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Improve Power Factor and Reduce the Harmonics Distortion of the System

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Abstract

This paper discusses the improve power factor and reduce the harmonics distortion of system. Poor power factor costs our community in increased electricity charges and unnecessary effect in the system and poor power quality. In electrical plants the loads draw from the network electric power (active) as power supply source (e.g. personal computers, printers, etc.) or convert it into another form of energy (e.g. electrical lamps or stoves) or into mechanical output (e.g. electrical motors) or rectifier. To smooth such negative effect, the power factor correction of the electrical plants is carried out. The power factor correction obtained by using power factor correction switches banks to generate locally the reactive energy necessary for the transfer of electrical useful power, allows a better and more rational technical-economical management of the plants. The system is capable of correcting power factor up to unity or adjusting it according to user desire. The proposed system is characterized by, no generation of harmonics, and reduction of transmission losses. Simulation results are reported and proved to be in good agreement with the relevant experimental results.

Keywords: Harmonics, power quality, power factor correction, MATLAB.

Introduction

The power factor of an AC electrical power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit and is a dimensionless number between 0 and 1. Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power will be greater than the real power. In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers where there is a low power factor[1].

Power factor improvement leads to a big reduction of apparent power drawn from the ac source which in turn saves energy and minimizes the transmission losses. It generally employs means that control reactive power in power system network. The process is usually denoted by reactive power compensation which is a productive technology employed for improving power systems performance. In recent years, the demand for controllable reactive power source has gone up mainly for efficient and reliable operation of ac electric power system. VAR compensators should be controlled to provide rapid and continuous reactive power supports during static and dynamic power system operating conditions [2]. Power quality problem is an occur as a non-standard voltage, current and frequency. The power quality has serious economic implications for customers, utilities and electrical equipment manufacturers. Advances in power electronics technology have allowed the development of various types of controlled electronics VAR compensator for power system applications, but power factor correction switches are the most reliable ones. Since they present high flexibility in design methodology and exhibit reasonable response amongst fast varying environments. By connecting power factor correction switch it also improves power quality.

Causes of transients and spikes: i. Non– linear loads, ii. power electronic devices, IT and office equipments, iv. arcing devices, v. load switching, vi. large motor starting. vii. Larger capacitor bank energies.

Problem associated with power quality: Transients: These are undesirable but decay with time and hence not a steady state problem. A broad definition is that a transient is that part of the change in a variable that disappears during transition from one steady state operating condition to the other. Another synonymous term is surge.

Transients are classified into two categories: i. Impulsive, ii. Oscillatory.

Long Duration Voltage Variations: When RMS (root mean square) deviations at power frequency last longer than one minute, we say they are long duration voltage variations. They can be either over voltages (greater than 1.1 p.u.) or under voltages (less than 0.9 p. u.). Over voltages is usually the result of switching a load or energizing a capacitor bank. Incorrect tap settings on transformers can also result in over voltages. Under voltages are the result of events which are the reverse of events that cause over voltages switching in a load or switching of a capacitor bank.

Voltage Fluctuations and Flicker: Voltage fluctuations are systematic variations of the voltage envelope or a series of random changes in the voltage magnitude (which lies in the range of 0.9 to 1.1 p. u.) High power loads that draw fluctuating current, such as large motor drives and arc furnaces, cause low frequency cyclic voltage variations that result in flickering of light sources (incandescent and fluorescent lamps) which can cause significant physiological discomfort or irritation in human beings[3]. The voltage flicker can also stable operation of electrical and electronic devices such as motors and CRT devices. The typical frequency spectrum of voltage flicker lies in the range from 1 Hz to 30 Hz.

Waveform Distortion: This is defined as a steady-state deviation from an ideal sine wave of power frequency. There are five types of waveform distortion: i. DC offset, ii. Harmonics, iii. Inter harmonics, iv. Notching, v. Noise.

The presence of DC voltage or current in AC power systems is termed as DC offset. This can occur as the result of a geomagnetic disturbance or ground return operating mode in mono polar HVDC links. The DC current flow in transformers causes magnetic saturation, increased heating and loss of transformer life. Nonlinear loads and power electronic controllers are the primary source of harmonics. Fourier analysis can be used to characterize harmonic distortion. Total Harmonic Distortion (THD) is one of the most commonly used measures for harmonics[3].

