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# USE OF DSTATCOM IN REACTIVE CONTROL

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## ABSTRACT

In this paper work among the different custom power devices, the role of DSTATCOM has been investigated to improve the quality of power under different conditions.. For this Self-Excited Induction Generators (SEIGs) are used which also presented the significance of renewable source of energy (solar energy, wind energy, geothermal energy, tidal energy) in energy crisis. The two SEIG's are connected in parallel, to get better power supply to the consumers. When the SEIG attains steady state condition, double loading will cause decrease in magnitude of generated voltage and shoot-up the current. In this paper effect of various power quality problems is analyzed i.e. by inserting three phase fault, by unbalancing the test system and by double loading the system. Under these conditions DSTATCOM will work as a regulator .The proposed controller used to control both current and voltage in the generator terminal. The proposed controllers consist of static synchronous compensator (DSTATCOM) which recompenses the loads and to make available the required reactive power of induction generators under loaded condition. The STATCOM consist of insulated gate bipolar transistor (IGBT) and any shortage of power in a grid is leveled by a BESS (Battery Energy Storage System) used with the DSTATCOM. The proposed generating system is simulated in MATLAB platform along with Simulink.

**KEYWORDS:** SEIG (Self-Excited Induction Generators) MATLAB, IGBT, DSTATCOM.

## INTRODUCTION

Now a days due to exhaustion of fossil fuel and also the increasing cost has forced mankind to look for (1) proficient and proper use of conventional fuel (2) or use of nonconventional source of energy. Consequently improving power quality and use of nonconventional resources has become the main area to be focused in modern electric power system. Solar wind and hydro are some of the sources of energy which can be renewed in nature and have not been fully exploited. Focus has now shifted to these unexploited sources of energy. Small hydro generation plants exist in relatively large number in the remote locations of the hills. These have the ability to feed local loads and with superior quality of power at relatively less cost. Also to provide the power to these inaccessible areas using overhead conductors or cables is not feasible due to too expensive cost of transmission system. One generator which met all of the requirements is the induction generator. Therefore Self-Excited Induction Generators with its excitation condition being met by a capacitor bank connected across its terminals, has become the most appropriate option.

In spite of the advantages, SEIG suffers from its intrinsic poor voltage regulation. D-STATCOM can be successfully utilized to control voltage for a series of small Induction motors loads which draw huge starting currents (5-6 times) of full rated current and may have an effect on working of sensitive loads. In early times Thyristor based systems were used for reactive power Compensation and for voltage flicker reduction due to arc furnace loads, but due to deficiency of passive devices such as large size, fixed compensation possibility of resonance etc, the use of innovative compensators such as D-STATCOM is growing to solve the power quality problems. The reason of D-STATOM is to supply efficient voltage regulation during short duration of SEIG starting; loading and unloading and faulty situations and thus prevent large voltage swing.

## POWER SYSTEM CONFIGURATION

Fig. 1 shows the schematic of the self-sufficient power system. In this three phase squirrel cage induction generator 4kW, 400V, 50Hz, 1440 rpm is used and feeds power to a distribution system having two loads at consumer end. A micro hydro turbine provides constant power to the induction generator. The current and voltage of the asynchronous generator and the load are used as feedback to the control system of the DSTATCOM.

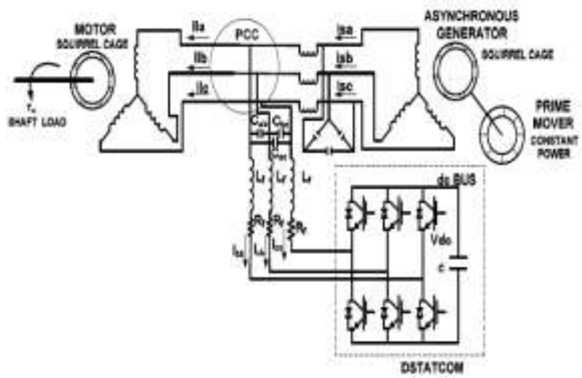

*Fig 1: Schematic diagram of the self-sufficient power system*

## DISTRIBUTION STATCOM

### Principle of Reactive Power Control

The principle of reactive power control via D-STATCOM is well known that the amount of type (capacitive or inductive) of reactive power exchange between the D-STATCOM and the system can be adjusted by controlling the magnitude of D-STATCOM output voltage with respect to that of system voltage. The reactive power supplied by the D-STATCOM is given by-

