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Power Quality Improvement Using Distribution Static Compensator (D-STATCOM)

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Abstract: **- Today, there is an increased demand among the consumers both domestic and industrial for the high quality and reliable power supply which has led to an increased awareness of power quality. Power quality is an occurrence of a non-standard voltage, current or frequency resulting in a failure or mis-operation of consumer end equipment. The various power quality issues are voltage sag/swell, harmonic distortion ,voltage fluctuation and low power factor. FACTS devices are used to solve power quality problems. D-STATCOM (Distribution Static Compensator) is one such type of FACTS device used to compensate or mitigate the power quality problems.**

This paper presents the MATLAB simulation model of D-SATCOM mitigating the power quality problem. The MATLAB version used is R2010.

***Keywords*—— Power quality, FACTS device, D-STATCOM**

I. INTRODUCTION

Until 1990s, the consumers were not concerned about the quality of electricity. The deregulation of power sector in 1990s created awareness among the consumers and from then the industries and domestic consumers realized the importance of good quality electricity. The problem in electricity power sector delivery is not limited to only energy efficiency and environment but more importantly on power quality and supply quality. The definition of electric power quality is different to different people. According to IEEE 519 standard power quality is "the concept of powering and grounding any discerning electronic equipment in a way suitable to that equipment". Some of the commonly encountered power quality issues are harmonics, voltage sag/swell, voltage fluctuations, etc. The modern power distribution system is constantly being challenged with an ever-growing demand in the load. Loads at various distribution ends like computers, process industries, adjustable speed drives, printers, and microprocessor based equipment etc. become intolerant to voltage fluctuations, harmonic content and interruptions. Therefore, there is a need to mitigate these power quality issues.

The conventional methods involved- installing capacitor banks or parallel feeders or using uninterruptible power supplies (UPS). However, these were not able to cater to the problems of all problems related to power quality due to uncontrollable reactive power compensation and high costs of feeders and UPS. Therefore, FACTS devices came into existence for the mitigation of these problems. Distribution Static Compensator (D-STATCOM) is one such device which takes care of various power quality issues like voltage sag/swell, harmonics and improvement of power factor due to harmonics. The DSTATCOM is a shunt-connected device, which can mitigate the current related power quality problems. The control algorithm used for generating the switching signals for the voltage source converter decides the effectiveness of D-STATCOM. For the control of DSTATCOM, many control algorithms have been reported in the literature based on the instantaneous reactive power theory, deadbeat or predictive control (Fuchs and Mausoum, 2008), instantaneous symmetrical component theory (Ghosh and Ledwich, 2009), nonlinear control technique (Rahmani et al, 2010), modified power balance theory(Singh and Kumar, 2010), enhanced phase locked loop technique (Sharma and Singh, 2011), addaline control technique, synchronous reference frame control technique (Singh and Solanki, 2009), ANN and fuzzy based controller, SVM based controller (Teke et al, 2011), correlation and cross-correlation coefficients based control algorithm (Tanaka 75 Singh and Arya / International Journal of Engineering, Science and Technology, Vol. 4, No. 1, 2012, pp. 74-86 et al, 2007) etc. Other techniques applied in active filters are based on Hilbert transform (Wetula, 2008), soft phase locked loop (Wu et al, 2007) and novel hysteresis current controller (Zeng et al, 2010) etc. In this paper, the SIMULINK model representing the application of PI controller with D-STATCOM for reducing the harmonic distortion of the distribution network with Non Linear load is presented.

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D-STATCOM

A. Basic Configuration

D-STATCOM is a compensating device which is connected in shunt with the distribution system. Proper adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Fig. 1 shows the schematic representation of D-STATCOM connected to ac mains. A voltage source converter (VSC) produces three phase ac voltage of desired magnitude and depending upon the compensation requirement. The energy storage includes battery storage or capacitors which provides the dc voltage which is converted into the three phase ac voltage. Line filters helps in eliminating harmonics present in the output of the VSC. Coupling transformer helps in connecting the D-STATCOM to the ac mains. And the control scheme helps in generating pulses which drives the VSC to give the desired ac voltage to be injected into the system.

