Reactive Power Compensation for Grid Connected Distribution System using DSTATCOM for Different Loads

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ABSTRACT: *In power system reactive power is one of the major concerns which affect the quality of power. . Management of reactive power is defined as the improvement of the power factor value so that we can cease the generation of reactive power. The concept of reactive power compensation is related to the issue faced in power quality but in general, the reactive power compensation can be done by considering two parameters i.e., load compensation and voltage support. In load compensation the aim is to increase the power factor of the system thus the real power in the system can be increased .In voltage support, the aim is to reduce the harmonic at the output due to fluctuating supply. The compensation of reactive power is essential to improve power quality using FACTS device such as DSTATCOM. A DSTATCOM is one of the fundamental facts devices, which is used for dynamic voltage control. In this work* I_d-I_q *control strategy is used .Using this control strategy the reference voltage and current signals are generated. These reference signals are used to generate pulses for the DSTATCOM. The generated pulses will dynamically vary depending on load variation. The proposed model and control technique is to be implemented by using Matlab/Simulink software which offers a smart tool for enhancement of reactive power for different loads using DSTATCOM, which increases the performance of system.*

Key words*: FACTS-Flexible alternating current transmission system, DSTATCOM-Distributed static synchronous compensator, Id-Iq control theory, reactive power.*

I.INTRODUCTION

The term power quality is used in synonymous with supply reliability to indicate the existence of an adequate and secure power supply. Power quality is generally used to express the quality of the voltage. Power Generation, Transmission and Distribution is a difficult process, requiring the working of many components of the power system to maximize the quality of the output. The quality may be reduced by many factors such as Harmonics, reactive power, voltage sag, swell, and transients.

Among all, the reactive power is the main component to decrease the quality of the waveform. So we need to compensate the reactive power. Reactive power is required to meet the inductive and capacitive loads. Most of the electrical loads are inductive; hence we need to compensate reactive power. The Reactive power may be compensated in many ways including FACTS controller, fixed capacitors and synchronous condensers etc.

Nowadays, FACTS controllers are used for compensating the reactive power. Here distributed static synchronous compensator (DSTATCOM) is used to compensate the reactive power. DSTATCOM has many advantages than other FACTS controllers. The advantages of DSTATCOM are compensating reactive power, and used for reducing the voltage drops improve the transfer capability of the power in the transmission and distribution lines .The advantages of reactive power compensation are improved power factor, voltage balancing, and improve system stability. So reactive power compensation is needed. The main objective of this work is to compensate the reactive power by using Id-Iq control method. This method also maintains the voltage at the stability level and the real power also compensated by connecting the same setup in series compensation. The Id-Iq control method is very easy to implement and it gives faster computation.

II.REACTIVE POWER

Real power is considered to be the work producing power measured in Watts or kilo Watts. Real power produces the mechanical output of a motor. Reactive power is not used but is needed to operate the equipment and is measured in volt-amperes-reactive VAr or kvar.

From the power triangle shown below, the compensation of reactive power decreases the apparent power. Thus, the total consumption of power is also reduced. It reduces the payment of the electricity bill, if kva is measured.

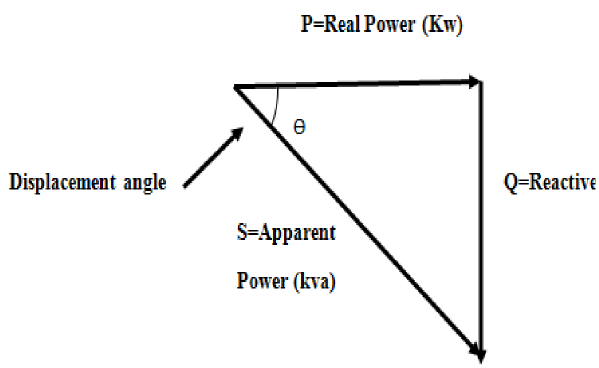


Fig: Equivalent diagram of Power

III.NEED FOR REACTIVE POWER COMPENSATION

The voltage regulation is used to increase the system stability, better utilization of machines connected to the system and to reduce the losses associated with the system.. The impedance of transmission line and the need for lagging VAr by most electrical machines in a generating system results in the consumption of reactive power (Q), thus affecting the stability limits of the system and transmission lines. Unnecessary voltage drops lead to increased losses which need to be supplied by the source and are leading to outages in the line due to stress on the system to carry this imaginary power.

