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# Comparison of UPQC and STATCOM in Wind Turbine Fed FSIG under Asymmetric Faults

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## Abstract

This paper presents the mitigation of faults in wind turbine connected fixed speed induction generator using unified power quality conditioner and static compensator. The UPQC consists of shunt and series converters connected back-to-back through a dc-to-dc step up converter. The presence of the dc-to-dc step converter permits the UPQC to compensate faults for long duration. The series converter is connected to the supply side whereas the shunt converter is connected to the load side. The control system of the proposed UPQC is based on SRF and Id-Iq theory. The STATCOM consists of voltage source inverter wit dc link capacitor . The control system is based on DSOGI-PLL fed vector control. The proposed wind turbine fed fixed speed induction generator is evaluated and simulated using MATLAB/SIMULINK environment with UPQC and STATCOM under asymmetric faults.

**Keywprd**: Fixed Speed Induction Generator, DSOGI-PLL, Unified power quality conditioner.

## Introduction

The wind power penetration has increased dramatically in the past few years, hence it has become necessary to address problems associated with maintaining a stable electric power system that contains different sources of energy including hydro, thermal, coal, nuclear, wind, and solar. In the past, the total installed wind power capacity was a small fraction of the power system and continuous connection of the wind farm to the grid was not a major concern. With an increasing share derived from wind power sources, continuous connection of wind farms to the system has played an increasing role in enabling uninterrupted power supply to the load, even in the case of minor disturbances. The wind farm capacity is being continuously increased through the installation of more and larger wind turbines [1]. Voltage stability and an efficient fault ride through capability are the basic requirements for higher penetration. Wind turbines have to be able to continue uninterrupted operation under transient voltage conditions to be in accordance with the grid codes.. Wind power systems should meet these requirements for interconnection to the grid. Different grid code standards are established by different regulating bodies[2] but Nordic grid codes are becoming increasingly popular. One of the major issues concerning a wind farm interconnection to a power grid concerns its dynamic stability on the power system. Voltage instability problems occur in a power system that is not able to meet the reactive power demand during faults and heavy loading conditions. Stand alone systems are easier to model, analyze, and control than large power systems in simulation studies. A wind farm is usually spread over a wide area and has many wind generators, which produce different amounts of power as they are exposed to different wind patterns but the fixed speed induction generators have a poor reactive power capability when compared to doubly fed induction generator[3]. Although different types of FACTS controllers are available, UPQC and STATCOM have a good fault mitigation capability[4].They are also known as custom power devices used for power quality[6].

## Wind Turbine Fixed Speed Induction Generator

### *A. Grid Connected Induction Generator*

Grid connected induction generators develop their excitation from the Utility grid. The generated power is fed to the supply system when the IG runs above synchronous speed. Machines with cage type rotor feed only through the stator and generally operate at low negative slip. But wound rotor machines can feed power through the stator as well as rotor to the bus over a wide range known as

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Doubly Fed Induction Machines.

*B. Fixed Speed Grid Connected Wind Turbine Generator*

The structure and performance of fixed-speed wind turbines as shown in Fig.1 depends on the features of mechanical sub-circuits, e.g., pitch control time constants etc.

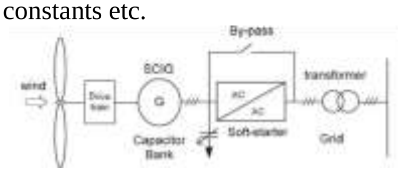


***Fig. 1 Fixed Speed Wind Turbine With Directly Grid Connected Squirrel - Cage Induction Generator***

The reaction time of these mechanical circuits may lie in the range of tens of milliseconds. As a result, each time a burst of wind hits the turbine, a rapid variation of electrical output power can be observed. These variations in electric power generated not only require a firm power grid to enable stable operation, but also require a well-built mechanical design to absorb high mechanical stress, which leads to expensive mechanical structure, especially at high-rated power.