Major problems that arise from harmonic distortion are: i. Extra losses and heating in rotating machines and capacitors, ii. Over voltages due to resonance, iii. Interference with ripple control systems used in Demand Side Management (DSM), iv. Telephone interference caused by noise on telephone lines.

Research Methodology

Power factor correction in non-linear loads: Passive PFC: The simplest way to control the harmonic current is to use a filter: it is possible to design a filter that passes current only at line frequency (50 or 60 Hz)This filter reduces the harmonic current, which means that the non-linear device now looks like a linear load. At this point the power factor can be brought to near unity, using capacitors or inductors as required. This filter requires large-value high-current inductors, however, which are bulky and expensive. A passive PFC requires an inductor larger than the inductor in an active PFC, but costs less. This is a simple way of correcting the nonlinearity of a load by using capacitor banks. It is not as effective as active PFC[4].

Passive PFCs are typically more power efficient than active PFCs. Efficiency is not to be confused with the PFC, though many computer hardware reviews conflate them. A passive PFC on a switching computer PSU has a typical power efficiency of around 96%, while an active PFC has a typical efficiency of about 94%.

Active PFC: An "active power factor corrector" (active PFC) is a power electronic system that changes the wave shape of current drawn by a load to improve the power factor. The purpose is to make the load circuitry that is power factor corrected appear purely resistive (apparent power equal to real power) In this case, the voltage and current are in phase and the reactive power consumption is zero. This enables the most efficient delivery of electrical power from the power company to the consumer[4]. Some types of active PFC are: i. Boost, ii. Buck, iii. Buck-boost

Solutions to improve power factor problems and reduce harmonics distortion: To achieve improve power factor is to use power factor correction switch connected at the near load terminals. The challenge is to improve power factor and any harmonic distortion is reduced to an acceptable level. This paper introduces power factor correction and harmonics reduction. At the end MATLAB SIMULINK model based simulated results were presented to validate the effectiveness of the proposed control method of power factor correction switch.

Importance of power factor in distribution system: Power factors below 1.0 require a utility to generate more than the minimum volt-amperes necessary to supply the real power (watts). This increases generation and transmission costs. For example, if the load power factor were as low as 0.7, the apparent power would be 1.4 times the real power used by the load. Line current in the circuit would also be 1.4 times the current required at 1.0 power factor, so the losses in the circuit would be doubled (since they are proportional to the square of the current). Alternatively all components of the system such as generators, conductors, transformers, and switchgear would be increased in size (and cost) to carry the extra current[5].

Utilities typically charge additional costs to customers who have a power factor below some limit, which is typically 0.9 to 0.95. Engineers are often interested in the power factor of a load as one of the factors that affect the efficiency of power transmission. With the rising cost of energy and concerns over the efficient delivery of power, active PFC has become more common in consumer electronics[6].

Technical advantages of power factor correction: By correcting the power factor of an installation supplying locally the necessary reactive power, at the same level of required output power, it is possible to reduce the current value and consequently the total power absorbed on the load side; this implies numerous advantages, among which a better utilization of electrical machines (generators and transformers) and of electrical lines (transmission and distribution lines).

Better utilization of electrical machines: Generators and transformers are sized according to the apparent power S. At the same active power P, the smaller the reactive power Q to be delivered, the smaller the apparent power. Thus, by improving the power factor of the installation, these machines can be sized for a lower apparent power, but still deliver the same active power.

Better utilization of electrical lines: Power factor correction allows obtaining advantages also for cable sizing. In fact, as previously said, at the same output power, by increasing the power factor the current diminishes. This reduction in current can be such as to allow the choice of conductors with lower cross sectional area.

Reduction of losses: The power losses of an electric conductor depend on the resistance of the conductor itself and on the square of the current flowing through it; since, with the same value of transmitted active power, the higher the power factor the lower the current, it follows that when the power factor rises, the losses in the conductor on the supply side of the point where the power factor correction has been carried out will decrease.

Economic advantages of power factor correction: Power supply authorities apply a tariff system which imposes penalties on the drawing of energy with a monthly average power factor lower than 0.9. The contracts applied are different from country to country and can vary also according to the typology of costumer: as a consequence, the following remarks are to be considered as a mere didactic and indicative information aimed at showing the economic saving which can be obtained thanks to the power factor correction. Generally speaking, the power supply contractual clauses require the payment of the absorbed reactive energy when the power factor is included in the range from 0.7 and 0.9, whereas nothing is due if it is higher than 0.9. For power factor is less than 0.7 power supply authorities can oblige.