IV.BLOCK DIAGRAM

The block diagram of the proposed Work is shown below. The three phase source supplies power to the load. This load consumes both real and reactive power, due to its inductive nature; not all the loads are purely resistive. It decreases the power quality. So the compensation of reactive power is essential, to improve the power quality. Here DSTATCOM is used to compensate the reactive power. It is used to control the DSTATCOM to inject reactive power to the load for compensation. Higher voltage side delivers reactive power to the lower voltage side. Based on this concept the controller operates and produces pulse to the inverter (DSTATCOM).The controller works on the basics of reference frame theory.

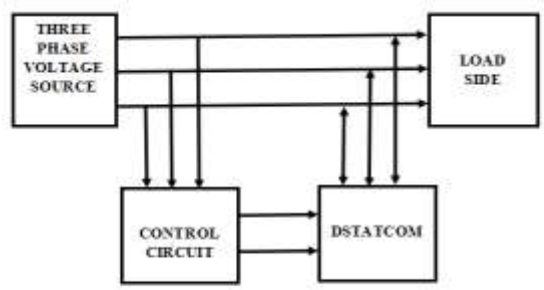


Fig: General Block Diagram

V.D-STATCOM

A DSTATCOM (Distributed static synchronous compensator),which is schematically depicted in figure shown below, consists of a two level voltage source inverter(VSI),a dc energy device, a coupling transformer are connected in shunt to the distribution network through a coupling transformer.VSI converts the dc voltage across the energy device into a set of three phase ac output voltage. These voltages are in phase and coupled with the system undergo the reactance of the coupling transformer. Suitable adjustment of the phase angle and magnitude of the dstatcom output voltages grant effective control of active and reactive power exchanges between the dstatcom and ac system.

The Voltage source inverter connected in shunt with the ac system provides a multifunctional topology which can be used for three quite distinct purposes:

1) Improves Voltage regulation and compensation of reactive power
2) Power factor correction.
3) Elimination of current harmonics

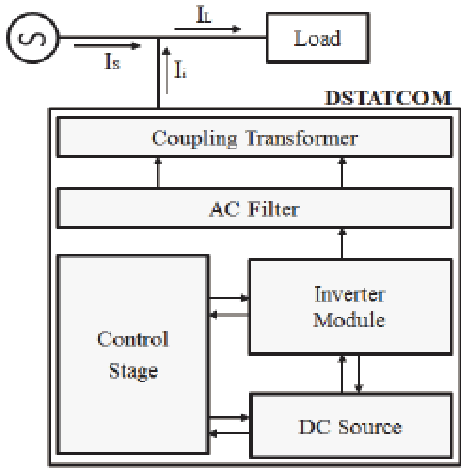


Fig: Single line Diagram of DSTATCOM

The DSTATCOM performance is used for compensating signals. Synchronous reference frame theory, estimation of reference currents by maintaining the voltage of dc link, reactive power theory, p-q theory and instantaneous id−iq theory for estimation of currents by maintaining the voltage of dc link are generally reported for an estimation of reference currents for the DSTATCOM through the extraction of positive-sequence real current from the load current.

These techniques generally incorporate a set of low-pass filter which results in a delay for computation of reference currents and therefore leads to slow dynamic response of the DSTATCOM. For controlling DSTATCOM, there are many controllers reported in the survey for extracting the reference current such as Linear Matrix Inequalities (LMI) controller, modified power balance theory, synchronous reference frame theory, and reactive power p-q theory and modified symmetrical component theory.

VI. D-STATCOM SIMULINK DIAGRAM

The simulation using the D-STATCOM is shown below. Here the fundamental voltage and frequency comprises 415v, 50Hz connected to current measurement block. The main source used in D-STATCOM is an inverter of type MOSFET.A 3000µF capacitor on the dc side provides the dstatcom energy storage capability. To show the effectiveness of the controller in providing continuous voltage regulation, simulations were carried out with and without DSTATCOM connected to the system.

