower leg switches when, Isabc >= Isabc_ref+h and for the upper leg switches when, Isabc <= Isabc_ref-h. The tracking becomes better if hysteresis band is narrower, but then the switching frequency is increased which results in increased switching losses. Therefore the choice of hysteresis band should be a compromise between tracking error and inverter losses. This method of tracking current controls is simple robust and exhibits an automatic current limiting characteristic.

5. SIMULATION RESULTS

In this work, the performance of VSC based power devices acting as a voltage controller is investigated. Moreover, it is assumed that the converter is directly controlled (i.e., both the angular position and the magnitude of the output voltage are controllable by appropriate on/off signals) for this it requires measurement of the rms voltage and current at the load point.

The DSTATCOM is commonly used for voltage sags mitigation and harmonic elimination at the point of connection. The DSTATCOM employs the same blocks as the DVR, but in this application the coupling transformer is connected in shunt with the ac system, as illustrated in Fig.8. The VSC generates a three-phase ac output current which is controllable in phase and magnitude. These currents are injected into the ac distribution system in order to maintain the load voltage at the desired voltage reference. Active and reactive power exchanges between the VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

1) Voltage regulation and compensation of reactive power;

2) Correction of power factor

3) Elimination of current harmonics.

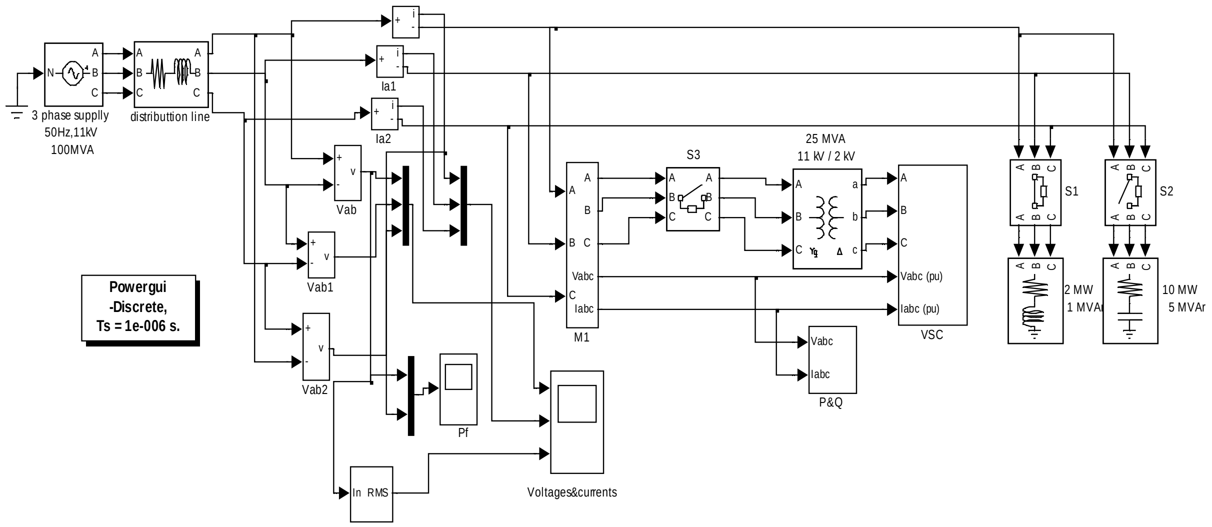


Fig.8. DSTATCOM connected to 11kVdistribution system

PWM Based Model of VSC

In the PWM based model, the switching elements–IGBTs/diodes, the PWM signal generator and the dc capacitor are explicitly represented. Considering the DSTATCOM as a voltage controller. Such a model consists of a six-pulse voltage-source converter using IGBTs/diodes, a 10000-μF dc capacitor, a PWM signal generator with switching frequency equal to 3 kHz, a passive filter to eliminate harmonic components, and a voltage controller as that shown in Fig.9. The dc voltage (Vdc) is measured and sent to the controller as well as the three-phase terminal voltages (VABC) and the injected three-phase currents (Iabc). Va, Vb and Vc are voltages at the converter output.