$$Q= (Vi-VS)/X * Vs$$

Where, Q is the reactive power. Vi is the magnitude of D-STATCOM output voltage. $V_S$ is the magnitude of system voltage. X is the equivalent impedance between D-STATCOM and the system. When Q is positive the D-STATCOM supplies reactive power to the system. Otherwise, the D-STATCOM absorbs reactive power from the system

### Load Compensation using D-STATCOM

The basic electronic block of the D-STATCOM is the voltage Source Converter (VSC) that converts an input DC voltage into a three phase output voltage at fundamental frequency. In its most basic form, the D-STATCOM configuration consists of a Voltage Source Converter (VSC), a DC capacitor for energy storage; a coupling transformer connected in shunt with the AC system, and associated control circuits. In this arrangement, the steady state power exchange between the device and the AC system is mainly reactive..

A SPWM control circuit, which gets feedback information about the generator and load voltages and currents, is used to provide triggering pulses to the IGBTs of the VSC.

For the analysis we are using two types of loads, one is 300 km away which is connected through transmission line and other is near the generating station. Three phase fault is inserted in the load which is at the distance of 300km and its effect is analyzed and also three phase fault is inserted at PCC. On the other hand test system is also double loaded by inserting the load for some point of time .By providing all these conditions the performance of DSTATCOM is analyzed i.e how the DSTATCOM will provide reactive power when any poor condition will met and make the system reliable.

## SINUSOIDAL PWM CONTROL SCHEME

The control approach of the power system is presented in Fig.2. A high frequency carrier based sinusoidal PWM is used for generating the switching pulses for the IGBTs of the VSC.

The three phase system is transformed to a synchronously rotating reference frame using Park's transformation. The compensation is achieved by control of id and iq. The immediate id reference current is generated by PI regulation of the dc terminal voltage with respect to a reference dc voltage. In the same way iq reference current is generated by PI

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regulation of the ac terminal voltage of the VSC with respect to a reference ac terminal voltage. The decoupled id and iq components obtained from abc to dq transformation of the calculated instantaneous three phase current, are then synchronized with two separate PI regulators with respect to the reference id and iq currents obtained earlier. In order to synchronize the abc to dq0 transformation a Phase Locked Loop (PLL) is used.

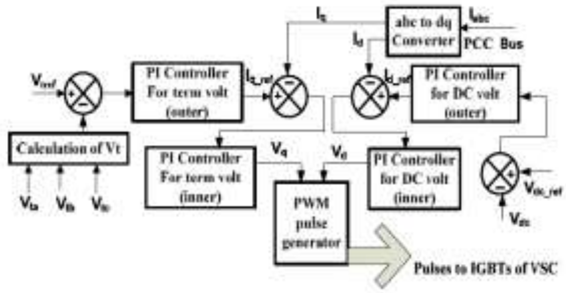


*Fig 2: Schematic diagram of Control Scheme*

The simulink model of the control scheme is shown in figure 3 below.

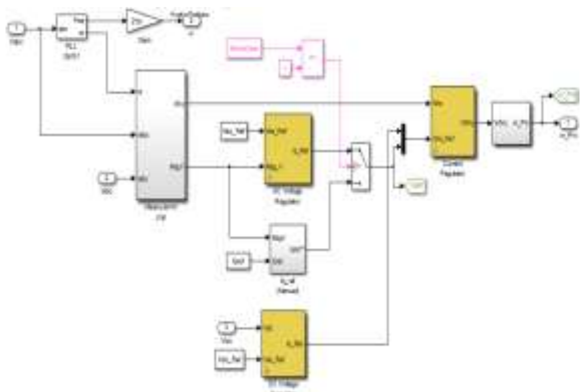

***Fig 3: Simulink Model of IGBT Control Scheme***

IGBT is controlled by two pulses. The one is which is described above by the Control scheme and the other one is given by the set of three, three winding linear transformers. We are taking the two pulses which are given by the SPWM control scheme, and these two pulses are delayed by sometime to one another. Then these two pulses are compared by the third pulse given by set of transformers and after comparison by two VSC, the adjusted and best pulse is taken by the IGBT as a triggering gate pulse for the further processing.

