MITIGATION OF POWER QUALITY DISTURBANCES IN POWER SYSTEMS USING DSTATCOM WITH DIFFERENT TRANSFORMER CONNECTIONS

K.Ramesh[1], Mr.V.Ganesh[2]
Asst.Prof, EEE
Malla Reddy Engineering College (Autonomous)

Abstract
This paper presents the systematic procedure of the modeling and simulation of a Distribution STATCOM (D-STATCOM) for power quality problems with unbalanced load which is based on different transformer connections. Power quality is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end use equipments. The major problems dealt here is the voltage variations with unbalanced loads. To solve this problem, custom power devices are used. One of those devices is the Distribution STATCOM (D-STATCOM), which is the most efficient and effective modern custom power device used in power distribution networks. D-STATCOM injects a current in to the system to correct either voltage sag, swell and unbalanced load. The control of the Voltage Source Converter (VSC) is done with the help of SPWM. The proposed D-STATCOM is modeled and simulated using MATLAB/SIMULINK software for linear and non-linear load for obtaining total harmonic distortion.

Index Terms: Distribution STATCOM (DSTATCOM), MATLAB/ SIMULINK, Power quality problems.

I. INTRODUCTION

The developed industrial devices are mostly based on the electronic devices such as programmable logic controllers and electronic drives. The electronic devices are very sensitive to disturbances and became less tolerant to power quality problems such as voltage sags, swells and harmonics. Voltage variations with loads have considered, being one of the most severe disturbances to the industrial equipments. Voltage support at a load can be achieved by reactive power injection at the load point of common coupling. D-STATCOM [1]. injects a current into the system to correct the voltage variations. These power quality devices are power electronic converters connected in parallel or series with the lines and the operation is controlled by a digital controllers. The modeling of these complex systems that contains both power circuits and control systems can be done different bases. One of those power electronic solutions to the voltage regulation is the use of a Distribution STATCOM (DSTATCOM).

D-STATCOM is a group of custom power devices for providing reliable distribution power quality. They include a shunt of voltage boost technology using solid state switches for compensating voltage variations. The DSTATCOM applications are mainly for sensitive loads that may be drastically affected by fluctuations in the system voltage.

II. POWER QUALITY PROBLEMS

The power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices make them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted communications, a frozen mouse, system crashes and equipment failure etc [2]. A power voltage spike can damage valuable components. Power quality problems encompass a wide range of disturbances of voltage transients and interruptions..

III. DISTRIBUTION STATIC COMPENSATOR (D-STATCOM)

A D-STATCOM (Distribution Static Compensator), which is schematically depicted in Fig. 1 and consists of a two-level Voltage Source Converter (VSC), a DC energy storage device, a coupling transformer connected in parallel to the distribution network through a coupling transformer. Necessary adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power which transfers between the D-STATCOM and the AC system. Such configuration allows the device to absorb or generate controllable active and reactive power flows. [7].

The D-STATCOM commonly utilized mainly for regulation of voltage, correction of power factor and elimination of current harmonics. Such a device may be employed to provide continuous voltage regulation using an indirectly controlled converter. In this paper, the D-STATCOM is used to regulate the voltage at the point of common connection. The control technique is based on sinusoidal PWM and requires the measurement of the rms voltage at the load variation.

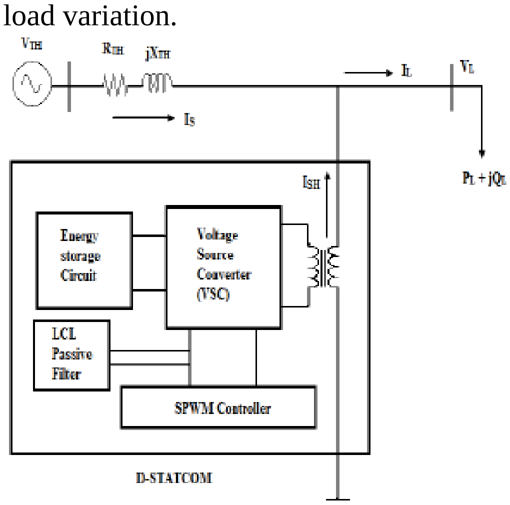


Fig 1: Schematic Diagram of D-STATCOM

The shunt injected current I_{SH} can be written as,

$$I_{SH} = I_L - I_S$$

Where $I_S = \frac{V_{TH} - V_L}{Z_{TH}}$

Therefore

$$I_{SH} = I_L - I_S = I_L - \frac{V_{TH} - V_L}{Z_{TH}}$$

Or

$$I_{SH}\angle\eta = I_L\angle-\theta - \frac{V_{TH}}{Z_{TH}}\angle(\delta-\beta) + \frac{V_L}{Z_{TH}}\angle-\beta$$

The complex power injection of the D-STATCOM can be expressed as,

$$S_{SH} = V_L I_{SH}$$

It may be mentioned that the effectiveness of the D-STATCOM in correcting voltage variations depends on the value of ZTH or fault level of the load bus. When the shunt injected current ISH is kept in quadrature with VL, the desired voltage correction can be achieved without injecting any active power into the system. On the other hand, when the value of ISH is minimized, the same voltage correction can be achieved with minimum apparent power injection into the system.

IV. METHODOLOGY

To enhance the performance of distribution system, D-STATCOM was connected to the distribution system. D-STATCOM to be designed using MATLAB - SIMULINK R2010a 7.10 version [6].

D-STATCOM Simulations and Results for THD Total harmonic distortion, which is the summation of all harmonic components of the Voltage or current waveform compared against the fundamental component of the voltage or current wave.

V. SIMULATION MODEL AND RESULTS

DSTATCOM for mitigating power quality problems like voltage variations with load balancing in 3-phase 4-wire distribution network.