Consumers to carry out power factor correction. It is to be noted that having a monthly average power factor higher than or equal to 0.9 means requesting from the network a reactive energy lower than or equal to 50% of the active energy: Therefore no penalties are applied if the requirements for reactive energy do not exceed 50% of the active one. The cost that the consumer bears on a yearly base when drawing a reactive energy exceeding that corresponding to a power factor equal to 0.9.

General Advantage of Power Factor: i. Decreased monthly energy costs, ii. Efficient electrical system, iii. Reduced loading on transformers, iv. Reduced loading on distribution lines, v. Reduced voltage drops, vi. Reduced wear and tear on electrical equipment, vii. Increased load handling capability of the plants electrical system.

Disadvantage of Low Power Factor: i. Increased energy costs, ii. Overloaded transformers, iii. Overloaded distribution lines, iv. Resulting in voltage drops and needless wear and tear on electrical equipment, v. Reduced load handling capability of the plants electrical system.

Results and Discussion

In simulink model figure 1 shows the harmonics is generated in the system using six pulse converter connected to the main drive non linear load. The percentage of total harmonic distortion in the main drive load side is, in phase 1 11.29%, in phase 2 15.95%, in phase 3 16.70%. In figure 1 MATLAB simulation is carried out with power factor correction technique.

The percentage of total harmonic distortion in the main drive load side is, in phase 1 0.00%, in phase 2 0.00%, in phase 3 0.00%. The simulation results show that the harmonics in the main drive load side is neglected. The harmonics distortions produced in all the three phases is shown using FFT analysis in figure 2.

The simulation results carried out with Power factor correction switch generated harmonics are reduced. The reduced harmonics distortions in all the three phases is shown using FFT analysis in figure 3.

The following tables show the simulation result carried out with and without using Power factor correction switch in Mitigating harmonics[7].

Table-1
System Parameters

S.No	System Quantities	Standards
1.	Supply Voltage	230V/ph
2.	Source Impedance	Ls=0.005mH, Rs=0.001 ohm
3.	Main Load	Active power=1 MW, Reactive power= 100 VAR
4.	Frequency	50Hz