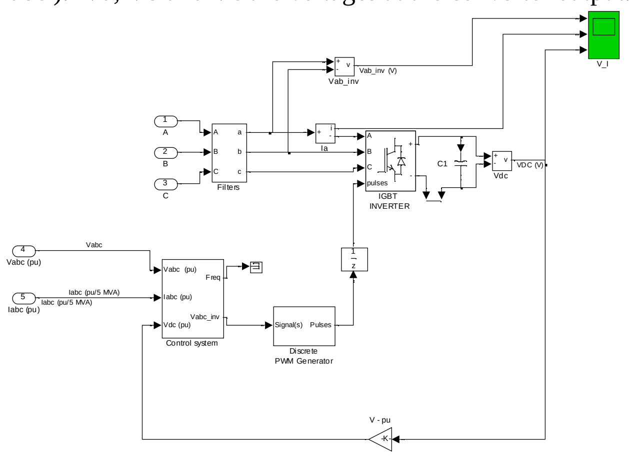


Fig.9. PWM based model of VSC implemented in SimPowerSystems.

For the DSTATCOM when the simulation starts, the DC capacitor starts charging. This requires Id component corresponding to the active power absorbed by the capacitor. When the DC voltage reaches its reference value, the Id component drops to a value very close to zero and the Iq component stays at the 1 pu reference value. In the case of the DSTATCOM, a constant dc source is provided across the capacitor for charging the capacitor to dc voltage reference value.

Voltage Controller of DSTATCOM

This section describes the PWM-based control scheme for the DSTATCOM. The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The voltage controller analyzed in this work is exhibited in Fig.9, and its simpower systems implementation is presented in Fig.10. Which employs the dq0 rotating reference frames because it offers higher accuracy than stationary frame based techniques. In this figure, VABC are the three-phase terminal voltages, Iabc are the three-phase currents injected by the devices into the network, Vrms is the rms terminal voltage, Vdc is the dc voltage measured in the capacitor and the superscripts * indicate reference values. Such controller employs a PLL (Phase Locked Loop) to synchronize the three-phase voltages at the converter output with the zero crossings of the fundamental component of the phase-A terminal voltage. Therefore, the PLL provides the angle φ to the abc-to-dq0 (and dq0-to-abc) transformation. There are also four PI regulators. The first one is responsible for controlling the terminal voltage through the reactive power exchange with the ac network

This PI regulator provides the reactive current reference Iq*, which is limited between +1 pu capacitive and -1 pu inductive. This regulator has one droop characteristic, usually ±5%, which allows the terminal voltage to suffer only small variations. Another PI regulator is responsible for keeping constant the dc voltage through a small active power exchange with the ac network, compensating the active power losses in the transformer and inverter. This PI regulator provides the active current reference Id*.

The other two PI regulators determine voltage reference Vd* and Vq*, which are sent to the PWM signal generator of the converter, after a dq0-to-abc transformation. Finally, Vabc* are the three-phase voltages desired at the converter output. The simulink implementation of Fig.10 is shown in Fig.11.