STAR-DELTA TRANSFORMER CONNECTION

a. WITH LINEAR LOAD

No. of switches used : Not MLI
DC capacitance Voltage: 3000e-6 Farads
Coupling inductor : 5.5e-3 Henry
Modulation index : 0.4
Power factor : 0.7
THD : 4.63 %

Load Improvements:

$P = 10e^3$
$Q_L = 20e^3$
$Q_c = 0$

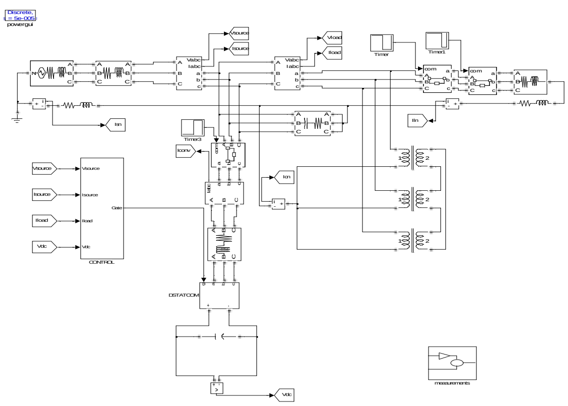


Fig 1: Simulation model with Linear Load

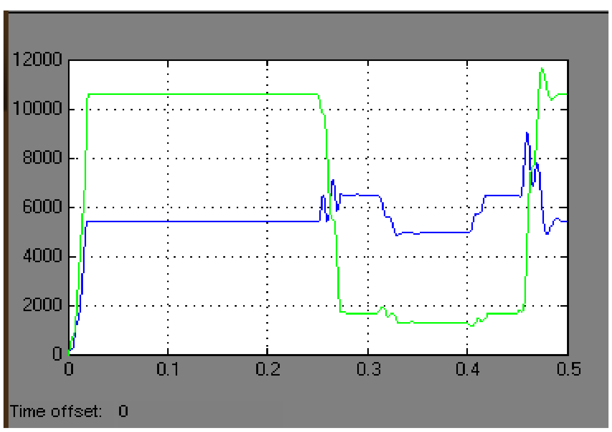


Fig 2: Active and Reactive power versus time (secs)

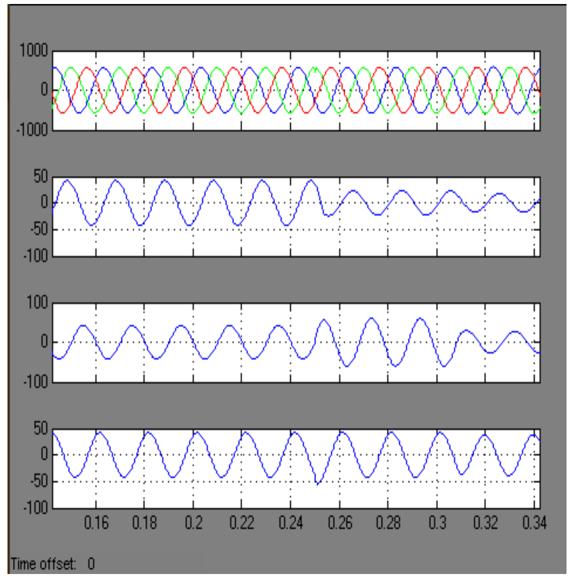


Fig 3: Source voltage and currents versus time (secs)

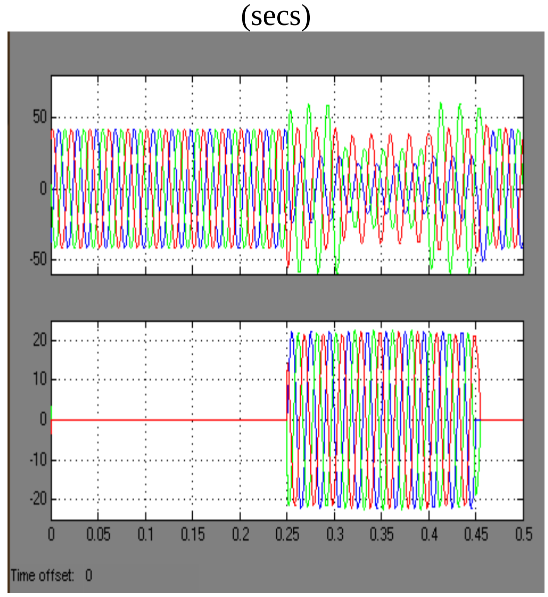


Fig 4: Source and Converter currents versus time (secs)

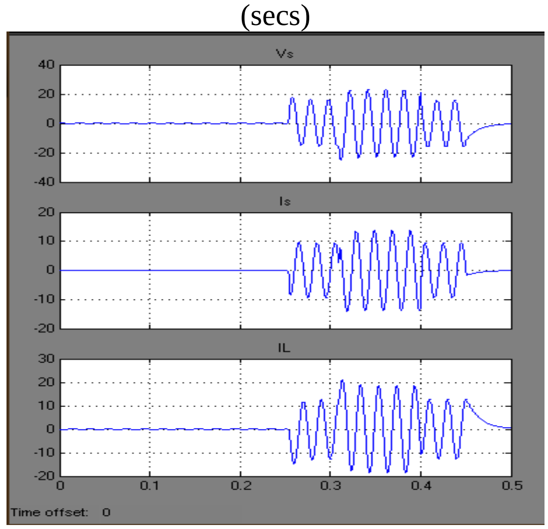


Fig 5: Neutralizing Currents versus time (secs)

b. WITH NON-LINEAR LOAD

No. of switches used : Not MLI
DC capacitance Voltage: 3000e-6 Farads
Coupling inductor : 5.5e-3 Henry
Modulation index : 0.4
Power factor : 0.7
THD : 6.63 %
Non-Linear Load parameters:
Diode Bridge (2 arms)
Snubber Resistance: 1000 ohms
Snubber capacitance: 3000 F
ON resistance: 1e-3 ohm
R = 50 ohms
C = 1000e-6 F