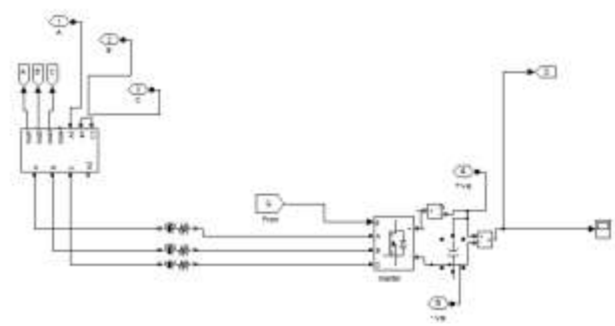


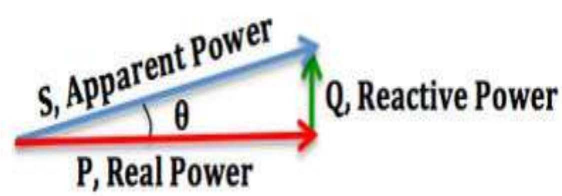
Fig: Simulation Model of DSTATCOM

The DSTATCOM model which is incorporated in the transmission system for voltage regulation is as shown.

VII.POWER FACTOR

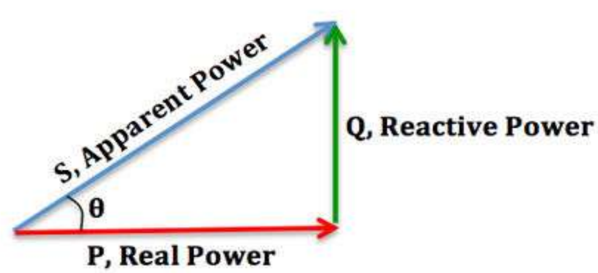
The ratio of the actual electrical power dissipated by an AC circuit divided by product of the RMS values of currents and voltages is known as "Power factor".

Increasing the Power Factor:



As the power factor (cos θ) increases, the ratio of true power to apparent power (which = cos θ), increases and approaches unity (1), while the phase angle θ decreases and the Q decreases. [As cos $\theta \rightarrow 1$, its maximum possible value, $\theta \rightarrow 0$ and so reactive power= 0, as the load becomes less reactive and more purely resistive].

Decreasing the Power Factor:



As the pf decreases, the ratio of true power to apparent power also decreases, as the angle θ increases and reactive power increases.

VIII.BATTERY (ENERGY STORAGE SYSTEM)

In recent years much of the focus on the development of storage technology has been on battery storage which is the main objective of this paper. There is a wide variety of battery types serving various advantages which would be examined in this paper. Electric batteries are devices that store electric energy in chemical form and deliver direct (dc) electricity. Electrode plates, typically consisting of chemical reactive materials , that are placed in an electrolyte which facilitates transfer of ions within the battery.

USES OF BATTERIES:

- In order to provide an interruptible supply of electricity to the power substation
- Used for backup power supply during power outage
- Power quality and reliability are increased
- Size: 0.14 – 2100 kva
- Operating time: 5 to 60 minutes
- Types: lead-acid (commercially available and widely used), sodium/sulfur,
- Zinc or bromine, lithium or air
- Uninterruptible Power Supply.
- Cost of a complete UPS system: $200/kva - $1,500/kva
- Battery cost of the complete UPS system: 60 – 70%
- Battery replacement frequency: every 5 – 7 years

Lithium ion Battery (Li Ion):

The advantages of Li ion batteries, compared to other advanced batteries, are: High energy density (300 to 400 kWh per m3, 130 kWh per ton). High efficiency (near 100%).Long csycle life (3,000 cycles @ 80% depth of discharge). The cathode in the battery is a lithiated metal oxide ($LiCoO_2$, $LiMO_2$, etc.) and the anode is made of graphitic carbon with a layered structure. The electrolyte is made up of li salts (such as $LiPF_6$) dissolved in organic carbonates. When battery is charged, the Li atoms in the cathode become ions and migrate through the electrolyte towards the carbon anode where there is a combination with external electrons and are deposited between carbon layers as lithium atoms. This process is reversed during discharge. While Li-ion batteries have over 50% of small portable market, there are some challenges for large-scale Li-ion batteries. The main problem is the high cost (above Rs.600/kWh) due to internal overcharge protection circuits. Several companies are working to reduce the production cost of these batteries is to capture large energy markets.

IX. Fuel cell

A fuel cell is defined as a cell, which unlike other devices can be fed with a fuel in order that the electrical power is to be maintained. The fuel cells convert hydrogen-containing fuels, directly into electrical energy, water through the electrochemical reaction of hydrogen and oxygen. Among several types of the fuel cells classified by the electrolyte used, four types are used for distributed generation systems: Phosphoric Acid fuel cell(PAFC), Solid Oxide fuel cell(SOFC), Molten Carbon fuel cell, Proton-Exchange- Membrane fuel cell (PEMFC).