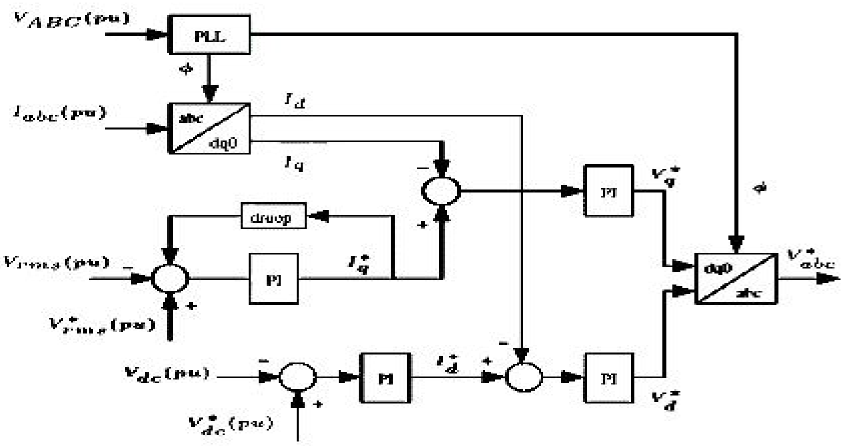


Fig.10Voltage controller of DSTATCOM

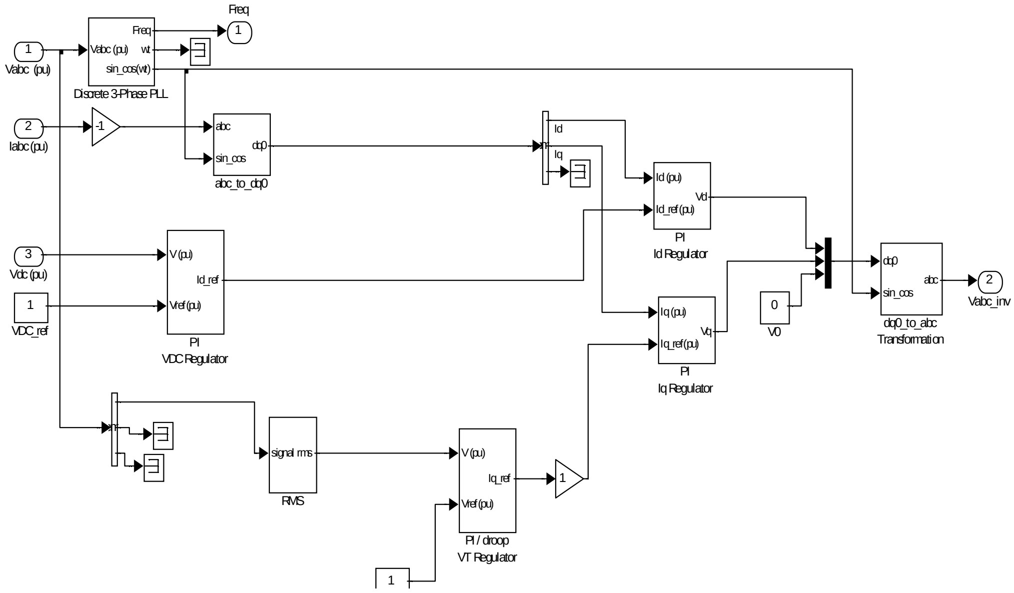


Fig.11.Voltage controller implemented in SimPowerSystems.

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

Without DSTATCOM compensation:

Case: 1 (an inductive load is applied .1seconds after the start of the simulation)

Initially there is a fixed inductive load is connected to the line. After .1 second the circuit breaker .is closed and the terminal voltage is decreased to.8pu. The top window shows the change in the three phase voltage waveforms, the second window shows the changes in the currents when the inductive load is applied after .1seconds and the bottom window shows the magnitude of the voltage. This simulation is shown in Fig.12 and results are shown in Fig.13.