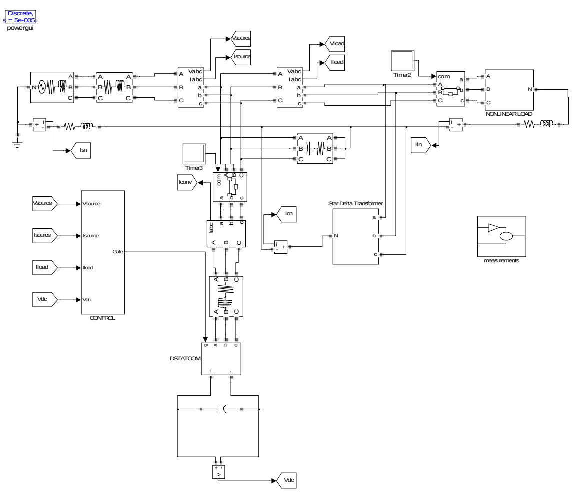


Fig 6: Simulation model with Non-Linear Load

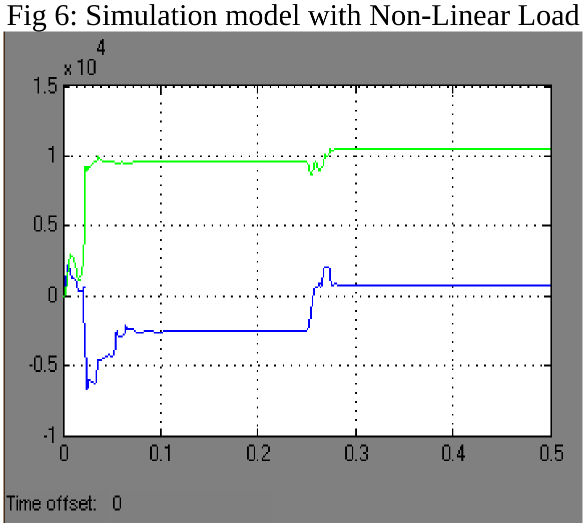


Fig 7: Active and Reactive power versus time (secs)

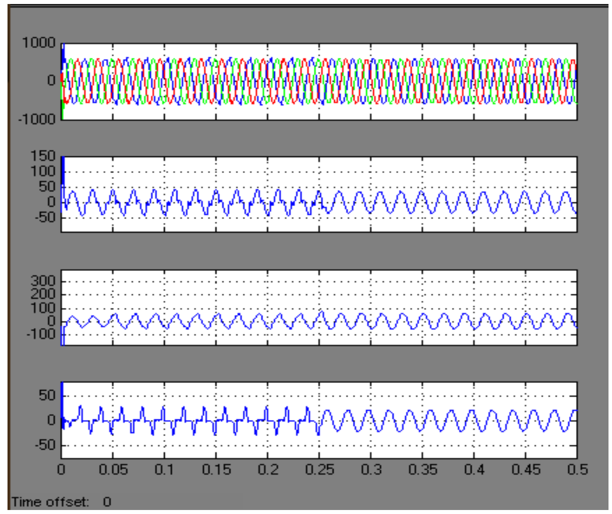


Fig 8: Source voltage and currents versus time (secs)

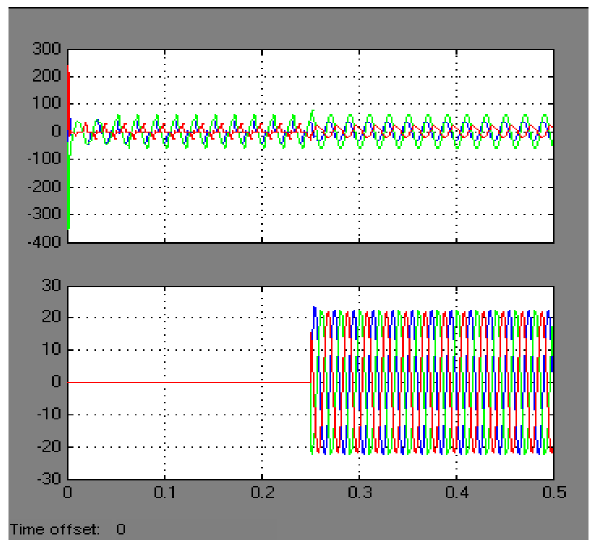


Fig 9: Source and Converter currents versus time (secs)

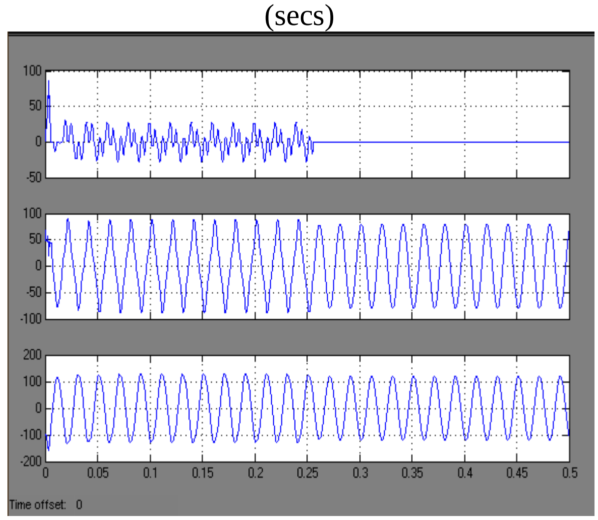


Fig 10: Neutralizing Currents versus time (secs)

a. WITH Induction motor LOAD

No. of switches used : Not MLI
DC capacitance Voltage: 3000e-6 Farads
Coupling inductor **:** 5.5e-3 Henry
Modulation index : 0.4
Power factor : 0.7
THD **:** 3.32 %

Induction motor parameters:
Torque as mechanical Input = 300N-m
Squirrel cage IM
Stationary Reference Frame
Stator resistance = 0.435
Stator inductance = 0.002
Rotor Resistance = 0.816
Rotor Inductance = 0.002
Mutual Inducatance = 69.31 mH
J = 0.089
F = 0.005
P = 2

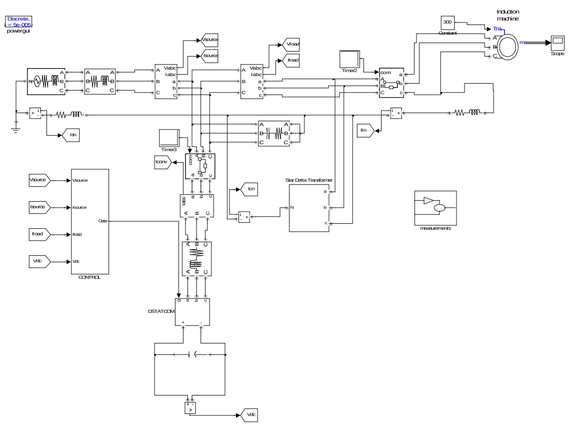


Fig 11: Simulation model with Induction Motor Load

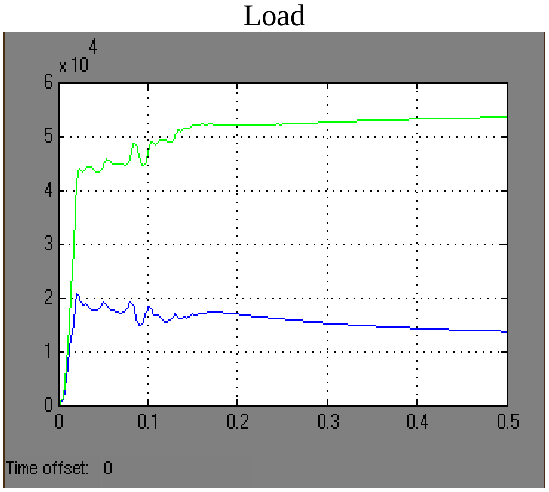


Fig 12: Active and Reactive power versus time (secs)

