Power Quality Improvement Using Facts Device (STATCOM)

Yashoda A. Kale, Sandip S. Rathod, Ganesh D. Shingade
Shreeyash College of Engineering & Technology, Aurangabad Maharashtra
Corresponding author's email id: *yashodaakale@gmail.com **
DOI: *http://doi.org/10.5281/zenodo.2638726*

Abstract

Power quality defines the fitness of electric power to consumer devices i.e. Synchronization of the voltage frequency and phase allow electrical system to function without any significant loss in performance. In distribution system the distribution networks and sensitive industrial loads are suffering from different type of outage and interruption which can lead to loss in production and other measurable and non-measurable factor. The factors that are affecting power quality are voltage sag, voltage variation, interruption, swells, brownout, distortions, Harmonic, noise, voltage spikes, voltage flicker etc. This causes some deviations in the power when compared with the normal standards. The above problems may overcome by using compensation devices (custom power devices) either compensate load i.e. correct its power factor, unbalance etc. or improve the quality of the supply voltage. These devices include static compensator (STATCOM), Dynamic voltage restorer (DVR), and unified power quality compensator (UPQC) to obtain Better performance which is simulated by using mat lab.

Keywords: *STATCOM, Dynamic voltage restorer (DVR), Unified power quality compensator (UPQC), Voltage, Power quality*

INTRODUCTION

Now a days due to increased power quality problems by using of switch off/on introduction loads, nonlinear load and induction motor etc in domestic and industries, power-quality (PQ) problems,

Page 27-38 © MANTECH PUBLICATIONS 2019. All Rights

such as harmonics, flicker, and imbalance have become serious concerns. In addition, lightning strikes on transmission lines, switching of capacitor banks, and various network Faults can also cause PQ problems, such as transients, voltage sag/swell, and interruption. On the other hand, an increase of sensitive loads involving digital electronics and complex process controllers requires a pure sinusoidal supply voltage for proper load operation. To meet power quality to the standard limits need some sort of compensation. In few years back to mitigate the power quality problems in distribution system by using passive filters like capacitor banks. Now these research going very fast to mitigate the power quality problems with help of power conditioning devices. The power conditioning devices are dynamic voltage restorer (DVR), static compensator (STATCOM), and unified power – quality conditioner (UPQC).

A static synchronous compensator (STATCOM), also known as a "static synchronous condenser" ("STATCOM"), is a regulating device used on alternating current electricity transmission networks. It is based on a power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of power it can also provide active AC power. It is a member of the FACTS family of devices. It is inherently modular and electable.

The proposed HCC method has many advantages such a being robust, having very fast response time and being independent of nonlinear loads. Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. There are however, other uses, the most common use is for voltage stability. A STATCOM is a voltage source converter (VSC)-based device, with the voltage source behind a reactor. The voltage source is created from a DC capacitor and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is connected across the DC capacitor. The aim of this project is the STATCOM-based control schemes for power quality improvement in grid connected wind generating system and with nonlinear load the power quality issues and its consequences on the consumer and electric utility.

Page 27-38 © MANTECH PUBLICATIONS 2019. All Rights

SOURCES AND EFFECTS OF POWER QUALITY PROBLEMS

The distortion in the quality of supply power can be introduced/ enhanced at various stages; however; some of the primary sources of distortion can be identified as below:

1. Power Electronic Devices
2. IT and Office Equipments
3. Arcing Devices
4. Load Switching
5. Large Motor Starting
6. Embedded Generation
7. Electromagnetic Radiations and Cables
8. Storm and Environment Related Causes etc.

Some of the common power quality issues and their prominent impact are

Harmonics: Excessive losses and heating in motors, capacitors and transformers connected to the system.

Flicker: Visual irritation, introduction of many harmonic components in the supply power and their associated equipment.

Transients: Tripping, components failures, flashover of instrument insulation hardware booting, software glitches, poor product quality etc.

Voltage sags: Devices /process down time, effect on product quality, failure / malfunction of customer equipments and associated scrap cost, clean up costs, maintenance and repair costs etc.