## Unified Power Quality Conditioner (UPQC)

A Unified Power Quality Conditioner (UPQC) is a device that is similar in construction to a Unified Power Flow Conditioner (UPFC). The UPQC, just as in a UPFC, employs two voltage source inverters (VSIs) that is connected to a dc energy storage capacitor. One of these two VSI is connected in series with ac line while the other is connected in shunt with the ac system.. It consists of a shunt active filter together with a series-active filter[5]. This combination allows a simultaneous compensation of the load currents and the supply voltages so that compensated current drawn from the network and the compensated supply voltage delivered to the load are sinusoidal, balanced and minimized [7]. The series and shunt-active filters are connected in a back-to-back configuration, in which the shunt converter is responsible for regulating the common DC-link voltage.

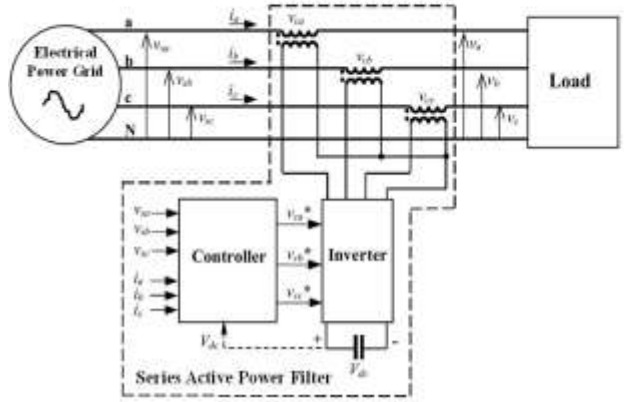


***Figure 2 Series Active Filter***

*A. SRF Theory*

Among the several methods presented in the literature, the Synchronous Reference Frame method (SRF) is one of the most common and probably it is widely used method. This section is organized as to describe succinctly the SRF methods[8]. The two methods presented in this section with some results obtained with the above mentioned methods. The nonlinear load considered is a three-phase diode bridge rectifier. The above figure shows the basic configuration of synchronous reference frame. SRF is a time varying angle that represents the angular position of the reference frame which is rotating at constant speed in synchronism with the three phase ac voltages. To implement the SRF method some kind of synchronizing system should be used. In Akagi *et al.* (2007) Phase-Locked Loop (PLL) is used for the implementation of this method. In this case the speed of the reference frame is practically constant, that is, the method behaves as if the reference frame's moment of inertia is infinite.

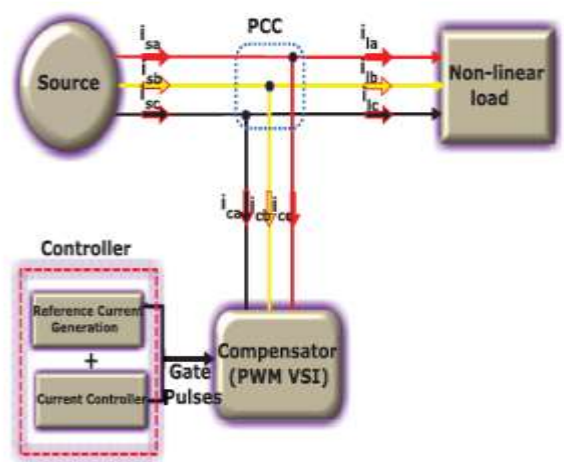


***Fig. 3 Shunt Active Filters***

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*B. Instantaneous Current Component ($i_d$–$i_q$) Theory*

The Modified Synchronous Frame method is presented in Graovac *et al.* (2007). It is called the instantaneous current component ($i_d$-$i_q$) method[9]. This is similar to the SRF frame method. The transformation angle is now obtained with the voltages of the ac network. The major difference is that, due to voltage harmonics and imbalance, the speed of the reference frame is no longer constant. It varies instantaneously depending on the waveform of the three phase voltage system. In this method the compensating currents are obtained from the instantaneous active and reactive current components and of the nonlinear load. In the same way, the mains voltages *V* (*a*, *b*, *c*) and the polluted currents *I* (*a*, *b*, *c*) in components must be calculated.