## CONTROL ALGORITHM

The discrete-time integrator block is used to realize the PI controller. Forward Euler method is used for integration. The discrete-time integrator block approximates 1/s by T/ (Z-1), which fallout in the following expression for the output Y(n) at the nth step .

$$Y(n) = Y(n-1) + KT^* U(n-1)$$

where U(n-1) is the input to the controller at the (n-1)th step.
T is the discretization time interval.

### Terminal Voltage Control

The three phase supply voltages (Vsa, Vsb and Vsc) are considered sinusoidal and therefore their amplitudes are computed as:

$$Vt = \sqrt{(2/3)(Vsa^2+Vsb^2+Vsc^2)}$$

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The value of Vt calculated above is compared with the desired amplitude of the terminal voltage Vtref. The ac voltage amplitude error Ver(n) at the *n*th sampling instant is given by,

$$Ver(n) = (Vtref - Vt(n))$$

where Vt(n) is the amplitude of the sensed three phase ac voltage at the PCC terminal at the *n*th instant. The error Ver(n) is fed to an outer PI controller, using discrete time integration, to generate the Iqref as

$$Iqref\ (n) = Iqref\ (n-1) + Kap\ \{Ver(n) - Ver(n-1)\} + Kai\ Ver(n)$$

where Kap and Kai are the proportional and integral gain Constants of the outer PI controller of the ac terminal voltage at the PCC.
The calculated value of Iq is generated by an abc to dq convertor using Park's transformation over the supply current. The Iqref and Iq components are compared and the error is fed to an inner PI current controller to generate Vq .

$$Iqer(n) = (Iqref\ (n) - Iq(n))$$

$$Vq(n) = Vq(n-1) + Kbp\ \{Iqer(n) - Iqer(n-1)\} + Kbi\ Iqer(n)$$

where Kbp and Kbi are the proportional and integral gain constants of the inner PI controller of the ac terminal voltage at the PCC.

**Control of Voltage at the dc terminal of DSTATCOM**
The Vdc of the dc bus is compared with the desired dc bus voltage Vdc_ref. The dc voltage error Vder(n) at the *n*th sampling instant is given by

$$Vdcer(n) = (Vdc\_ref - Vdc(n))$$

where Vdc(n) is the sensed dc voltage at the dc bus of the DSTATCOM at the *n*th instant.
The error is then fed to the outer PI controller to generate Idref as:

$$Idref\ (n) = Idref\ (n-1) + Kap\{Vdcer(n) - Vdcer(n-1)\} + KaiVdcer(n)$$

where Kap and Kai are the proportional and integral gain constants of the outer PI controller of the dc bus voltage.
The actual Id is generated by an 'abc to dq' convertor using Park's transformation over the supply currents. The signals Idref and Id are compared and the error is fed to an inner PI current controller to generate Vd.

$$Ider(n) = (Idref\ (n) - Id(n))$$

$$Vd(n) = Vd(n-1) + Kbp\ \{Ider(n) - Ider(n-1)\} + Kbi\ Ider(n)$$

where Kbp and Kbi are the proportional and integral gain constants of the inner PI controller of the dc bus voltage.

## MATLAB MODELLING
Figure 4 shows the MATLAB based simulation model of the power system along with its controller. A 4kW, 415V, 50Hz, 4-pole, Y-connected asynchronous machine is used for autonomous operation. The simulation is performed on MATLAB platform in discrete mode.