Table-2
Total Harmonics Distortion – Before Power Factor Correction Switch

Sr. no.	Phase	THD %
1.	Phase1	11.29%
2.	Phase2	15.95%
3.	Phase3	16.70%

Table-3
Total Harmonics Distortion – After Power Factor Correction Switch

Sr. no.	Phase	THD%
1.	Phase1	0.00%
2.	Phase2	0.00%
3.	Phase3	0.00%

Table-4
Power Factor – Before Power Factor Correction Switch

S.No	Power Factor
1.	0.25

Table-5
Power Factor – After Power Factor Correction Switch

S.No	Power Factor
Table-1	**System Parameters**

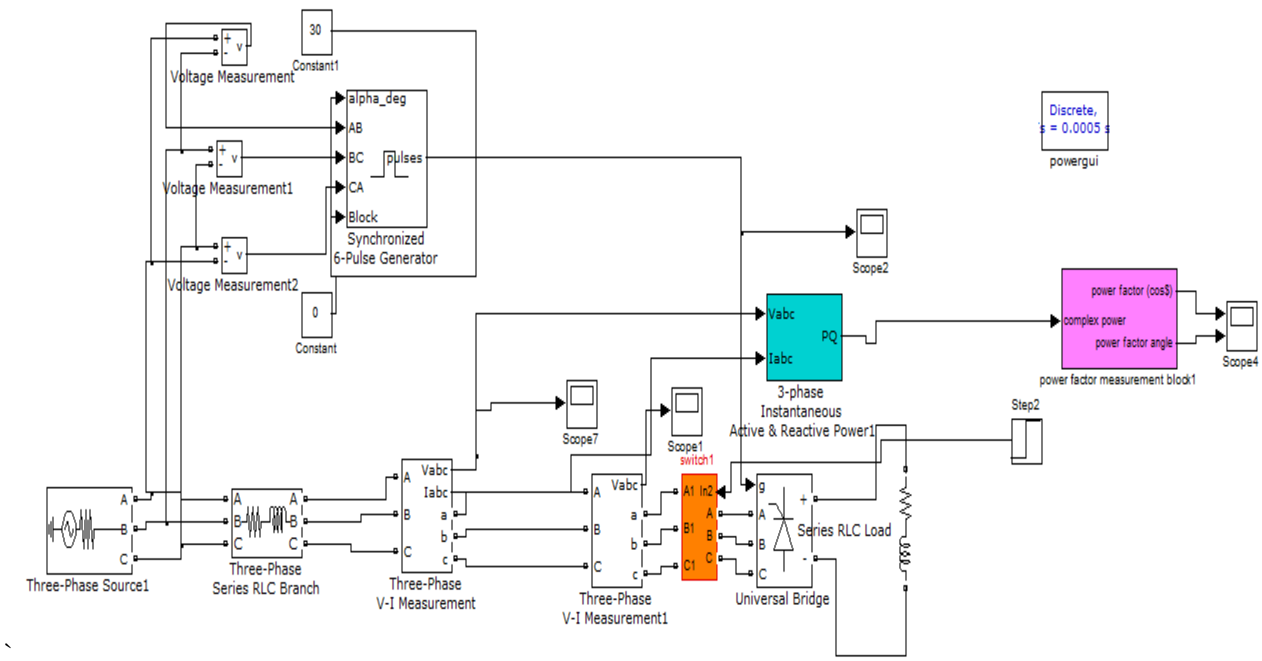

Figure-1
Simulation model

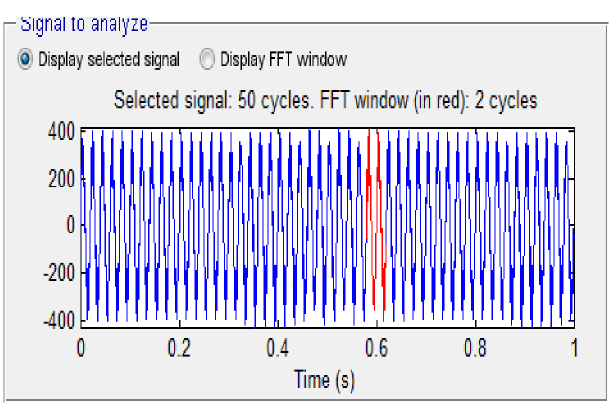

Figure-2a
Output of phase 1 harmonics without Power factor correction switch

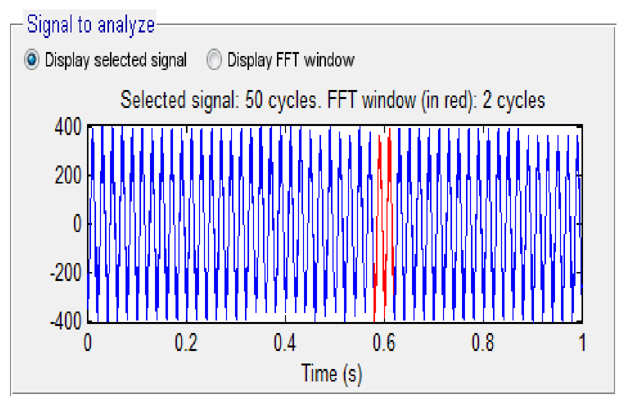

Figure-2c
Output of phase2 harmonics without Power factor correction switch

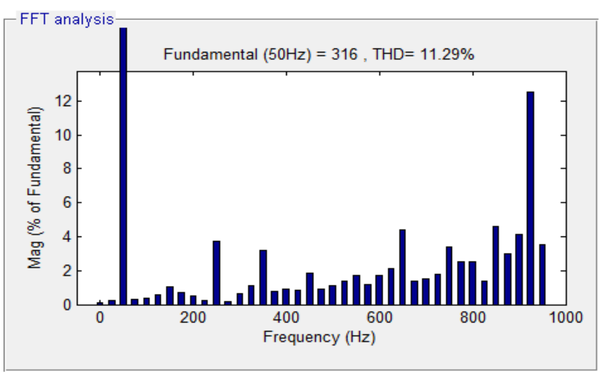

Figure-2b
THD in harmonics order in phase1 without Power factor correction switch