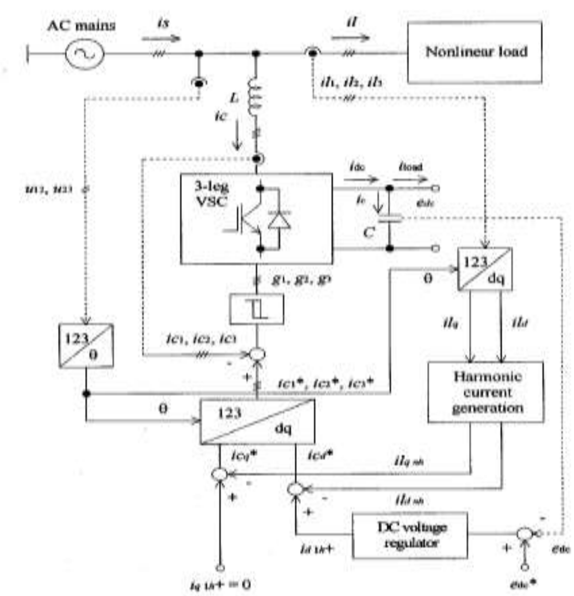


***Fig.4, Instantaneous Active and Reactive Current Control***

## Static Compensator (STATCOM)

The basic electronic block of the STATCOM is the voltage source inverter that converts an input dc voltage into a three-phase output voltage at fundamental frequency. 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 allow effective control of active and reactive power exchanges between the STATCOM and the ac system[10]. The first transformer is in Y-Y connection and the second transformer is in Y- connection. The first transformer is step down and the second one is step up transformer. The IGBT of the proposed STATCOM is in turn fed to dq reference frame and DSOGI-PLL which is used to separate the positive sequence and negative sequence voltages and currents.