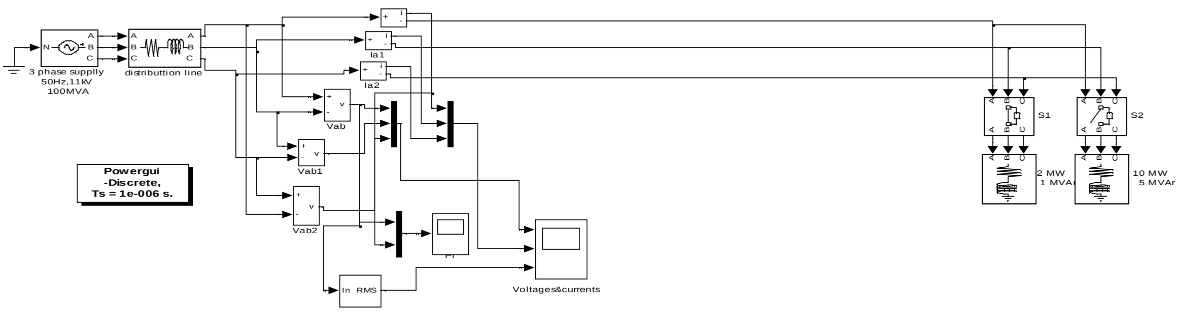


Fig.12 simulink model of uncompensated lines with inductive load

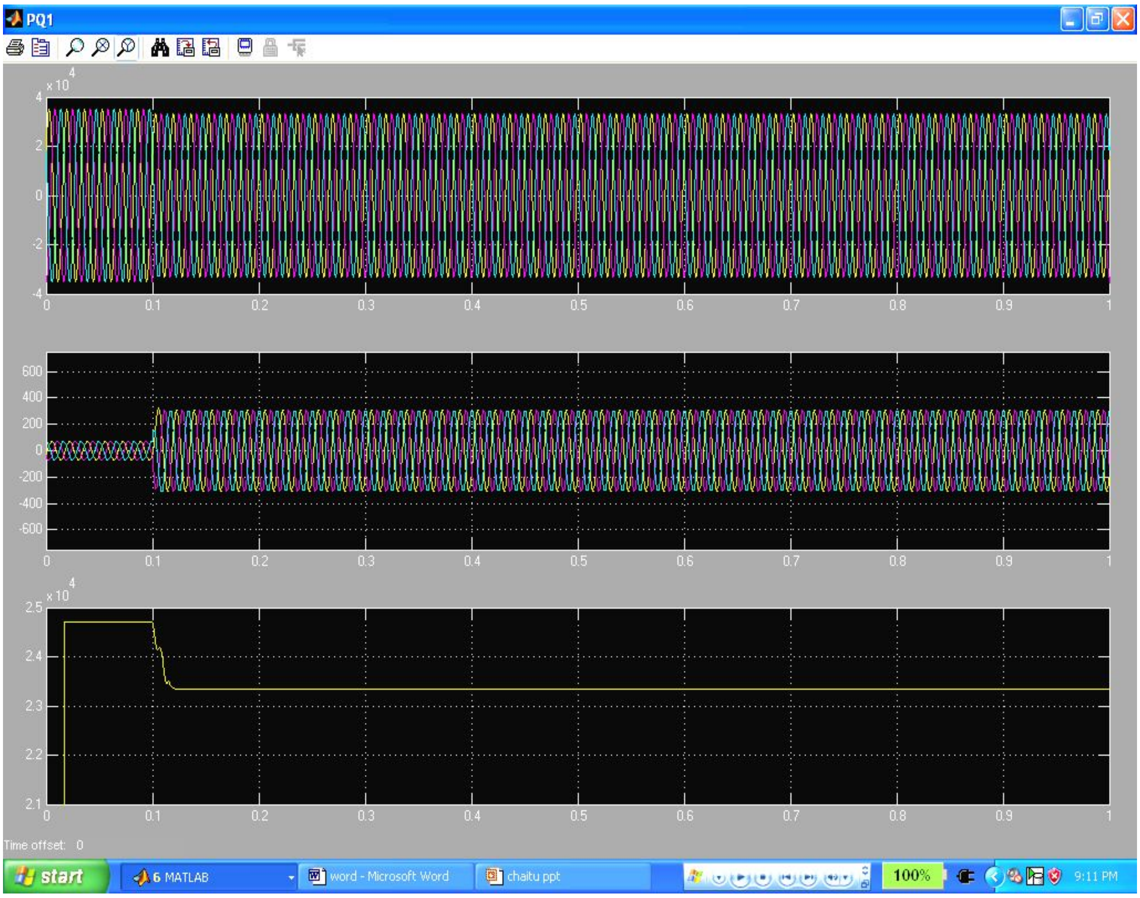


Fig.13..load voltage, load current & load voltage magnitude respectively with Inductive load in the uncompensated line

Case: 2 (An capacitive load is applied at .2seconds after the start of the simulation)

Initially there is a fixed inductive load is connected to the line. After 0.2seconds start of the simulation the circuit breaker is closed. The top window shows the changes in the three phase voltage waveform, the second window shows the changes in the currents when the capacitive load is applied after 0.2seconds and the bottom window shows the magnitude of the voltage. The simulation block is shown in Fig.14 and corresponding results are shown in Fig.15.