**SIMULATION MODELS**

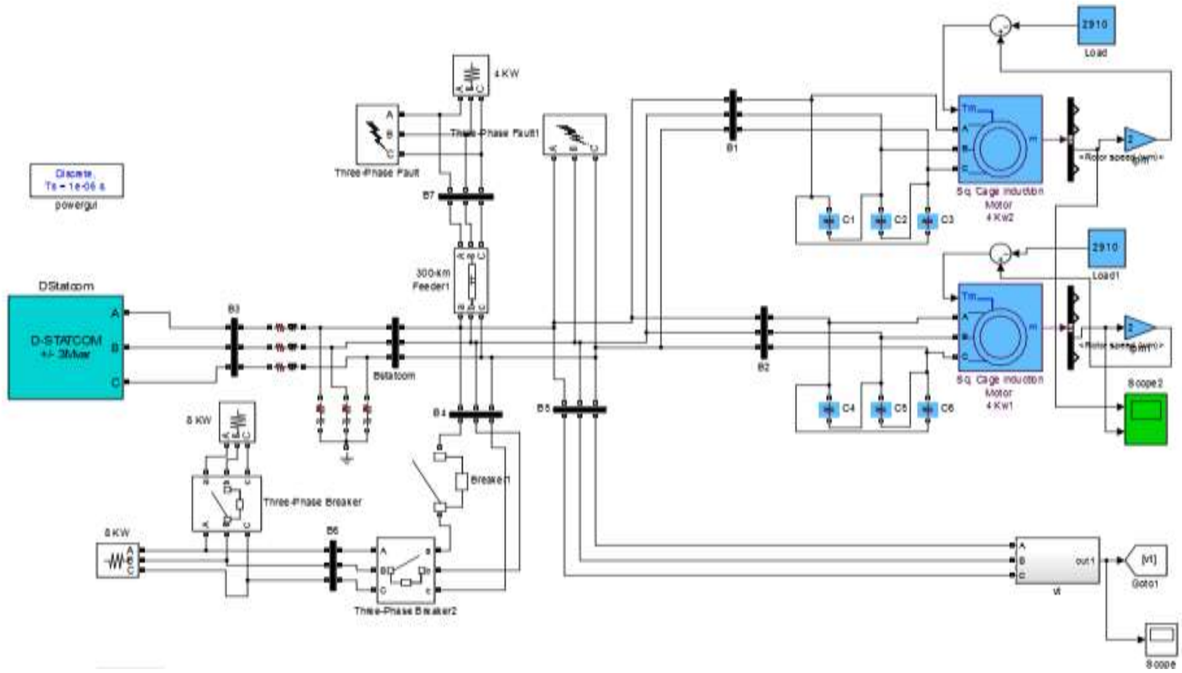


*Fig 4: SIMULINK MODEL of Proposed System with DSTATCOM*

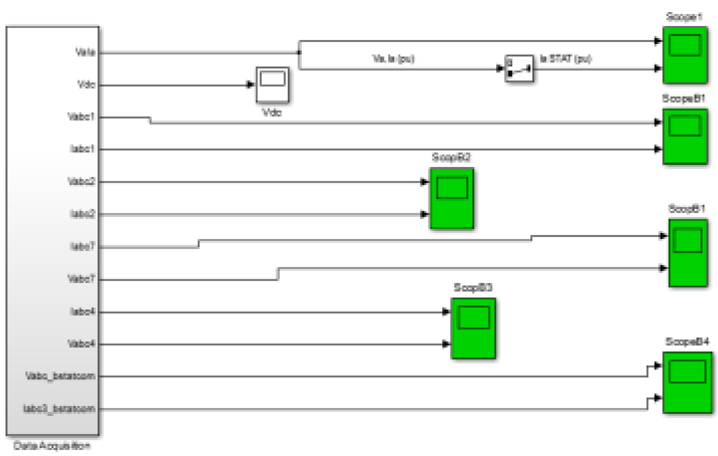


*Fig 5:  Data Acquisition Block*

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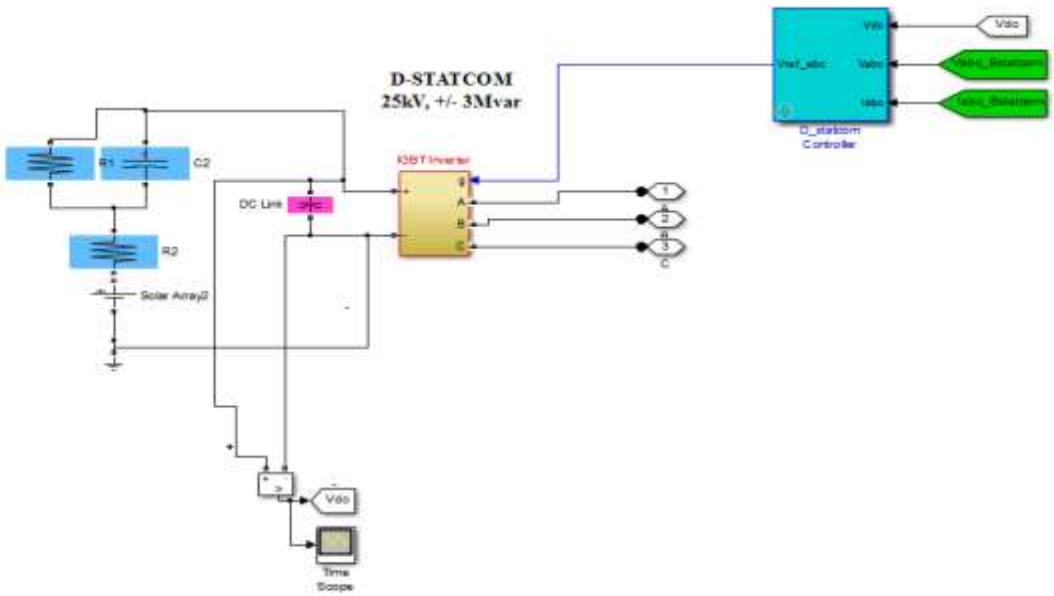


***Fig 6: SIMULINK MODEL of DSTATCOM***

## SIMULATION & RESULTS

The below table shows the all parameters used here for the result analysis under changeable and three phase fault conditions

| **Description** | **Graph Parameter** |
|---|---|
| SEIG Generator-1 voltage | Vabc1 |
| SEIG generator-1 current | Iabc1 |
| SEIG Generator-2 voltage | Vabc2 |
| SEIG Generator-2 current | Iabc2 |
| DSTATCOM currents | Icabc |
| Load1(8KW) current at bus B4 | Iabc4 |
| load 2(4KW) current at bus B7 | Iabc7 |
| calculated terminal voltage at PCC | Vt |
| measured value of dc side voltage | Vdc |
| Speed of SEIG 1 & 2 | N1, N2 |

***Table 1***

The response of SEIG's under distribution loads and other three phase fault conditions at different time periods is shown in graphs below.

The BESS based DSTATCOM supplies the extra power causing a true operation of the system when the load on the SEIG Generators increases ahead of its rated capacity.

| Time Period | Description |
|---|---|
| 0.0 s | Load 1 (8KW) start + Load 2 (4KW) start |
| 0.2s to 0.3s | Additional Load 3 (8KW) inserted |
| 0.4s | Three phase fault short circuit to ground inserted at B7 |
| 0.5s | Fault removed at B7 |
| 0.8 to 0.9 s | phase to ground short circuit fault inserted at PCC |

***Table 2***

As given in the above table the simulation starts with 8kW load on the system. The system also is connected to a 4kW load through a 300 km transmission line. At 0.2 s an additional load 8kW load is switched on. The changes in the loads are shown in the graphs of load 2 having voltage Vabc4 and the load current Iabc4. At 0.3s the addition load inserted is unswitched. Then 0.4 s a three phase short circuit to ground fault is simulated at the bus B7. The effect of this fault is shown by increase in the bus current (Iabc7). At 0.6 s this fault is unswitched. The DSTATCOM steps in and Supplies the extra current requirement and prevents the voltage at PCC from falling. From 0.8s to 0.9s a phase to ground short circuit fault is simulated on the PCC. Though Disorder is observed and DSTATCOM supplies the necessary reactive current and prevents the PCC voltage from collapsing. Throughout the whole simulation as the total load on the generators of the system is maintained constant by the DSTATCOM the speed of the generators remain constant at around 1450 rpm