- Proton Exchange Membrane fuel cell delivers high power and offer lighter weight and smaller volume than other fuel cell systems.

X.DIFFERENT LOADS:

The various loads in the proposed work are mentioned below

1) Balanced linear load
2) Balanced non linear load
3) Unbalanced linear load
4) Unbalanced non linear load
5) Variable load

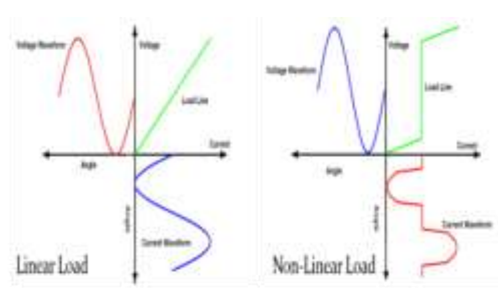


Fig: Linear Vs Non linear curves

Linear Vs Non linear load:

LINEAR LOADS	NON-LINER LOADS
Ohms law is applicable	Ohms law is not applicable
Inductive or capacitive.	Can't be categorized. As leading or lagging Loads.
Load current does not contain harmonics	Load current contains all ODD harmonics.
Resistive, Inductive or capacitive	Usually equipment with Diode and Capacitor.
Zero neutral current if one Phase. loads are equally balanced on three Phase. Mains(Vector sum of line current)	Neutral current may be 2.7 times the line current even if 1Ph. loads are equally balanced on 3 Ph. Mains
May not demand high current while starting	Essentially very high inrush current (20 time of I Normal) is drawn while starting for approx. One cycle.

XI.BLOCK DIAGRAM OF PROPOSED WORK

The blocks diagram for different loads in proposed system is shown,

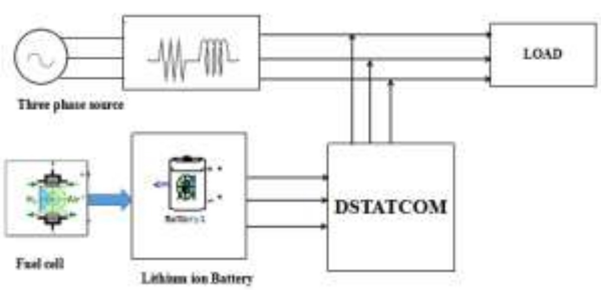


Fig: Block diagram of proposed work

SYSTEM PARAMETERS

PARAMETERS	VALUES
THREE PHASE SOURCE	
RATED VOLTAGE (V)	415V
RATED FREQUENCY (F)	50Hz
SOURCE CURRENT	200Amp
RESISTANCE (R)	0.1ohm
INDUCTANCE (L)	0.9e-3H
FILTER	BANDPASS
CIRCUIT BREAKER	
RESISTANCE (R)	0.01ohm
SWITCHING TIME	5 sec
LOAD SIDE	
GAIN FACTOR (K)	10
INDUCTANCE (L)	50e-3H
RESISTANCE (R)	50 ohm
POWER (P)	50 Kw
BATTERY	850V
D-STATCOM	
RESISTANCE (R)	0.0001 ohm
INDUCTANCE (L)	10e-3H
CAPACITANCE (C)	3000e-6
DEVICE	MOSFET
VOLTAGE	700V
CURRENT	26.5A

Table: Simulation system parameters

XII.RESULTS AND DISCUSSION

The simulation results and its output performance are discussed. The output waveform shows the results after carrying out the reactive power compensation by source, load and DSTATCOM. Voltage stability will be maintained at these output waveforms. Voltage stability consists of both source and load finally the reactive power compensation is done using dstatcom and output waveforms are discussed.

- **REACTIVE COMPENSATION:**

The whole model consists of 3 phase source (415v) connected to the linear R-L load through the bus interfacing system.

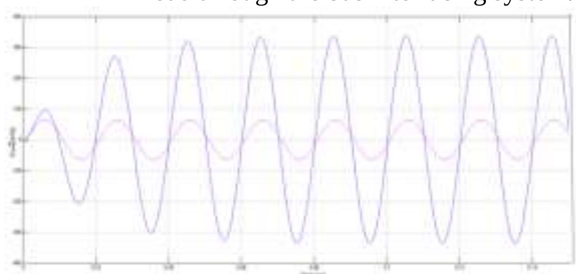


Fig: Results for reactive compensation without dstatcom

NAME	REAL POWER (Watts)	REACTIVE POWER (Var)
Source Side	3191	660.1
Load Side	9.385	1.942

Table: Real and Reactive Power values with DSTATCOM

In order to simulate the dynamic performance of the system, DSTATCOM (700V) is used to compensate reactive power. The above figure shows the reactive power compensation without DSTATCOM.