Load currents	Linear Load	Non-Linear Load	Induction motor
THD	4.43	6.63	3.32

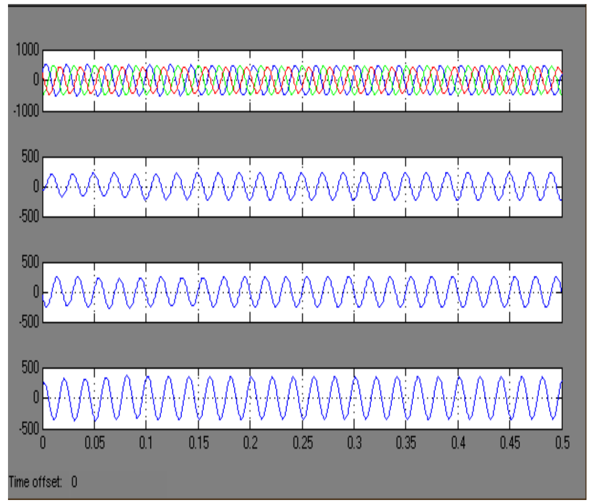


Fig 13: Source voltage and currents versus time (secs)

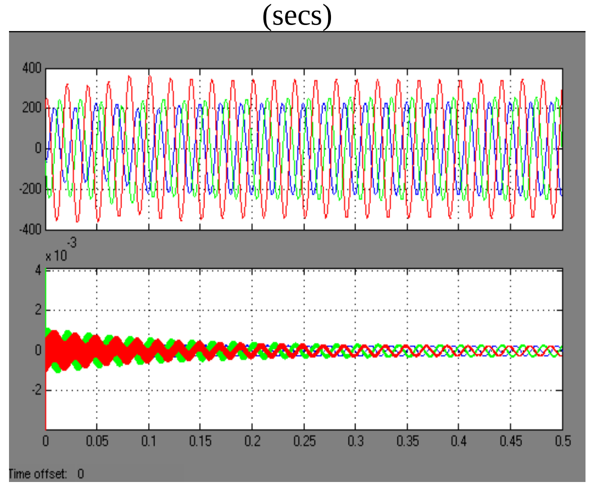


Fig 14: Source and Converter currents versus time (secs)

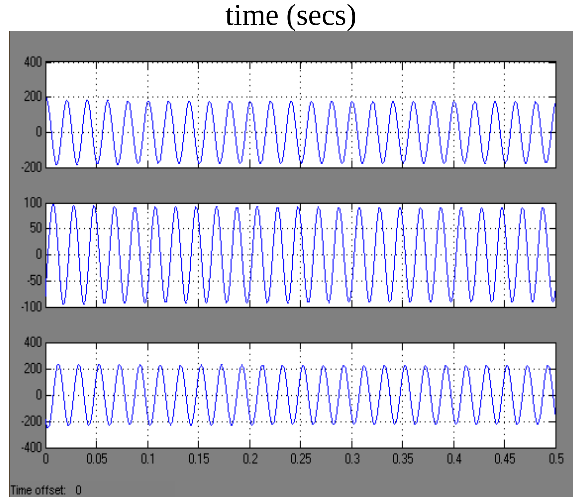


Fig 15: Neutralizing Currents versus time (secs)

T-CONNECTED TRANSFORMER CONNECTION

WITH LINEAR LOAD:

No. of switches used : Not MLI
DC capacitance Voltage: 0.005 Farads
Coupling inductor : 2e-3 Henry
Modulation index : 0.4
Power factor : 0.7
THD : 0.55 %

Load Improvements:

P = 16e^3
Q$_L$ = 12e^3
Q$_c$ = 0

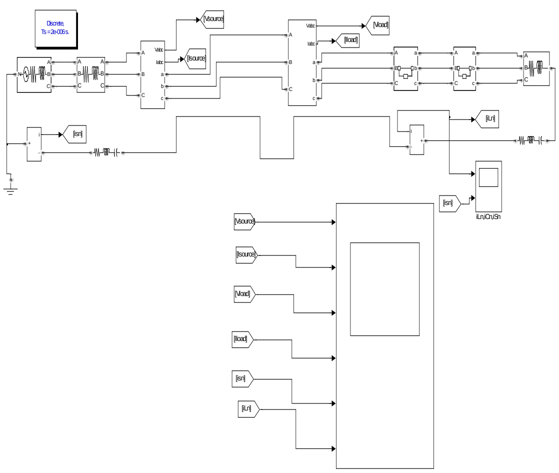


Fig 16: Simulation Model with Linear Load

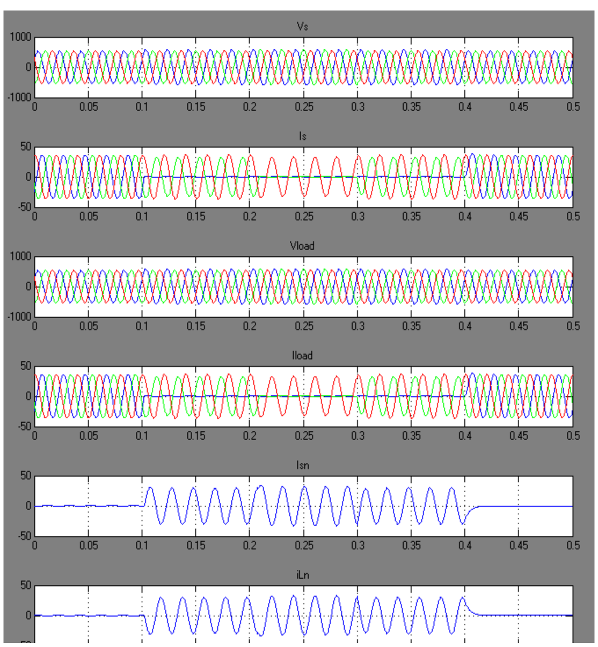


Fig 17: Source voltages and currents, Load currents versus time (secs)