***Fig7: Speed curves of SEIG Generator 1 and SEIG Generator 2***

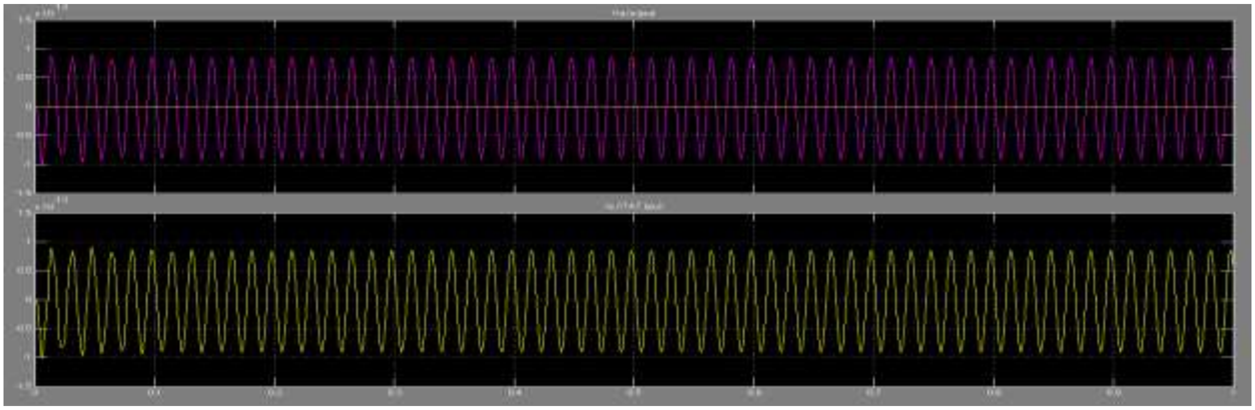

***Fig8: Voltage & Current waveform of DSTATCOM***

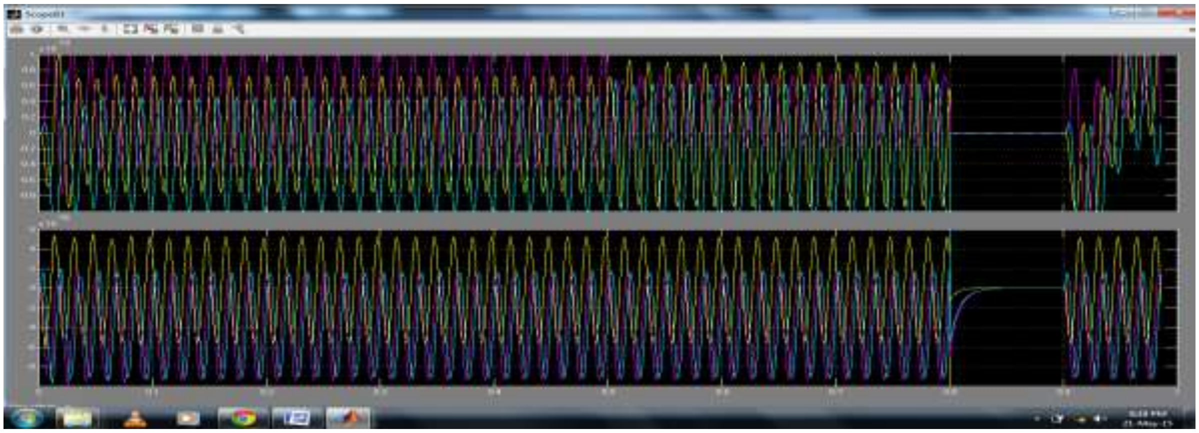

***Fig9: Voltage & Current waveform of SEIG