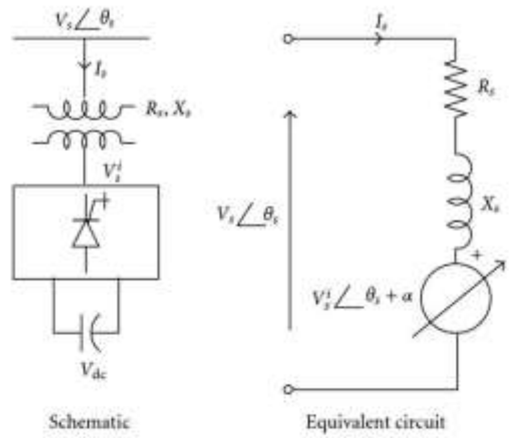


***Fig 5: STATCOM structure***

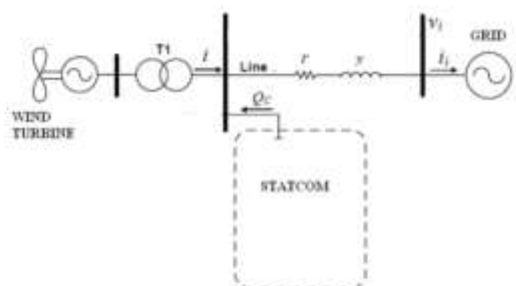


***Fig: 6: System Model***

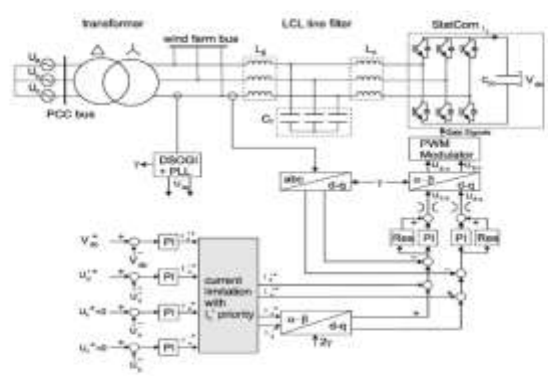

***Fig:7: STATCOM Control Structure***

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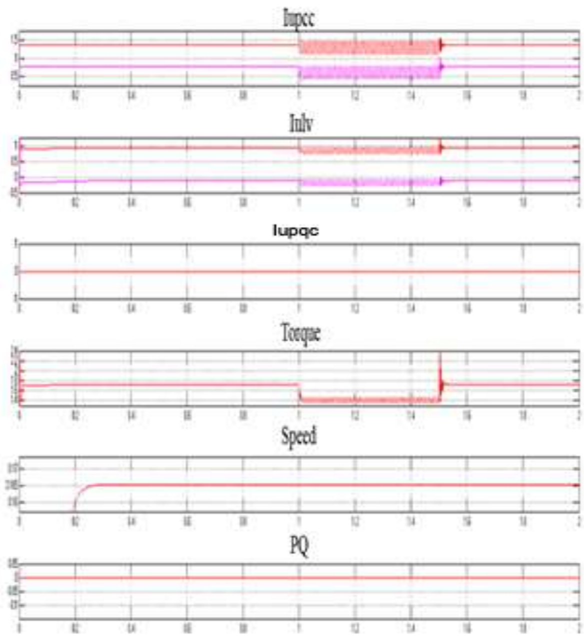
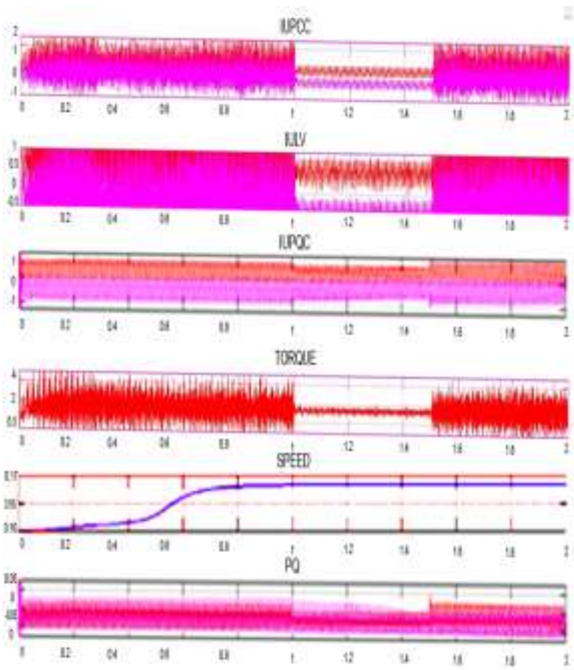
## Simulation Results