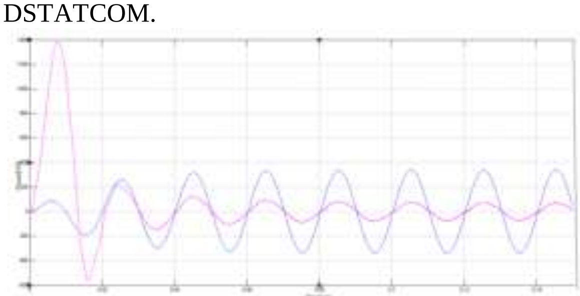


Fig: Results for reactive compensation with dstatcom.

NAME	REAL POWER (Watts)	REACTIVE POWER (Var)
Source Side	3531	193.9
Load Side	9.399	1.943

Table: Real and Reactive Power values with DSTATCOM

The above figure shows the reactive power compensation using DSTATCOM with a source voltage as 415V.

- **BALANCED LINEAR LOAD:**

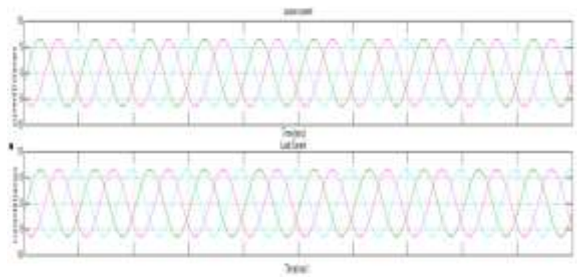


Fig: Results for balanced linear load without dstatcom

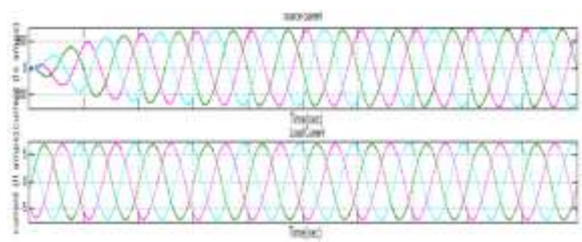


Fig: Results for balanced linear load with dstatcom

The system consists of a three phase source (415v) connected to the linear loads (R-L) through the bus interfacing system. In this system fuel cell and battery are connected to the DSTATCOM.

The above figure shows the reactive power compensation for balanced linear load using DSTATCOM.

- **BALANCED NON-LINEAR LOAD:**

The system consists of a three phase source (415v) connected to the non-linear load (Thyristor) through the bus interfacing system. In this system fuel cell and battery are connected to the DSTATCOM.

The figure shows the reactive power compensation for balanced non linear load using DSTATCOM.