Generator 1***

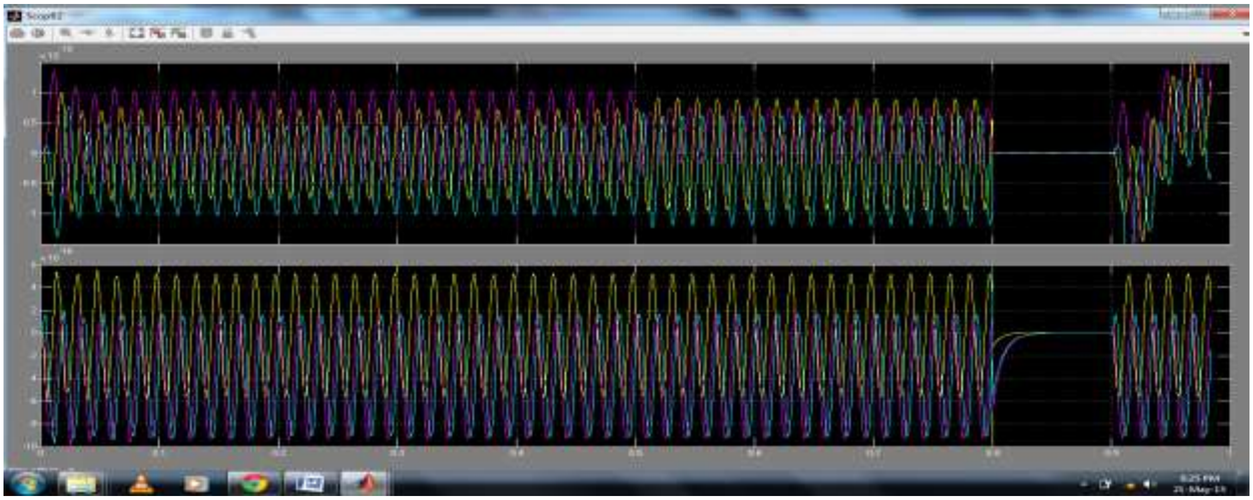

*Fig10: Voltage & Current waveform of SEIG Generator 2*

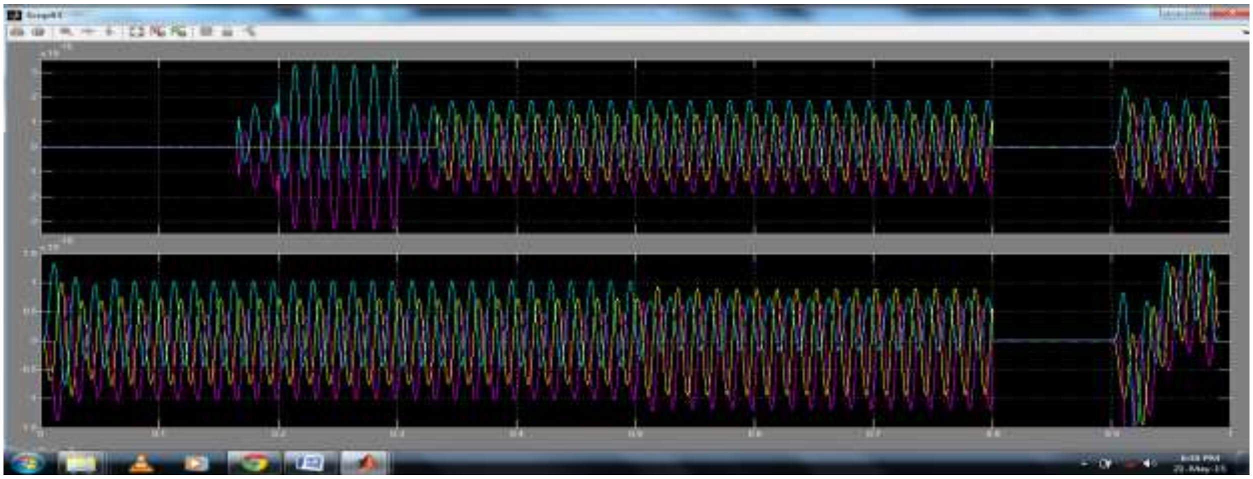

*Fig11: Current & Voltage Waveform of load 1(8KW) and double loading by Load 3(8KW)*