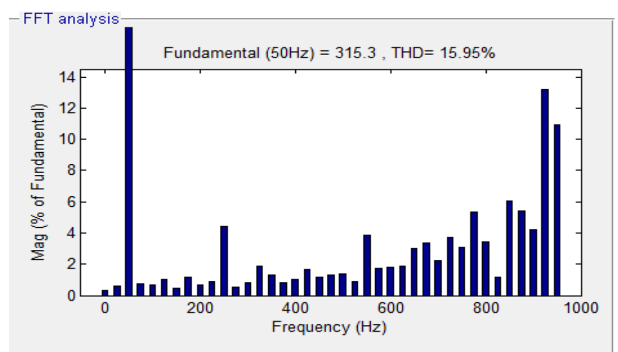

Figure-2d
THD in harmonics order in phase 2 without Power factor correction switch

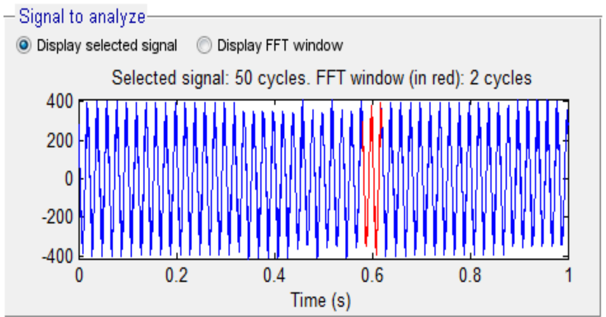

Figure-2e
Output of phase3 harmonics without Power factor correction switch

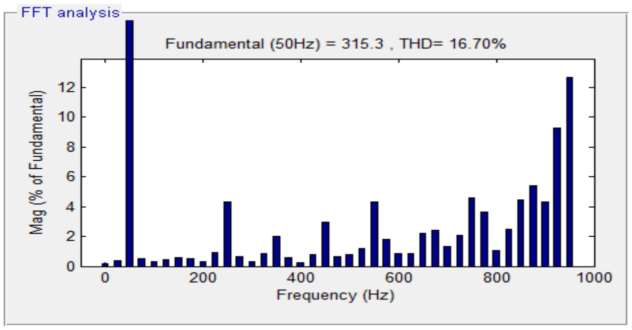

Figure-2f
THD in harmonics order in phase3 without Power factor correction switch