Control Objectives of STATCOM

The shunt connected converter has the following control objectives

- Voltage support and control
- Voltage Fluctuation And Flicker Mitigation
- Unsymmetrical load balancing
- Power factor correction
- Active harmonics cancellation
- Improve transient stability of the power system

USE OF CUSTOM POWER DEVICES TO IMPROVE POWER QUALITY:

In order to overcome the problem mentioned above conventional devices such as:

- Line-voltage regulators: Tap changers, buck-boost regulator, CVT (Constant-voltage transformer).
- M-G Sets (Motor-generator Sets)
- Magnetic Synthesizers
- SVC (Static VAR Compensators)
- UPS (Uninterruptible Power Supplies)
- Static Transfer Switch
- Fuel Cell Based Inverter System

Page 27-38 © MANTECH PUBLICATIONS 2019. All Rights

Can be used but present day modem equipments are very sensitive to voltage sags and they need the mitigating device to be very fast in acting, which cannot possible by the above conventional devices. So in order to overcome the above disadvantages, a new category of devices called custom power devices are developed. Custom power devices are the new generation of power electronics-based equipment aimed at enhancing the reliability and quality power flows in low-voltage distribution networks.

In this paper, distribution static compensator (STATCOM) is Presented the proposed topology can be used for compensation of current reactive power compensation, power factor correction and harmonic reduction in both feeders by sharing power compensation capabilities between two adjacent feeders which are not connected.

MODELLING OF STATCOM AND SIMULATION RESULTS:

The proposed STATCOM control scheme for grid connected wind energy generation for power quality improvement has following objectives, Unity power factor at the source side, Reactive power support only from STATCOM to win Generator and Load and Controller for STATCOM to achieve fast dynamic response. The STATCOM consists of a PWM inverter connected to the network through a transformer. The dc link voltage is provided by capacitor C which is charged with power taken from the network. The control system ensures the regulation of the bus voltage and the dc link voltage. The STATCOM function is to regulate the bus voltage by absorbing or generating reactive power to the network, like a thyristor static compensator.

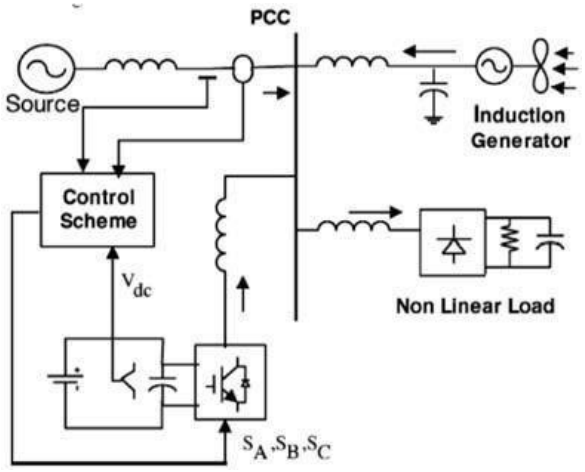


Fig. 1 Block diagram of the proposed model

Page 27-38 © MANTECH PUBLICATIONS 2019. All Rights

A STATCOM consists of a two-level Voltage Source Converter (VSC), a DC energy storage device connected in shunt to the distribution network through the coupling transformer. The VSC converts the DC voltage across the storage device into a set of three-phase AC output voltages. These voltages are in phase and coupled with the AC system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the STATCOM output voltages allows effective control of active and reactive power exchanges between the STATCOM and the AC system. Such configuration allows the device to absorb or generate controllable active and reactive power.

The SIMULINK model to enhance the performance of distribution system, STATCOM with was connected to the distribution system shown in fig 2.