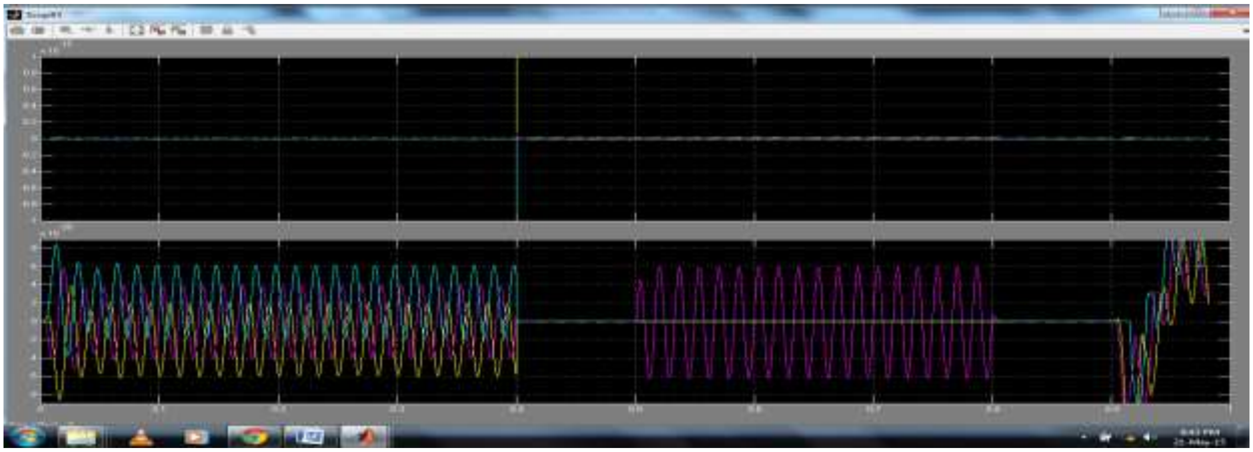

*Fig 12: Current & Voltage Waveform of Load 2 (4KW) and three phase fault inserted at transmission line and PCC*

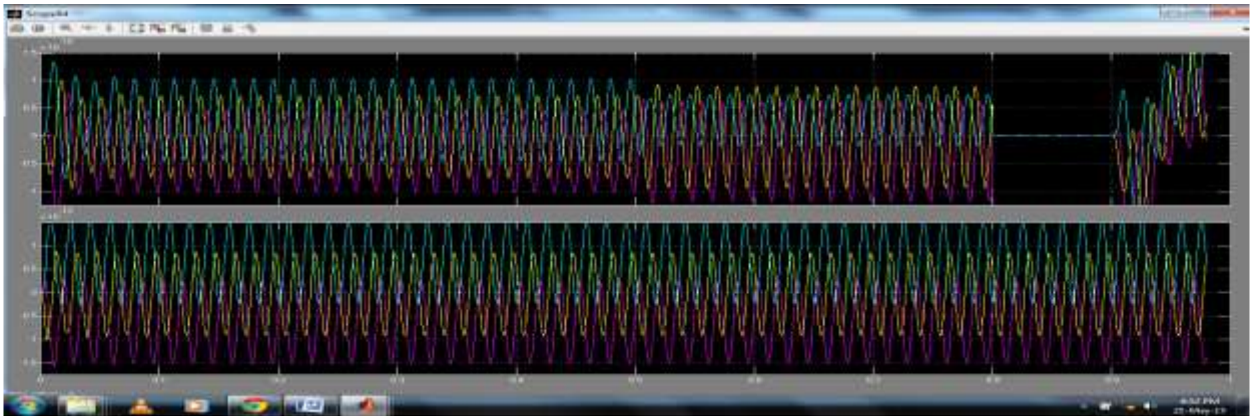

*Fig13: Vabc_bstatcom & Iabc_bstatcom Waveform*

## CONCLUSION

In this work, the investigation on the role of DSTATCOM is carried out to improve the power quality in distribution networks with non linear loads. . Also any increase in load beyond the rated value of the system is maintained by the BESS based DSTATCOM. PI controller's are used with the device to control its operation. Test system is analyzed and results are presented in the graphs shown above. It has also investigated that if any fault occurs on the transmission line coming from long distance generating station the DSTATOM is able to maintain the terminal voltage at the PCC by supplying the extra current and enhancing the stability of the power system The results give the satisfactory applications of DSTATCOM in the distribution networks under different fault conditions and it can be concluded that DSTATCOM effectively improves the power quality in distribution networks with static non-linear loads Thus the simulation has recognized that an proposed system supplying eminence power to its immediate neighborhood.

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