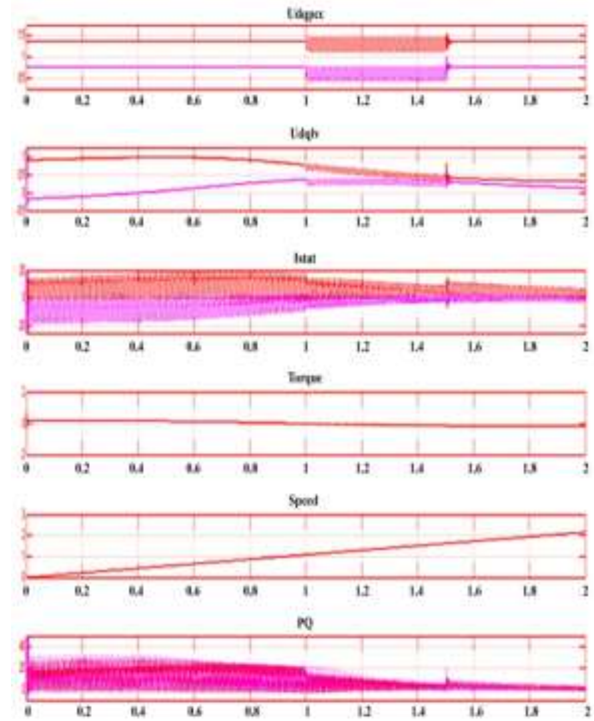
*A. Wind Turbine Fed Fsig Without UPQC*




*B. Wind Turbine Fed Fsig With UPQC 1Ph - 50%*




*C. Wind Turbine Fed Fsig With STATCOM 1Ph – 50 %*




## Tabulation

| Sl. No | PARAMETERS | Vector Control | |
|---|---|---|---|
| | | UPQC | STATCOM |
| | 1 ph – Fault 50 % | (THD) | (THD) |
| 1 | Iupcc | 27.16 | 9.84 |
| 2 | Iulv | 27.35 | 9.26 |
| 3 | Istat | 45.88 | 12.14 |
| 4 | Torque | 40.99 | 14.55 |
| 5 | Speed | 19.36 | 6.27 |
| 6 | PQ | 15.88 | 2.42 |

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## Conclusion

In this paper windturbine fed fixed speed induction generator is modeled under single phase asymmetric grid fault . To mitigate these faults UPQC is injected into the windturbine fed fixed speed induction generator and the same compensation is repeated for STATCOM. The harmonics andtorsional oscillations are reduced better in STATCOM than UPQC. Hence STATCOM gives better performance than UPQC in windturbine fed FSIG under asymmetric faults.

*A. Appendix*

***TABLE I. Simulation Parameters***

| Wind Farm Induction Generator | Simulation Parameters |
|---|---|
| Base Apparent Power | 575 MW |
| Rated Active Power | 50 MW |
| Rated Voltage ( Line To Line) | 690 V |
| Stator Resistance | 0.0108 p.u |
| Stator Stray Impedance | 0.107 p.u |
| Mutual Impedance | 4.4 p.u |
| Rotor Impedance | 0.01214 p.u |
| Rotor Stray Impedance | 0.1407 p.u |
| Compensation Capacitors | 0.17 F |
| Mechanical Time Constant | 3s |

*B.Grid And Transformer Parameters*

| | Grid | High Voltage Transformer | Medium Voltage Transformer |
|---|---|---|---|
| Base Apparent Power and Rated Voltage | 1000 MW 110 KV | 100 MW 30 KV | 100 MW 690 V |
| Stray Impedance | 0.98 p.u | 0.05 p.u | 0.1 p.u |
| Resistance | 0.02 p.u | 0.01 p.u | 0.02 p.u |

## *References*


[1] M. Liserre, R. Cardenas, M. Molinas, and J. Rodriguez, "Overview of multi-MW wind turbines and wind parks," IEEE Trans. Ind. Electron.,vol. 58, no. 4, pp. 1081–1095, Apr. 2011.

[2] M. Tsili and S. Papathanassiou, "A review of grid code technical requirements for wind farms," IET Renewable Power Gener., vol. 3, no. 3,pp. 308–332, Sep. 2009.

[3] M. Ali and B. Wu, "Comparison of stabilization methods for fixed speed wind generator systems," IEEE Trans. Power Del., vol. 25, no. 1,pp. 323–331, Jan. 2010.

[4] D. Soto and T. Green, "A comparison of high-power convert topologies for the implementation of FACTS controllers," IEEE Trans. Ind. Electron., vol. 49, no. 5, pp. 1072–1080, Oct. 2002.

[5] Aredes M (1995), "A Combined Series and Shunt Active Power Filter", in Proc.

[6] Sankaran C (2002), Power Quality, p. 202, CRC Press, Boca Raton.

[7] Fujita H and Akagi H (1998), "The Unified Power Quality Conditioner: The Integration of Series and Shunt-Active Filters", IEEE Trans. Power Electron., Vol. 13, No. 2, pp. 315-322.

[8] Singh B., Haddad K. A., and Chandra A.,"A review of active power filter for power quality improvement", IEEE Trans. Industrial Electronics, vol.46. no.5, (1999):pp. 960-971.

[9] V.Soares Pedro Verdelho, "An Instatntaneous Active and Reactive Current component method for Active Filters," IEEE transactions on Power Electronics, Vol15,No.4,July200

[10] Graovac D, Katie A and Rufer A (2007), "Power Quality Problems Compensation with Universal Power Quality Conditioning System", IEEE Transaction on Power Delivery, Vol. 22, No. 2.