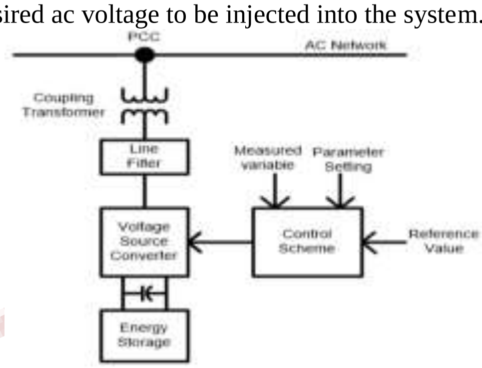

Fig. 1 Schematic representation of D-STATCOM

B. Principle of Operation

The principle of operation of D-STATCOM is similar to that of synchronous condensers. A voltage source converter produce a set of three phase voltages, V_i which is in phase with the system voltage, V_s. When $V_s = V_i$, the reactive current is zero, and therefore, no exchange of reactive power (Fig. 2(a)). When $V_i > V_s$, leading current is produced which generates capacitive reactive power (Fig. 2(b)). And when $V_i < V_s$, lagging current is produced and as a result inductive reactive power is produced (Fig. 2(c))

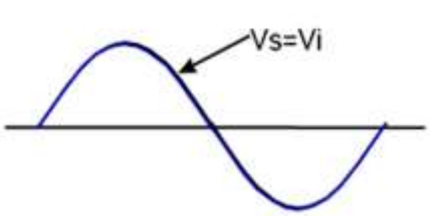

Fig. 2(a) No load Operation

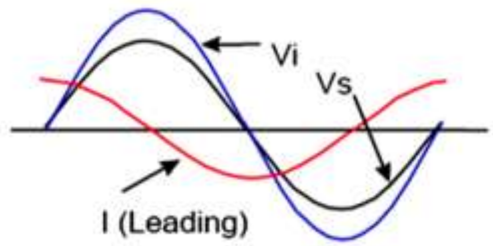

Fig. 2(b) Capacitive Operation

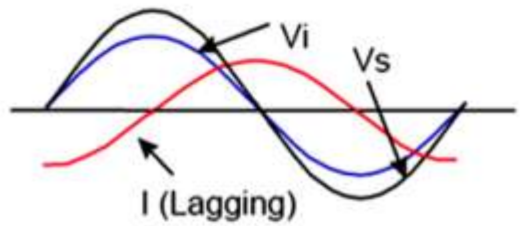

Fig. 2(c) Inductive Operation

II. CONTROL STRATEGY

A unit template or PI- controller based algorithm is used for controlling DSTATCOM. This control algorithm provides a self-supporting DC bus of the VSC used as a DSTATCOM. For this, three-phase reference supply currents are derived using sensed AC voltages (at PCC) and DC bus voltage of the DSTATCOM as feedback signals. Two PI voltage controllers are used, one to regulate the DC bus of the VSC used as a DSTATCOM and other to regulate amplitude of the PCC voltages, are used to estimate the amplitudes of in-phase and quadrature components of reference supply currents. Fig. 3 shows the control strategy block diagram used.

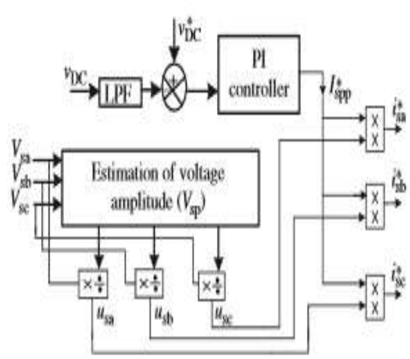

Fig. 3 Control algorithm of DSTATCOM with PI controller

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III. SIMULATION MODEL

The simulation model of the system is shown in Fig. 4. An unbalanced linear load is connected to the source and non-linear load is connected in the system which is switched on at 0.3sec instant. The DSTATCOM is connected in the system at 0.5 sec. The system parameters are given in the Table 1.