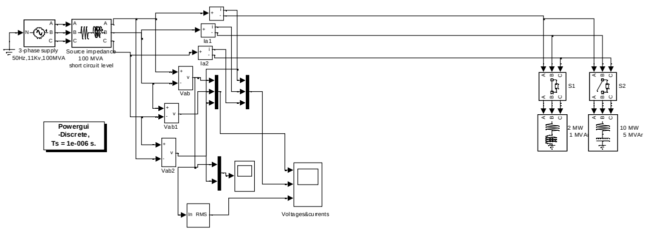


Fig.14 simulink model of uncompensated lines with capacitive load

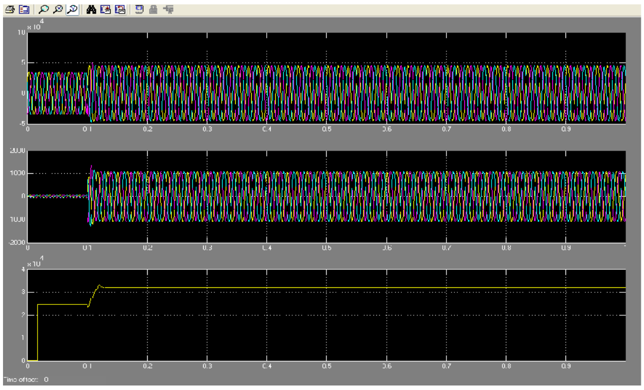


Fig.15. load voltage, load current & load voltage magnitude respectively with Capacitive load in the uncompensated line

Case: 3 (a capacitive load is applied .1seconds after the start of the simulation and an inductive load is applied at .2seconds after the start of the simulation).

In this simulation we observe the variations in the terminal voltage. When a capacitive load is applied then the terminal voltage rises, this condition is known as swell. When the inductive capacitive load is applied then the terminal voltage drops, i.e. this condition is known as sag. Initially there is a fixed inductive load is connected to the line. After 0.1seconds start of the simulation a capacitive load is applied, and at 0.2seconds start of the simulation a indutivee load is applied. The top window shows the changes in the three phase voltage waveform, the second window shows the changes in the currents when the inductive and capacitive loads are applied after 0.1and0.2seconds respectively after the start of the simulation and the bottom window shows the magnitude of the voltage. The simulink based model for this case is shown in Fig.16 and corresponding results are shown in Fig.17.