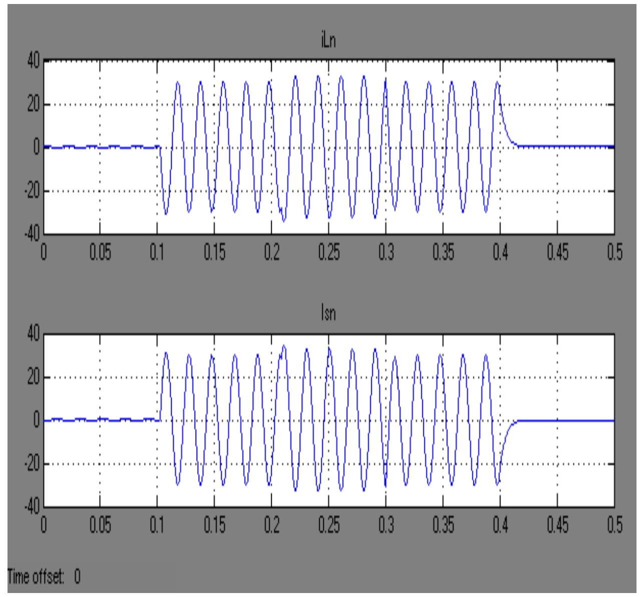


Fig 18: Neutralizing currents versus time (secs)

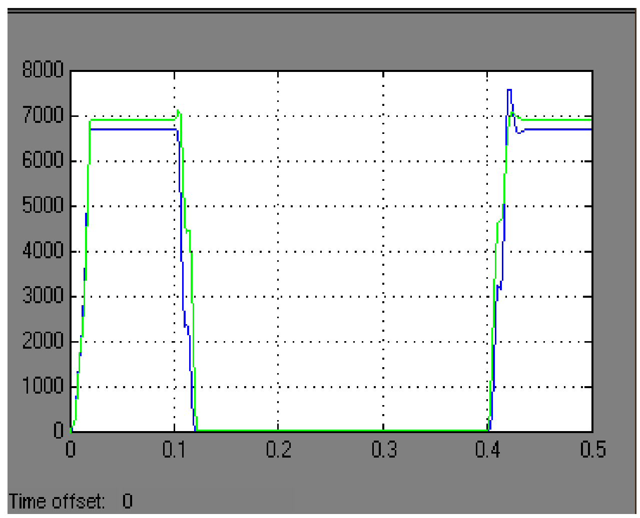


Fig 19: Active and reactive power versus time (secs)

a. WITH NON-LINEAR LOAD

No. of switches used : Not MLI
DC capacitance Voltage: 3000e-6 Farads
Coupling inductor : 5.5e-3 Henry
Modulation index : 0.4
Power factor : 0.7
THD : 0.84 %
Non-Linear Load parameters:
Diode Bridge (2 arms)
Snubber Resistance: 1000 ohms
Snubber capacitance: 3000 F
ON resistance: 1e-3 ohm

R = **2**5 ohms
C = 470e-6 F

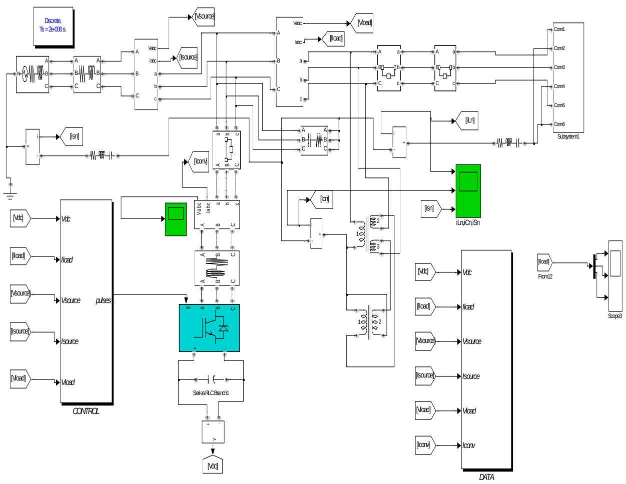


Fig 20: Simulation with Non-Linear Load

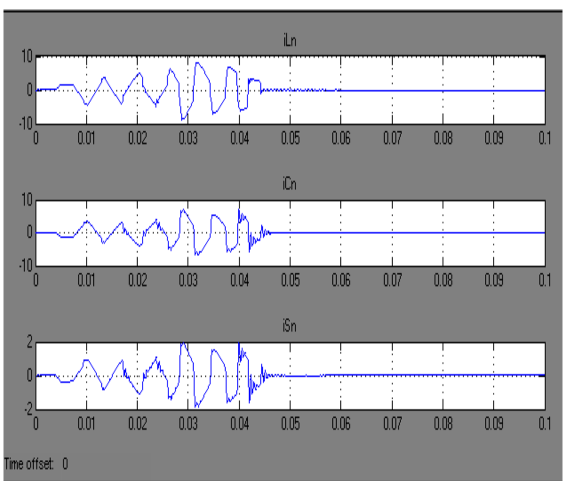


Fig 21: Simulation with Non-Linear Load

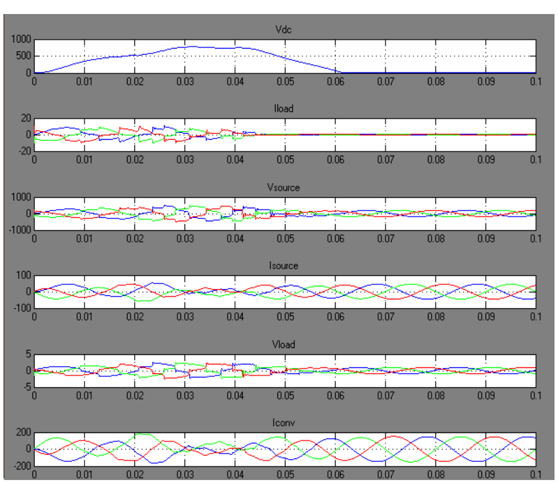


Fig 22: Source voltages and currents, Load currents versus time (secs)

b. WITH Induction motor LOAD

No. of switches used : Not MLI
DC capacitance Voltage: 3000e-6 Farads
Coupling inductor **:** 5.5e-3 Henry
Modulation index : 0.4
Power factor : 0.7
THD **:** 0.62 %

Induction motor parameters:
Torque as mechanical Input = 300N-m
Squirrel cage IM
Stationary Reference Frame
Stator resistance = 0.435
Stator inductance = 0.002
Rotor Resistance = 0.816
Rotor Inductance = 0.002
Mutual Inducatance = 69.31 mH
J = 0.089
F = 0.005
P = 2