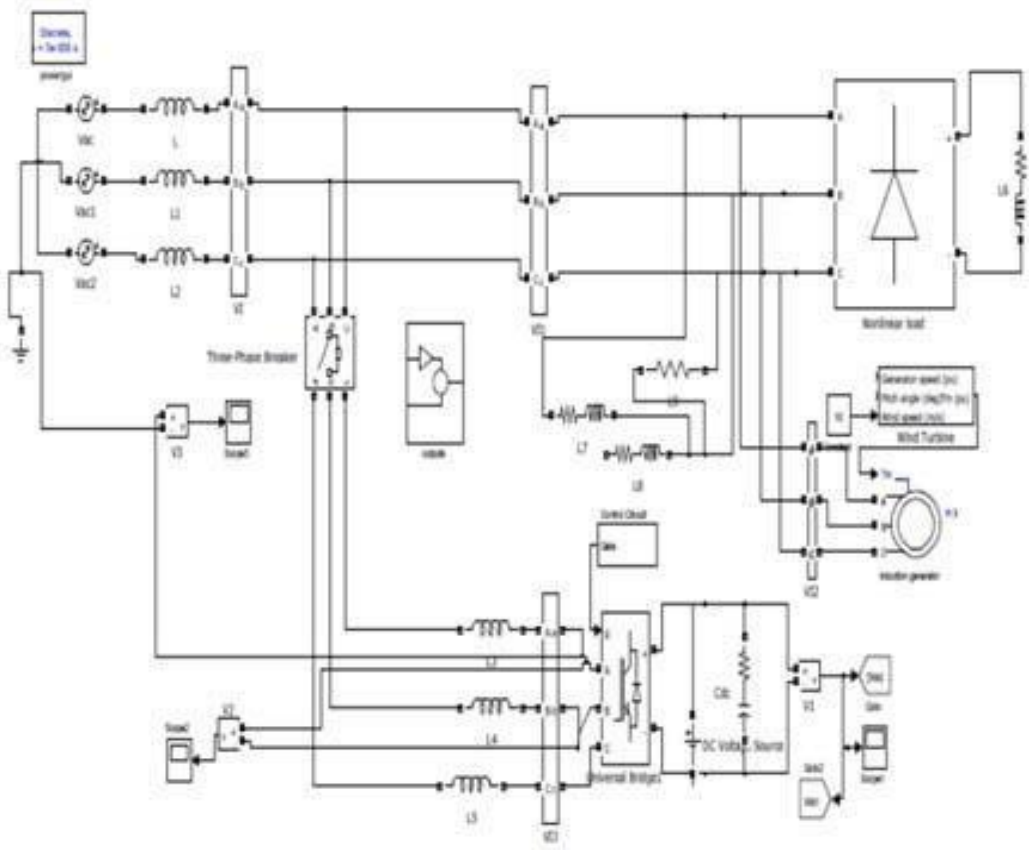


Figure: - 2 Simulink model for source, load and compensator current imperfections using STATCOM