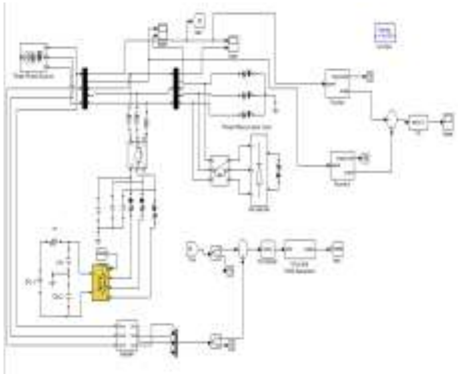

Fig. 4 Simulink model of the Test System

Table 1. Simulation Parameters

Sr. No.	System Quantities	Values
1	Source voltage	400 V RMS line to line, 50 Hz
2	Feeder Impedance	1+ 3.14*j*Ω
3	Linear Load	Z_{la} = 30+ 62.8*j* Ω Z_{lb} = 40+ 75.8*j* Ω Z_{lc} = 50+ 50.24*j*Ω
4	Non Linear Load	An R-L load of 50+62.8jΩ
5	VSI Parameters	V_{DC} = 650V, C_{DC} = 2600µF, L_f = 220 mH, C_f = 140µF, R_f = 20 Ω

IV. SIMULATION RESULTS

a. Harmonics Mitigation In Source Current

Fig. 5 shows the waveform of the source current versus time from t= 0sec to t=1 sec. From 0sec to 0.3 sec, the unbalanced linear load is connected in the system as a result the source current is not balanced and the magnitude is also very low as shown in Fig. 6. At t= 0.3 sec, the linear load is switched on till t= 1 sec. As a result harmonics get injected into the source current and therefore the waveforms get distorted, shown in Fig. 7. At t= 0.5 sec, D-STATCOM is switched on and it balances the three phase source current and also increases the magnitude of it, shown in Fig. 8. The harmonics get almost eliminated from the source current.

Total Harmonic Distortion (THD) analysis before and after D-STATCOM in the system is shown in Fig. 9 and 10 respectively. It is seen that with the insertion of D-STATCOM in the system at t=0.5 sec, the THD improves from 15.36% to 4.92% which is an acceptable content of THD in the current.

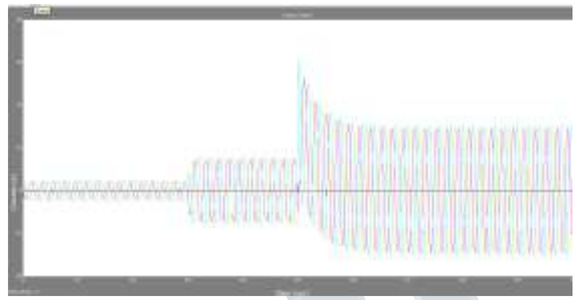

Fig. 5 Waveform of Source Current (Amp) v/s time (sec)