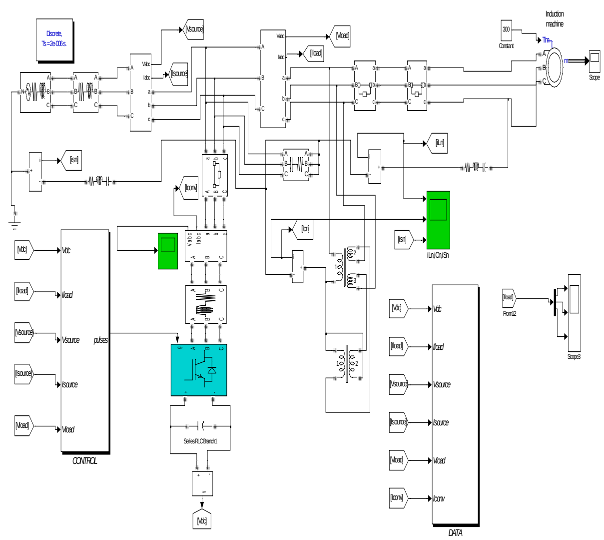


Fig 23: Simulation Model with Induction Motor

Load currents	Linear Load	Non-Linear Load	Induction motor
THD	0.55	0.82	0.62

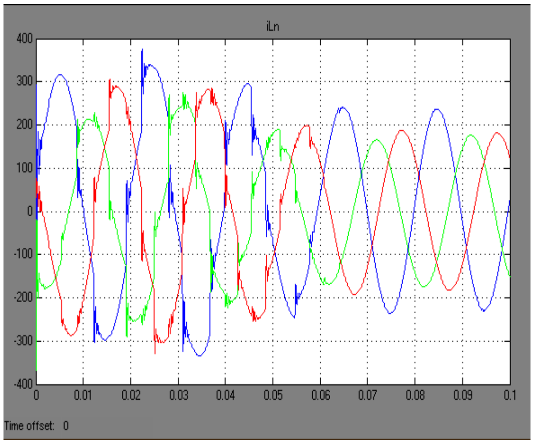


Fig 24: Neutralizing currents versus time (secs)

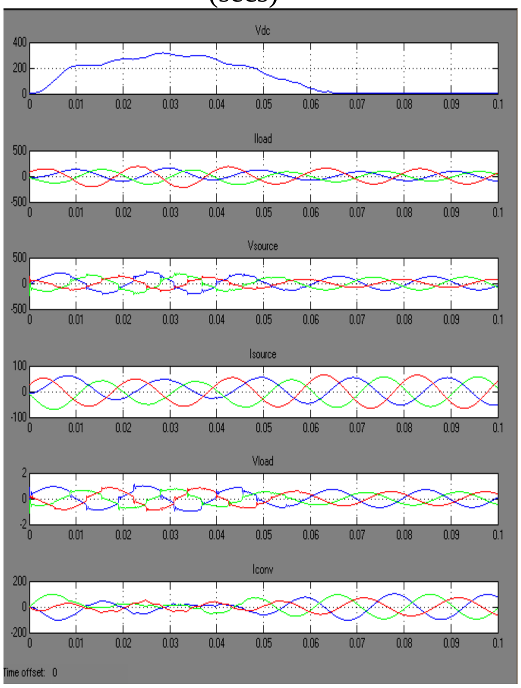


Fig 25: Source voltages and currents, Load currents versus time (secs)

SIMULATION RESULTS WITH ZIG-ZAG LINEAR LOAD:

No. of switches used : Not MLI
DC capacitance Voltage: 3000e-6 Farads
Coupling inductor : 5.5e-3 Henry
Modulation index : 0.4
Power factor : 0.7
THD : 0.63 %