Page 27-38 © MANTECH PUBLICATIONS 2019. All Rights

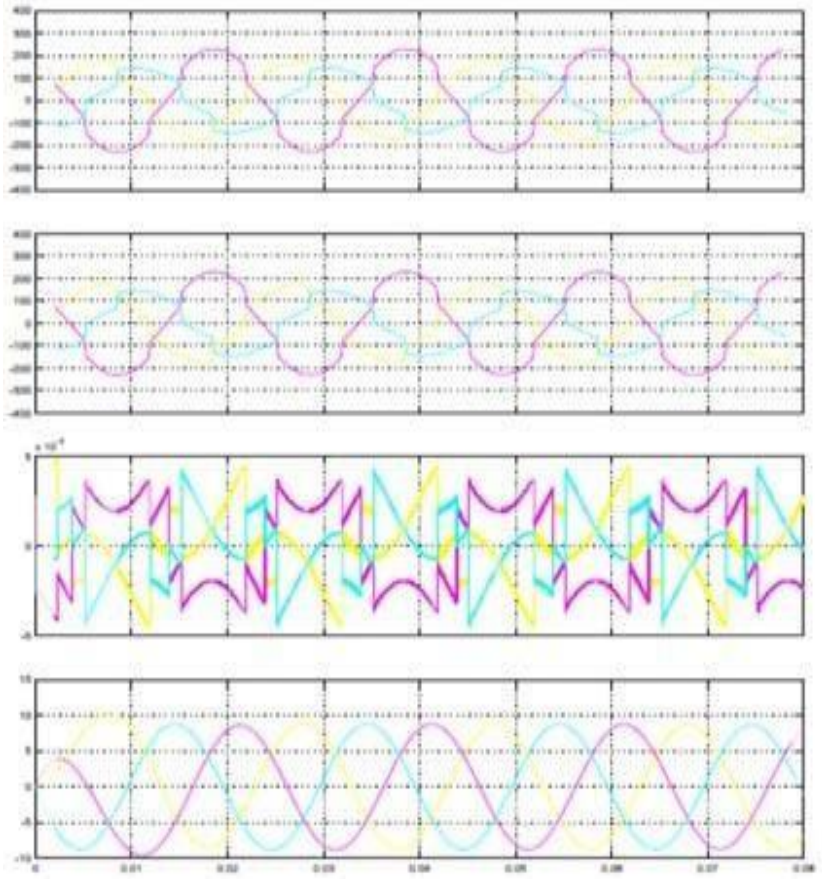


Figure:-3 Source, load and compensator current waveforms

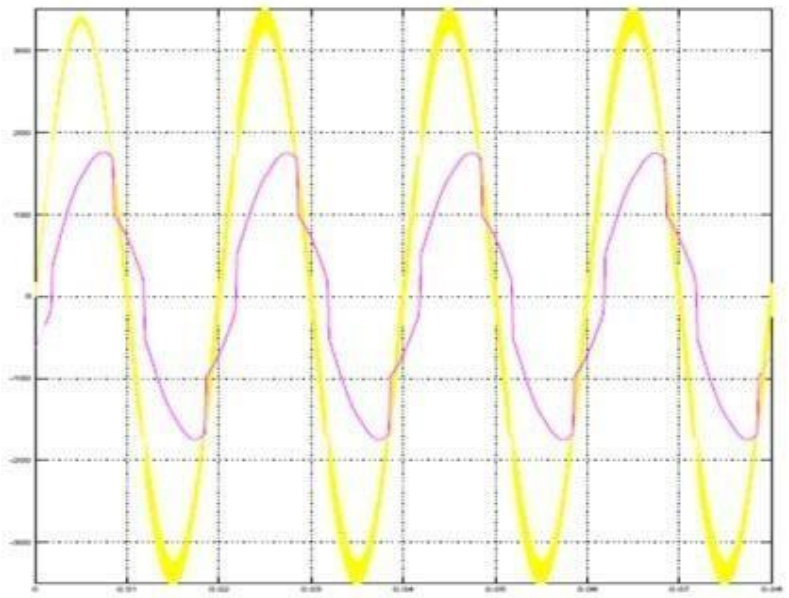


Figure: - 4 power factor waveforms

Page 27-38 © MANTECH PUBLICATIONS 2019. All Rights

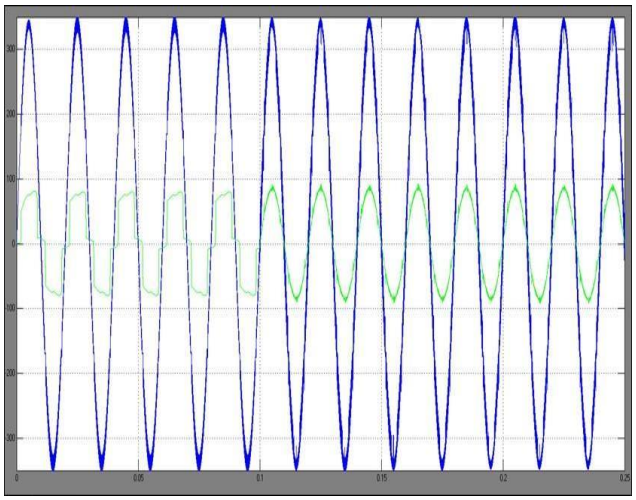


Figure: - 5 voltage and current waveforms

VOLTAGE SOURCE CONVERTERS (VSC):

A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. Voltage source converters are widely used in adjustable-speed drives, but can also be used to mitigate voltage dips. The VSC is used to either completely replace the voltage or to inject the „missing voltage". The „missing voltage" is the difference between the nominal voltage and the actual. The converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage. The solid-state electronics in the converter is then switched to get the desired output voltage. Normally the VSC is not only used for voltage dip mitigation, but also for other power quality issues, e.g. flicker and harmonics.

The voltage source rectifier operates by keeping the dc link voltage at a desired reference value, using a feedback control loop as shown in Fig:-6

To accomplish this task, the dc link voltage is measured and compared with a reference VREF. The error signal generated from this comparison is used to switch the six valves of the rectifier ON and OFF. In this way, power can come or return to the ac source according to dc link voltage requirements. Voltage VD is measured at capacitor CD. When the current ID is positive (rectifier operation), the capacitor CD is discharged, and the error signal ask the Control Block for more power from the ac supply. The Control