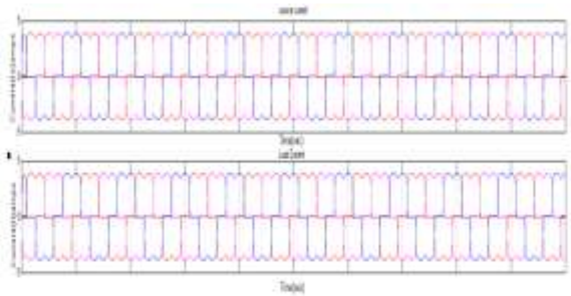


Fig: Results for balanced non linear load without dstatcom

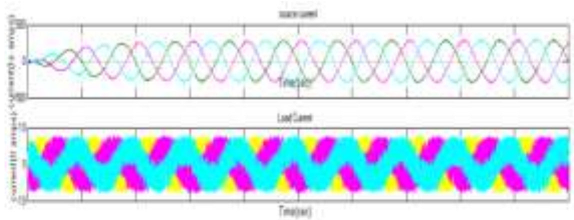


Fig: Results for balanced non linear load with dstatcom

- **UNBALANCED LINEAR LOAD:**

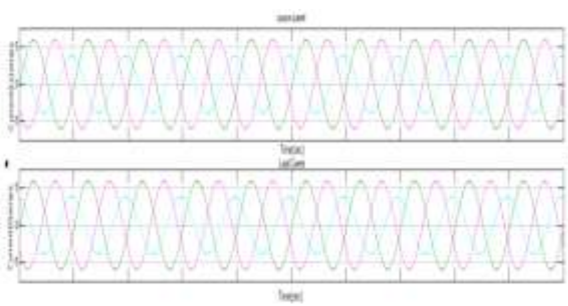


Fig: Results for unbalanced linear load without dstatcom

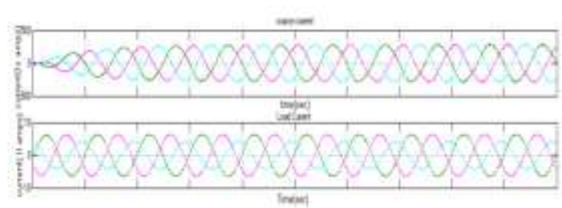


Fig: Results for unbalanced linear load with dstatcom

The system consists of a three phase source (415v) connected to the linear loads (R-L) through the bus interfacing system. In this system fuel cell and battery are connected to the DSTATCOM.

The above figure shows the reactive power compensation for unbalanced linear load using DSTATCOM.

- **UNBALANCED NON-LINEAR LOAD:**

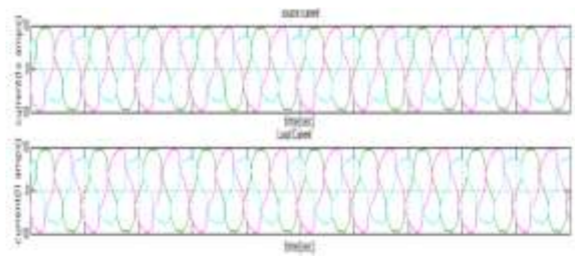


Fig: Results for unbalanced non linear load without dstatcom

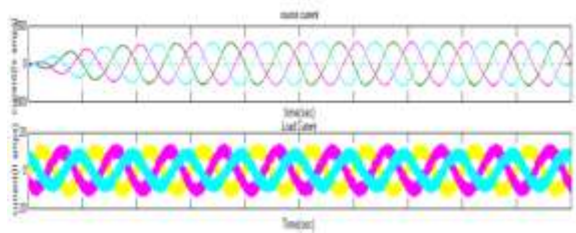


Fig: Results for unbalanced non linear load with dstatcom

The system consists of a three phase source (415v) connected to the nonlinear loads (Thyristor) through the bus interfacing system. In this system fuel cell and battery are connected to the DSTATCOM.

The above figure shows the reactive power compensation for unbalanced non linear load using DSTATCOM.

- **VARIABLE LOAD:**

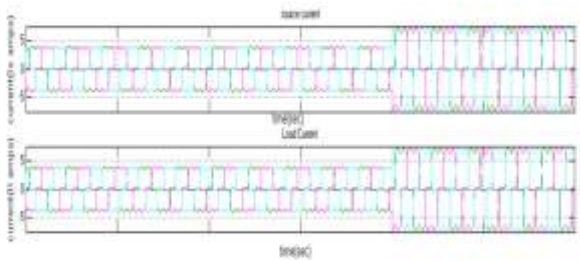


Fig: Results for variable load without dstatcom

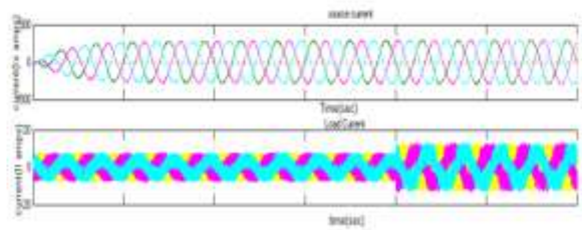


Fig: Results for variable load with dstatcom

The system consists of a three phase source (415v) connected to the non linear loads (Thyristor) through the bus interfacing system. In this system fuel cell and battery are connected to the DSTATCOM and an ideal switch is connected at load side.

The above figure shows the reactive power compensation for variable load using DSTATCOM.

CONCLUSION

This proposed work introduces a simulation model for d-q control based DSTATCOM for reactive power compensation to be used in MATLAB Simulink environment. The proposed model is a solution for reactive power compensation using DSTATCOM. The proposed model has a voltage will be maintained at stable for particular limit. This simulation model clearly shows that the DSTATCOM can be successfully implemented for the reactive power compensation. The proposed system also maintains the source (Electricity Board) voltage and current in phase with each other after compensation. Thus the power factor of the utility supply is always maintained at unity. This results in reduction of payment for electricity and avoids the penalty, for poor power factor.

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