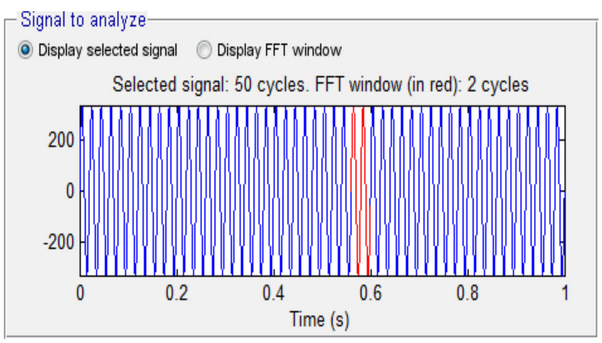

Figure-3a
Output of phase1 harmonics with Power factor correction switch

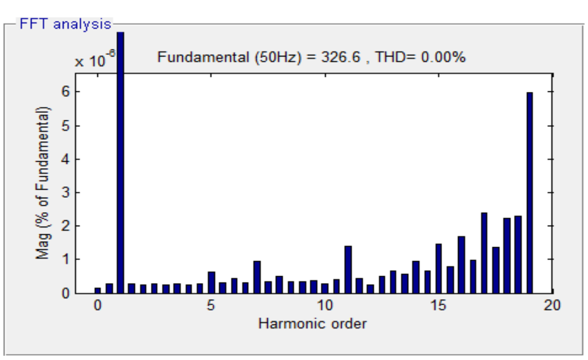

Figure-3b
THD in harmonics order in phase1 with Power factor correction switch

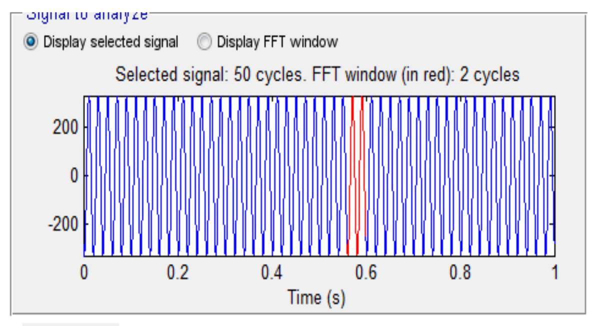

Figure-3c
Output of phase2 harmonics with Power factor correction switch

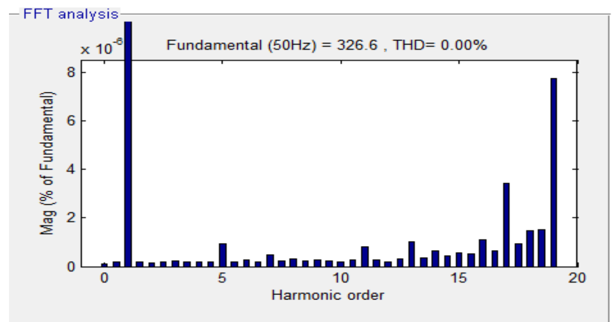

Figure-3d
THD in harmonics order in phase2 with Power factor correction switch

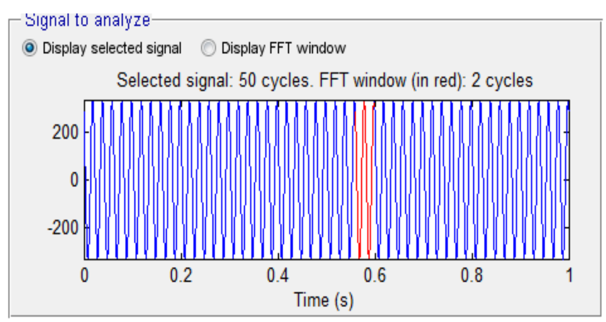

Figure-3e
Output of phase3 harmonics with Power factor correction switch

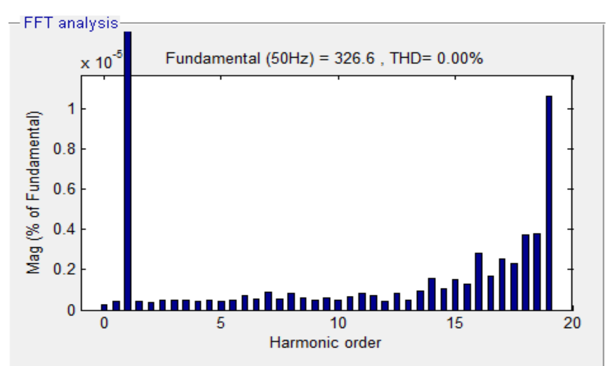

Figure-3f
THD in harmonics order in phase 3 with Power factor correction switch

Conclusion

The proposed single-phase and three-phase automatic power factor correction systems have certain reactive current or reactive power ratings. When the detected reactive power absorbed by the load is greater than the compensator rating, the power factor will not be corrected to unity, but certainly will be improved and the apparent power supplied by the ac supply will be reduced. These systems respond almost linearly throughout their pre-assigned areas of operation. They achieve better power quality by reducing the apparent power drawn from the ac supply and minimizing the power transmission losses. In addition, no harmonics disturbing the power system network are released, and hence no filtering is required. The proposed system performs better than the traditional methods in mitigating harmonics and power factor improvement.

References

1. Rashid M., Power electronics handbook, Academic Press **(2001)**
2. Miller T.J., Reactive power Control in Electric Systems, John Willey & Sons **(1982)**
3. Roger C. Dugan, Mark F. Mcgranaghan, Surya Santos and H. Wayne Beaty, Electrical power system Quality, Tata McGraw Hills publications **(2002)**
4. Wikipedia **(2012)**
5. Walker L Force-commutated reactive power compensator, *IEEE t Ind. Appl., IA-22*, 1091-1104 **(1986)**
6. Gyugy L., Otto R.A. and Putman T.H., Principles and applications of static, thyristor-controlled shunt compensators, *IEEE t Power Appl. Syst., PAS-97*, 1935-1945 **(1978)**
7. Sadaiappan S., Modelling and simulation of series compensator to mitigate power quality problem, *IJEST*, **2(12),** 7385-7394 **(2010)**