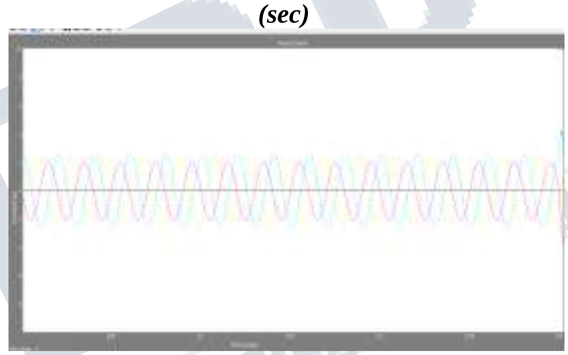

Fig. 6 Source current at t=0sec to t= 0.3sec

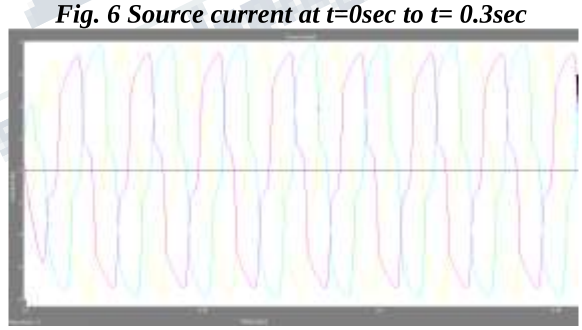

Fig. 7 Source current when non-linear load switched at t= 0.3sec

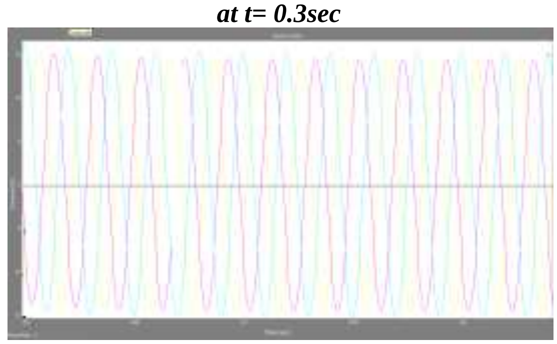

Fig. 8 Source current when D-STATCOM switched at t= 0.5sec

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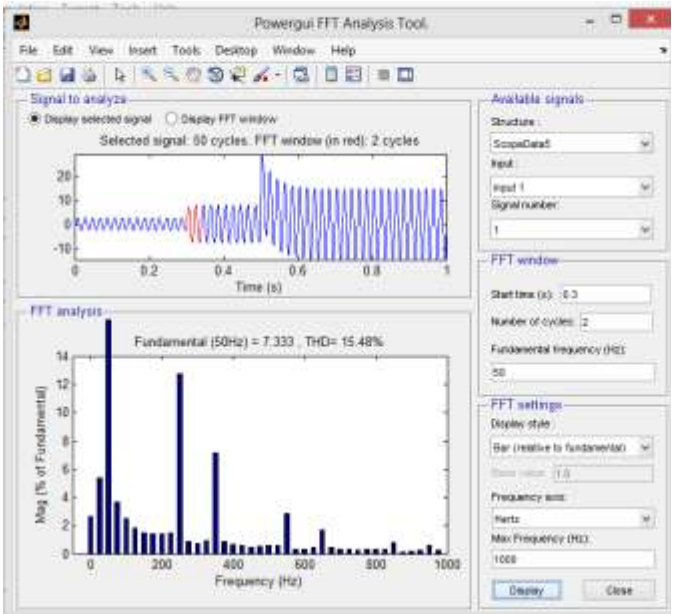

Fig. 9 THD Analysis with Non-Linear Load and NO D-STATCOM

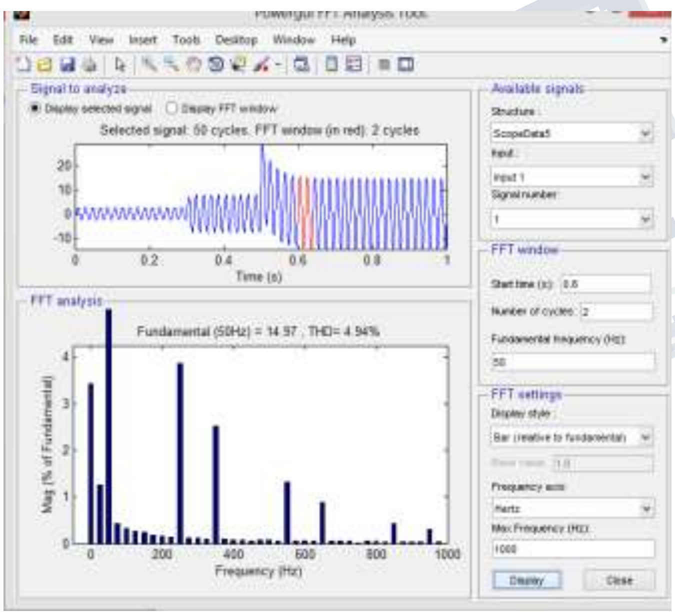

Fig. 10 THD Analysis with Non-linear load and with D-STATCOM

b. Power Factor Improvement

Fig. 10 shows the improvement in the power factor with D-STATCOM. The power factor was very less approx. 0.4 which is not acceptable but with the switching on the device, the power factor has reached almost unity i.e 0.96.

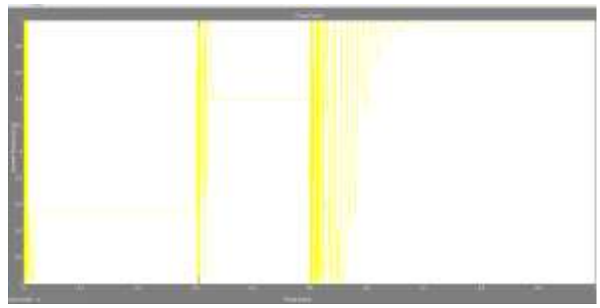

Fig. 11 Power Factor improvement using D-STATCOM

V. CONCLUSION

In this paper, a FACTS device i.e., D-STATCOM is designed for mitigating the power quality issues. The device is used to compensate for the harmonics in the source current and also the power factor improvement. The simulation results show that this device is capable to solve the quality related issues. The device is used in the unity power factor mode (UPF) to solve current related problems. However, with proper adjustments in the design and controlling methods it can be made to work with the advantages of both UPF mode and zero voltage regulation (ZVR) mode.

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