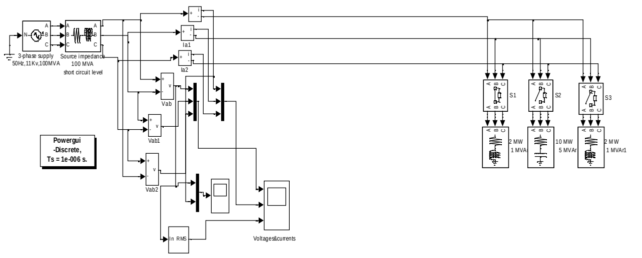


Fig.15. Simulink model of uncompensated lines with capacitive & inductive load

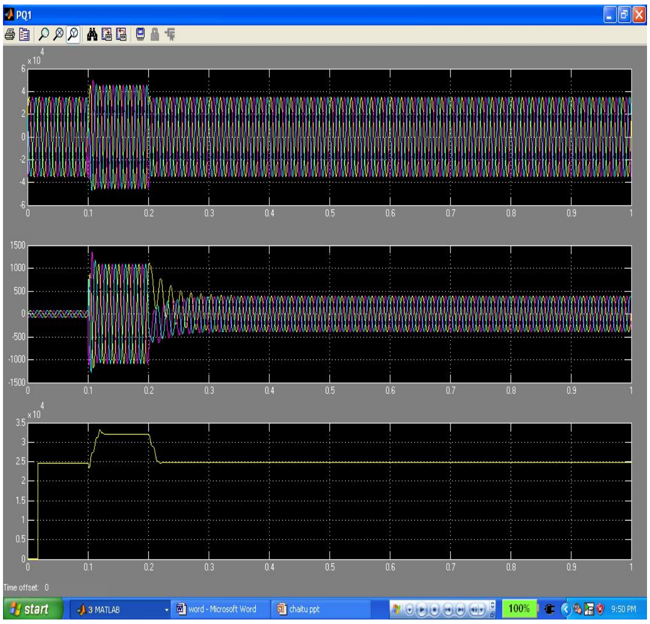


Fig.16. .load voltage, load current & load voltage magnitude respectively with Capacitive & inductive load in the uncompensated line

Compensation using decoupled current control or instantaneous p-q theory control

With DSTATCOM compensation:

Case: 1 (an inductive load is applied .2seconds after the start of the simulation)

Considering that the DSTATCOM is connected in shunt with the line. Initially there is a fixed inductive load is connected to the line. After 0.2 seconds the circuit breaker is closed an inductive load is applied, but in both the cases we observe that there is no drop in the terminal voltage due to the injection of reactive power by the DSTATCOM .Therefore the load is maintained at unity power factor. The top window shows that there is no change in the voltage waveform and it is maintained at unity power factor. The second window shows the variations in the currents when inductive loads are applied at different instances of the simulation. The simulation block and corresponding results for this case are shown in Fig.17 and Fig.18 respectively and the real and reactive powers are shown in Fig.19.

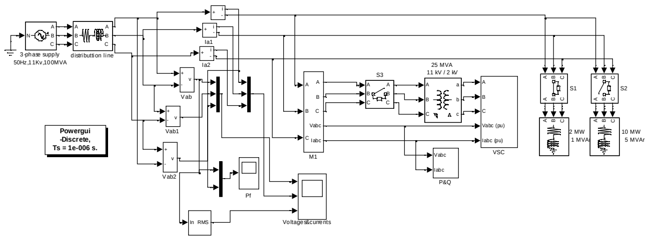


Fig.17. Simulink model of compensated lines with inductive load

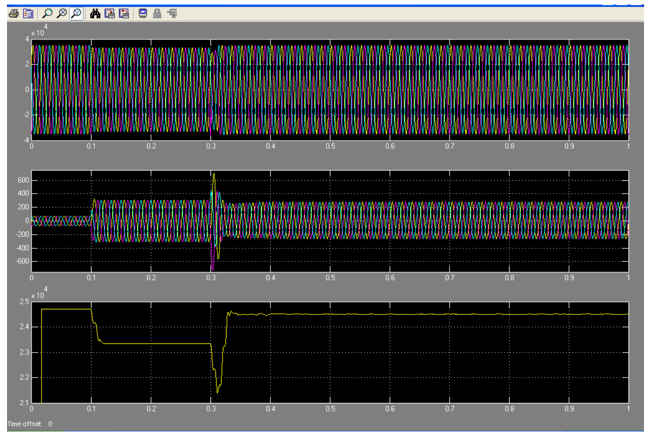


Fig.18. Load voltage, load current & load voltage magnitude respectively with Inductive load in the compensated line