Page 27-38 © MANTECH PUBLICATIONS 2019. All Rights

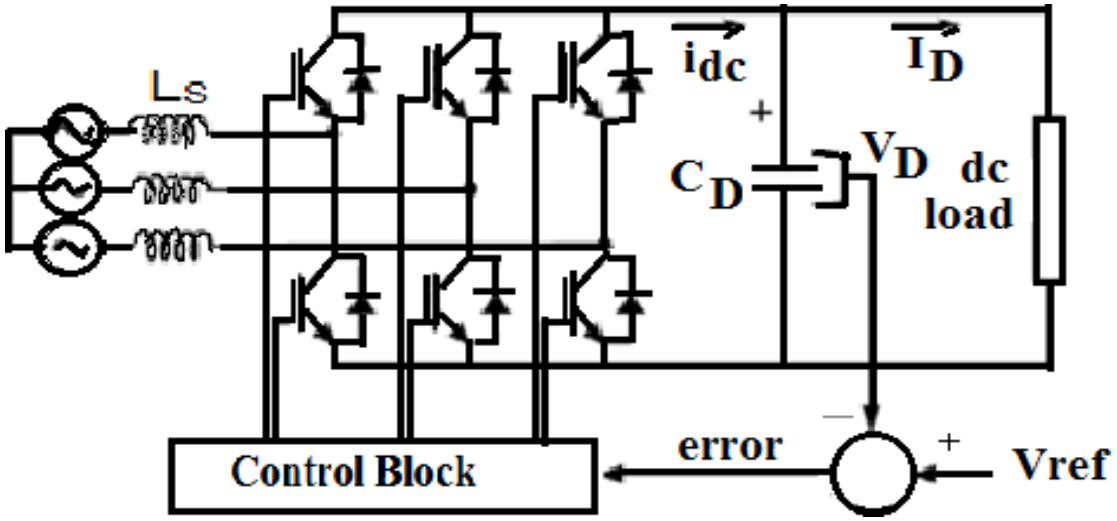


Fig 6 schematic structure of a VSC with closed loop

The Control Block takes the power from the supply by generating the appropriate PWM signals for the six valves. In this way, more current flows from the ac to the dc side, and the capacitor voltage is recovered. Inversely, when ID becomes negative (inverter operation), the capacitor CD is overcharged, and the error signal asks the control to discharge the capacitor and return power to the ac mains.

The PWM control not only can manage the active power, but also reactive power, allowing this type of rectifier to correct power factor. In addition, the ac current waveforms can be maintained as almost sinusoidal, which reduces harmonic contamination to the mains supply. Pulse width- modulation consists of switching the valves ON and OFF, following a pre-established template.

OPERATION OF STATCOM:

Basic Principle of Operation:

In the case of two AC sources, which have the same frequency and are connected through a series reactance, the power flows will be:

- Active or Real Power flows from the leading source to the lagging source.
- Reactive Power flows from the higher to the lower voltage magnitude source.

Consequently, the phase angle difference between the sources decides the active power flow, while the voltage magnitude difference between the sources determines the reactive power flow. Based on this principle, a STATCOM can be used to regulate the reactive power flow by

Page 27-38 © MANTECH PUBLICATIONS 2019. All Rights

changing the output voltage of the voltage-source converter with respect to the system voltage.

MODES OF OPERATION:

The STATCOM can be operated in two different modes:

A. Voltage Regulation

The static synchronous compensator regulates voltage at its connection point by controlling the amount of reactive power that is absorbed from or injected into the power system through a voltage-source converter.

In steady-state operation, the voltage V2 generated by the VSC through the DC capacitor is in phase with the system voltage V1 (δ=0), so that only reactive power (Q) is flowing (P=0).

1. When system voltage is high, the STATCOM will absorb reactive power (inductive behavior)

2. When system voltage is low, the STATCOM will generate and inject reactive power into the system (capacitive).

Subsequently, the amount of reactive power flow is given by the equation:

1. **Q = [V1 (V1-V2)] / X**

B. VAR Control:

In this mode, the STATCOM reactive power output is kept constant independent of other system parameter.

Three-Phase Voltage Source Inverters:

The standard three-phase VSI topology is shown in Fig. 4 and the eight valid switch states. As in single-phase VSIs, the switches of any leg of the inverter (S1 and S4, S3 and S6, or S5 and S2) cannot be switched on simultaneously because this would result in a short circuit across the dc link voltage supply. Similarly, in order to avoid undefined states in the VSI, and thus undefined ac output line voltages, the switches of any leg of the inverter cannot be switched off simultaneously as this will result in voltages that will depend upon the respective line current polarity of the eight valid states, two of them produce zero ac line voltages. In this case, the ac line currents freewheel through either the upper or lower components. The remaining states produce nonzero ac output voltages. In order to generate a given voltage waveform, the inverter moves from one state to another. Thus the resulting ac output line voltages consist of discrete values of voltages that are Vi, 0, and Vi+ for the topology The selection of the states

Page 27-38 © MANTECH PUBLICATIONS 2019. All Rights

in order to generate the given waveform is done by the modulating technique that should ensure the use of only the valid states.

Principle of Hysteresis Current Controller:

Hysteresis current control is an instantaneous closed loop control technique in which the output current I of the inverter is made to track the command current i* and maintain the error within the hysteresis band (δ) .