<u>Load Improvements:</u>

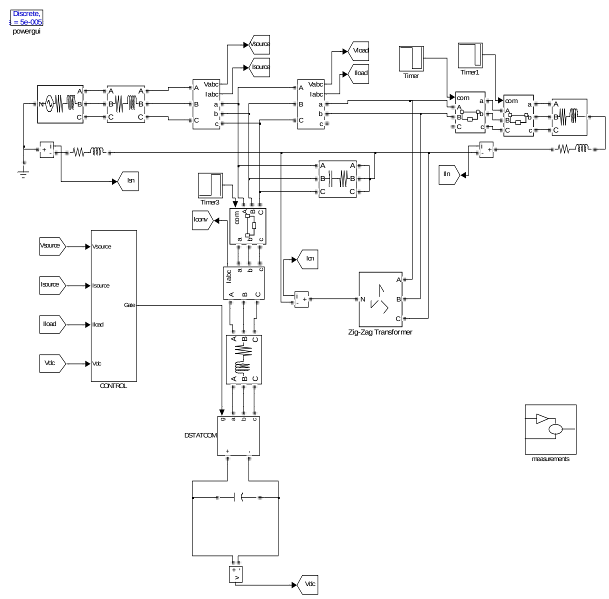
$P = 10e^3$

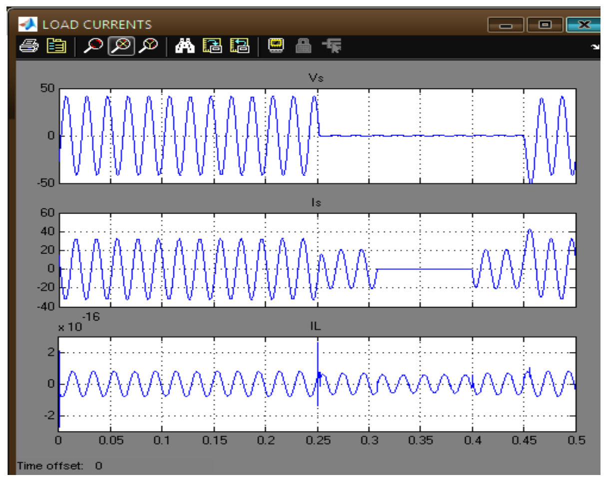
$Q_L = 20e^3$

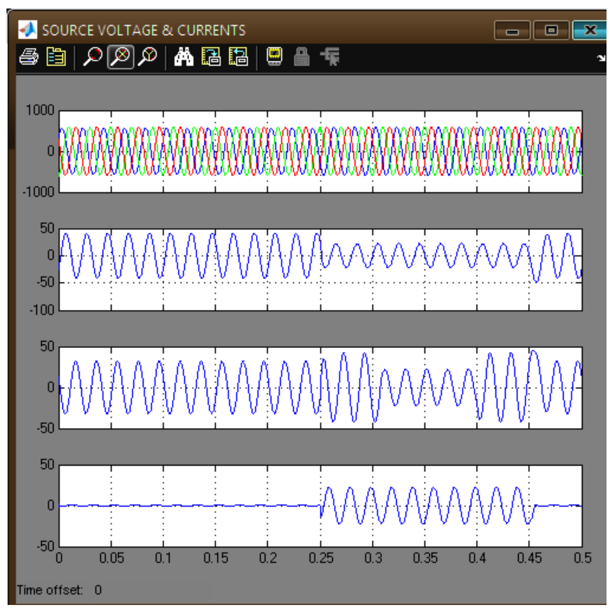
$Q_c = 0$

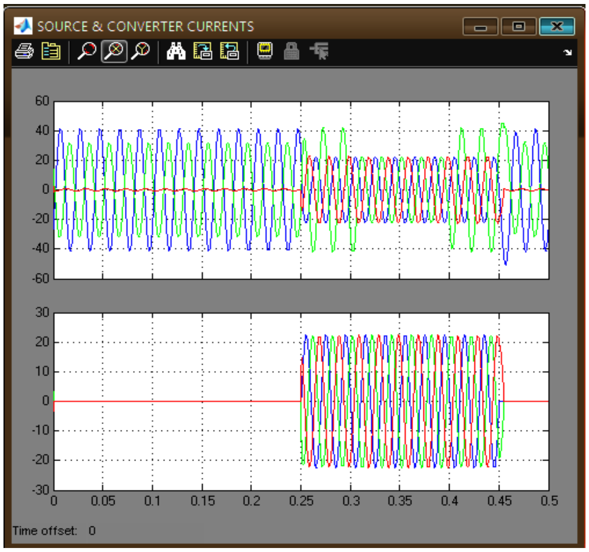
$R = 1\Omega$

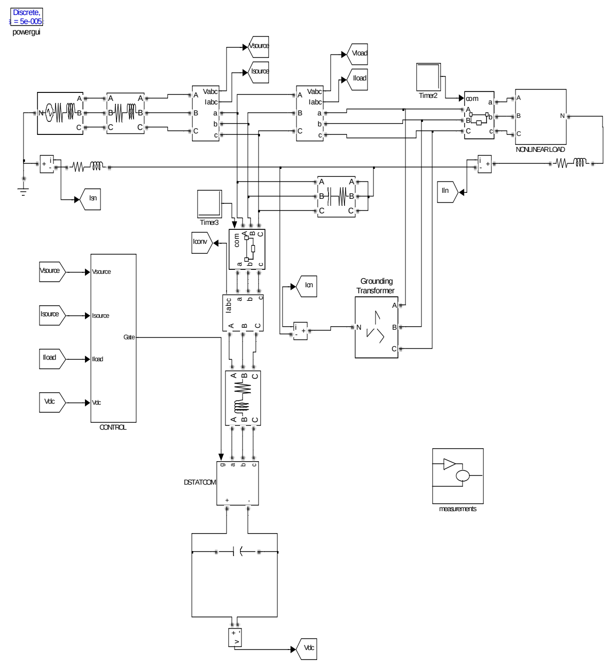
L = 1mH

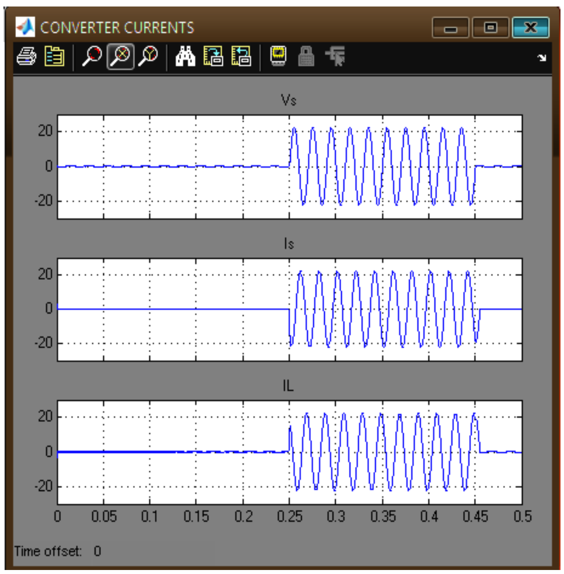






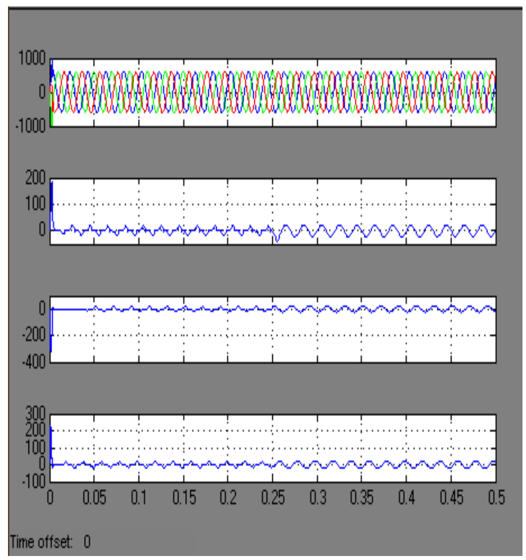


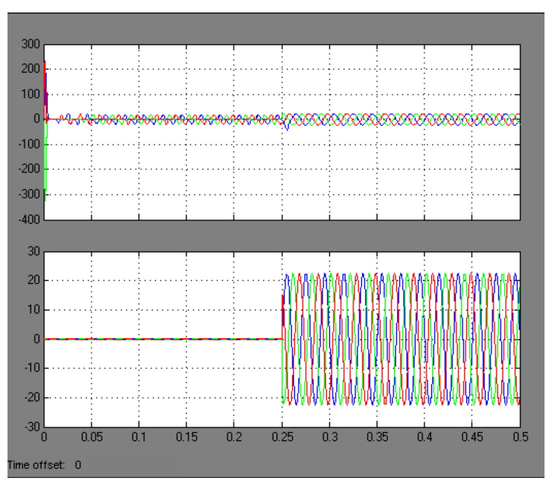


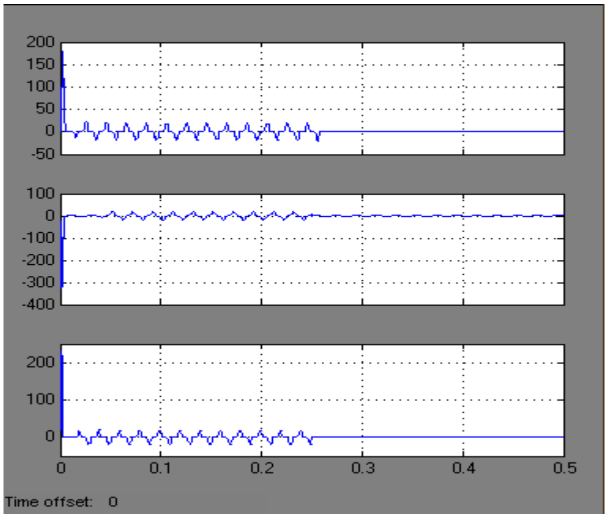


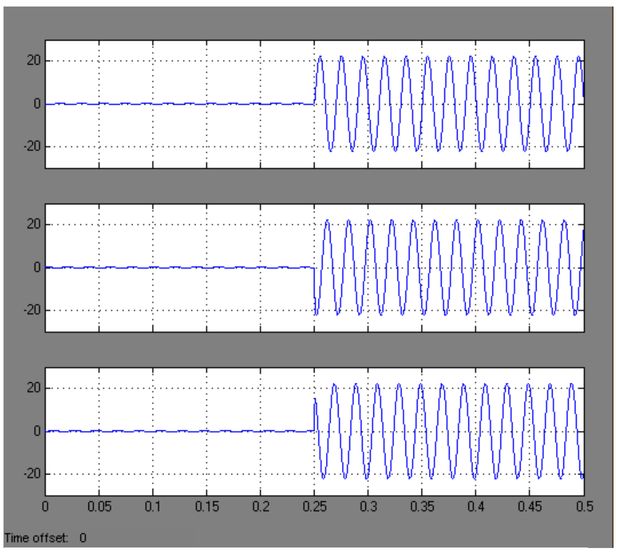
NON-LINEAR LOAD:

No. of switches used : Not MLI
DC capacitance Voltage: 3000e-6 Farads
Coupling inductor : 5.5e-3 Henry
Modulation index : 0.4
Power factor : 0.7
THD : 0.11 %
Non-Linear Load parameters:
Diode Bridge (2 arms)
Snubber Resistance: 1000 ohms
Snubber capacitance: 3000 F
ON resistance: 1e-3 ohm
R = 50 ohms
C = 1000e-6 F

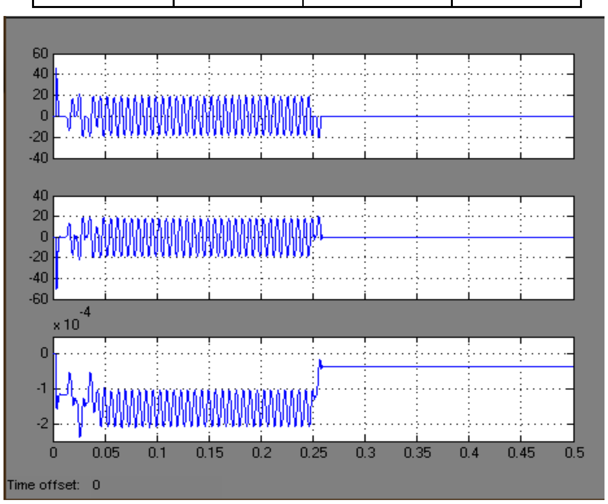








Load currents	Linear Load	Non-Linear Load	Induction motor
THD	0.63	0.11	0.82

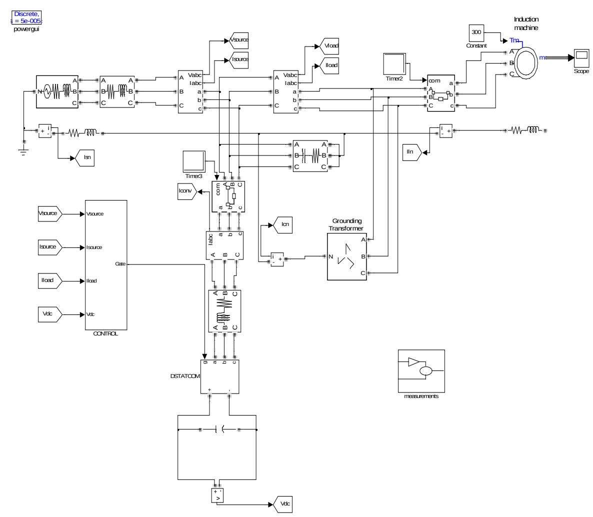


WITH Induction motor LOAD

No. of switches used : Not MLI
DC capacitance Voltage: 3000e-6 Farads
Coupling inductor : 5.5e-3 Henry
Modulation index : 0.4
Power factor : 0.7
THD : 0.82 %

Induction motor parameters:

Torque as mechanical Input = 300N-m
Squirrel cage IM
Stationary Reference Frame
Stator resistance = 0.435
Stator inductance = 0.002
Rotor Resistance = 0.816
Rotor Inductance = 0.002
Mutual Inducatance = 69.31 mH
J = 0.089
F = 0.005
P = 2



FINAL RESULTS FOR ALL MODELS:

Load currents (THD)	Linear Load	Non-Linear Load	Induction motor
Star-delta	4.43	6.63	3.32
T-connected	**0.55**	0.82	**0.62**
Zig-Zag	0.63	**0.11**	0.82

Analysis:

- For T-connected connected DSTATCOM has less THD value when compared with other transformer connections in linear load.
- For Zig-Zag connected DSTATCOM has less THD value when compared with other transformer connected in Non-linear load.
- For T-connected connected DSTATCOM has less THD value when compared with other transformer connected in Induction Motor.
- For Zig-Zag connected DSTATCOM has less THD value when compared with other transformer connected in Non-linear load.

VI. CONCLUSION

This paper has presented the power quality problem which mitigates total harmonic distortion, voltage variations in the distribution system and simulation technique of a D-STATCOM. The simulation results with different transformer connections shows that the total harmonic distortion reduced and also power factor improved and close to unity.

VII. REFERENCES

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