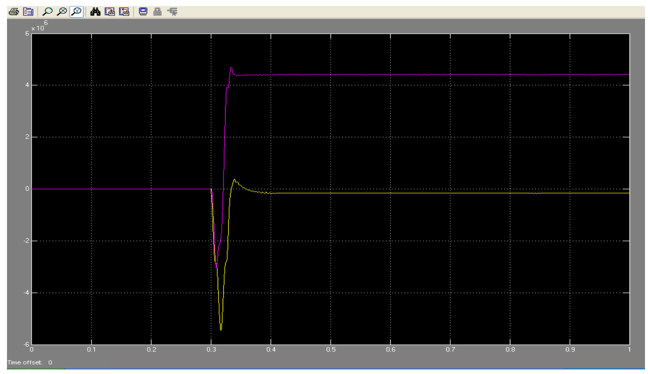


Fig.19. Reactive power of compensated lines with inductive load

Case:2 (an capacitive load is applied at .2seconds after the start of the simulation)

Considering that the DSTATCOM is connected in shunt with the line. Initially there is a fixed inductive load is connected to the line. After 0.2 seconds the circuit breaker is closed a capacitive load is applied, but in both the cases we observe that there is no rise in the terminal voltage due to the absorption of reactive power by the Dstatcom.

Therefore the load is maintained at unity power factor. The top window shows that there is no change in the voltage waveform and it is maintained at unity power factor. The second window shows the variations in the currents when inductive loads are applied at different instances of the simulation. The simulation block and corresponding results for this case are shown in Fig.20 and Fig.21 respectively and the real and reactive powers are shown in Fig.22.

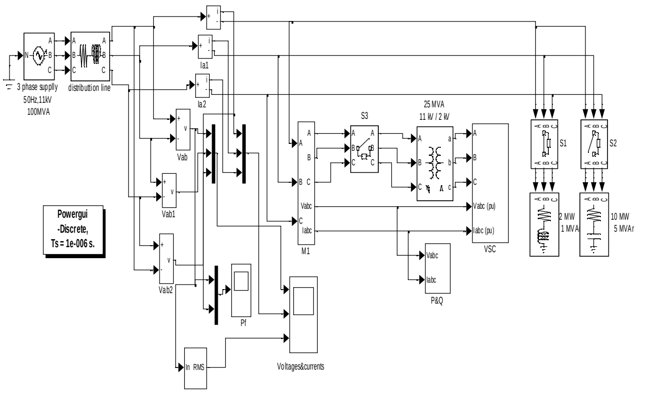


Fig.20. Simulink model of compensated lines with capacitive load

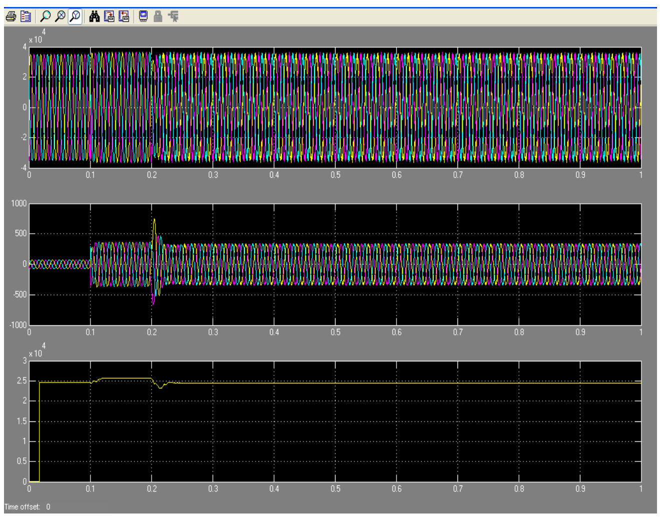


Fig.21. Load voltage, load current & load voltage magnitude respectively with Capacitive load in the compensated line

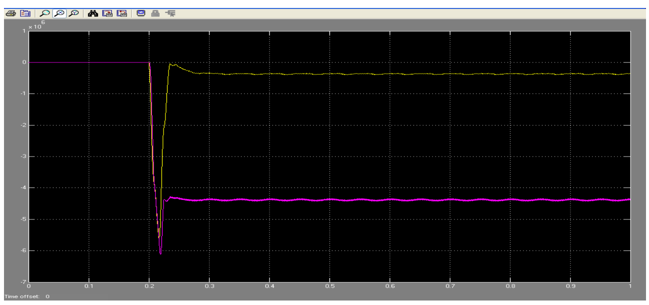


Fig.22. Reactive power of compensated lines with capacitive load

6. Conclusions

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

FUTURE WORK:

This project presents a detailed modeling and analysis of one of the custom power device DSTATCOM. Instantaneous Decoupled Current Control or instantaneous p-q theory is discussed in detailed and verified through detailed simulations by developing the models in MATLAB simulink using the sim power system control tool boxes. Now we are posing a challenge to complete If the remaining control strategies which includes the synchronous frame theory, regulation of Bus and DC link voltage, and ANN based Adaline theory .these control strategies are implemented and studied in detail through various simulations then it would be of immense help for the real time implementation of the DSTATCOM across all over the globe. If thrown light on other custom power devices like the Dynamic voltage Regulator (DVR), and Unified power quality conditioner (UPQC), applying different strategies then we can bring a revolution in the control of power in the distribution systems.

References

[1] "Control Algorithms for Distribution Static Compensator" by Deepika Masand, Shailendra Jain and Gayatri Agnihotri and Maulana Azad Dept. Of Electrical Engineering National Institute of Technology, Bhopal (MP), India.

[2] "A comparative study of Control algorithms for DSTATCOM for load compensation" by Bhim Singh,

Department of Electrical Engineering, Indian Institute of Technology, Hauz Khas, New Delhi
[3] "The Concept and Operating Principles of a Mini Custom Power Park" by Arindam Ghosh, Senior Member, IEEE, and Avinash Joshi Senior Member, IEEE
[4] "Steady state modeling of custom power compensation power distribution networks" by P. Pohjanheimo & E. Lakervi, Helsinki University of Technology, Power Systems Laboratory, Finland
[5] "Power Quality Enhancement with DSTATCOM for Small Isolated Alternator feeding Distribution System" by Bhim Singh, Department of Electrical Engineering, Indian Institute of Technology, Hauz Khas, New Delhi.
[6] "FACTS and custom power equipment for the enhancement of power transmission system performance and power quality" by John J. Paserba, Gregory F. Reed Mitsubishi electric power products, inc.. Warren dale, Pennsylvania, U.S.A, Masatoshi takeda and tomoshiko Aritsuk, Mitsubishi Electric Corporation, Japan
[7] Benefits of SVC and STATCOM for Electric Utility Application" by M. Noroozian, SM IEEE Åke, N Petersson, B. Thorvaldson, Bo A. Nilsson ABB Utilities, FACTS Division, Västerås, Sweden and C.W. Taylor, Fellow IEEE Carson Taylor Seminars Portland, Oregon USA.
[8] "An alternative cost-effective applications of power factor correction" by Richard A. Flusher, member, IEEE
[9] "Operation of a DSTATCOM in Voltage Control Mode" by Mahesh K. Mishra, Student Member, IEEE, Arindam Ghosh, Senior Member, IEEE, and Avinash Joshi
[10] "The role, of custom power products In enhancing power quality at industrial facilities" by Michael D. Stump, P.E. Westinghouse generation Gerald J. Keane Power Westinghouse and Frederick K. S. Leong Power Westinghouse Industry Services Asia private limited
[11] "Modeling, Analysis and Performance of a DSTATCOM for Unbalanced and Non-Linear Load" by Dinesh Kumar, Rajesh
[12] "Voltage Sag and Swell Generator for the Evaluation of Custom Power Devices" by Y.H. Chrmg. G.H Kwon T.B. Park and K. Y Lim
[13] "Voltage Flicker Mitigation Using PWM-Based Distribution STATCOM" by J. Sun, Student Member, IEEE, D. Czarkowski, Member, IEEE, and Z. Zabar, Senior Member, IEEE
[14] "Power Quality enhancement using custom power devices" by Arindam Ghosh and Gerard Ledwich .
[15] "Understanding FACTS; Concepts and Technology of Flexible AC Transmission Systems" by N. G. Hingorani, L. Gyugyi.

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