When the error in current (i.e.=i*-i) crosses the error band, inverters are switched to bring the output current within the error band .When the output current exceeds the upper band (i*+ δ/2), it is brought back to within the band of δ by turning ON the lower switch and turning OFF the upper switch of the inverter leg of the phase considered. As a result, the voltage across the load changes from Vdc to 0 and the current decreases. Similarly when the output current goes below the lower band (i*- δ/2), the load is connected to Vdc by turning OFF the lower switch and turning ON the upper switch. As a result, the output voltage across the load changes from 0to Vdc and the output current starts to build up. An optimal value of δ must be chosen to maintain a balance between the output current ripple and the switching losses and thereby eliminate particular harmonics. In this control technique, since each phase is controlled independently, switching frequency goes abnormally high, which increases the switching losses. The instantaneous active power (P*) that is to be supplied by the D-STATCOM can be evaluated from the energy stored in the DC capacitor and is given by:

$$P^* = -\frac{dE}{dt} = \frac{1}{2}C\,\frac{d(V_{DC}^2)}{dt}$$

Where, VDC is capacitor voltage.

CONCLUSION

This paper presents the grid connected wind energy system for power quality improvement by using STATCOM. The power quality problems, its consequences and their mitigation techniques are presented here. In this proposed scheme to eliminate the harmonic content of the load current the STATCOM-BESS control system is used. So that power quality is maintained at the point of common coupling. And hysteresis current control scheme in the STATCOM is used for the fast dynamic response. It also maintains voltage and current in phase. That means unity power factor is maintained at the

Page 27-38 © MANTECH PUBLICATIONS 2019. All Rights

source end. This project presents the STATCOM-based control scheme for reactive power compensation and harmonic reduction in grid connected wind generating system feeding nonlinear load. The control system for the STATCOM is simulated using MATLAB/SIMULINK.

The Simulation results shows the grid voltage and current are in-phase, making the power factor unity, which implies that the reactive power demand of Induction generator and load is no longer, fed by the grid rather it is supplied by the STATCOM. Also the shape of the grid current is almost sinusoidal and the % THD has been improved from 1l.08 % to 5.78 % after compensation. The proposed control scheme has improved the power quality requirement of a low voltage grid connected wind driven IG system feeding a non-linear load.

This proposed model is implemented by using MATLAB SIMULINK software and the obtained resultant waveforms are evaluated and system stability effectiveness and power system performance have been established.

REFERENCES:

I. M L. Crow,"Power quality enhancement using custom power devices," IEEE Power and Energy Magazine, vol.2, pp.50, April 2004.

II. Han. A, Huang. Q, Baran. M, Bhattacharya. S and Litzen berger. W, "STATCOM impact study on the integration of a large wind farm

III. Mohapatra M. and Babu B.C. 2010. Fixed and sinusoidal-band hysteresis current controller for PWM voltage source inverter with LC filter. Proceedings of 2010 IEEE Students'

IV. Heier. S, Grid Integration of Wind Energy Conversions. Hoboken, NJ: Wiley, pp. 256–259, 2007.

V. Stones and A. Collinson,"Power quality, "Power Eng.Journal, vol.15, pp.58 64, April 2001.

VI. A.ElMofty, K . Youssef," Industrial power quality problems, "in Proc. on IEE Int. ConfExhib. On1, vol.2, June 2001.

VII. N. G. Hingorani, "Introducing custom power," vol.32, pp.41-48, June1995 23.

Page 27-38 © MANTECH PUBLICATIONS 2019. All Rights

VIII. Mohod. S. W and Aware. M. V, "Power quality issues & its mitigation technique in wind energy conversion," in Proc. of IEEE Int. Conf. Quality Power & Harmonic, Wollongong.

Cite this Article

Yashoda A. Kale, Sandip S. Rathod & Ganesh D. Shingade**Power Quality Improvement Using Facts Device (STATCOM)** Recent Trends in Electrical Machines and Drives, 4(1) 1-12

http://doi.org/10.5281/zenodo.2638726

AUTHORS' PROFILE

[1] Yashoda A. Kale, *Assistant Professor*
Department: Electrical
College: Shreeyash College of Engineering & Technology
Email Id: yashodaakale@gmail.com

[2] Sandip S. Rathod, *Assistant Professor*
Department: Electrical
College: Shreeyash College of Engineering & Technology

[3] Ganesh D. Shingade, *Assistant Professor*
Department: Electrical
College: Shreeyash College of Engineering & Technology

Page 27-38 © MANTECH PUBLICATIONS 2019. All Rights