COMPARISON OF UPQC AND DVR 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 Id-Iq theory. The DVR 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 DVR 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 DVR is based on hysteresis voltage controlThe proposed wind turbine fed fixed speed induction generator is evaluated and simulated using MATLAB/SIMULINK environment with UPQC and DVR under asymmetric faults.

KEYWORDS

Fixed Speed Induction Generator, DSOGI-PLL, Unified power quality conditioner

1. 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

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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 DVR have a good fault mitigation capability[4].They are also known as custom power devices used for power quality[6].

2. WIND TURBINE FIXED SPEED INDUCTION GENERATOR

2.1. 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 Doubly Fed Induction Machines.

2.2. Fixed Speed Grid Connected Wind Turbine Generator

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

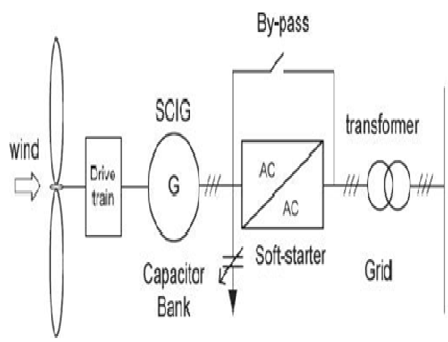

Figure.1: Fixed Speed Wind Turbine With Directly Grid Connected Squirrel - Cage Induction Generator

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.

3. 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.

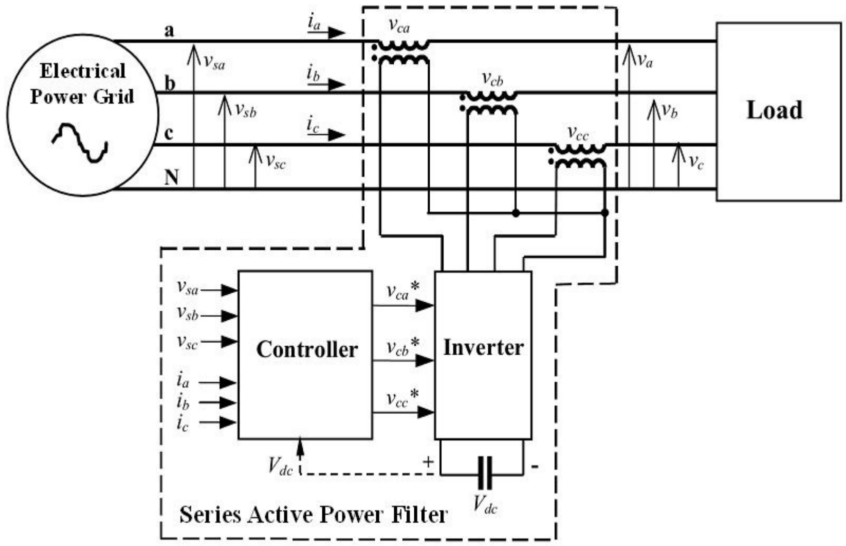

Figure.2:Series Active Filter

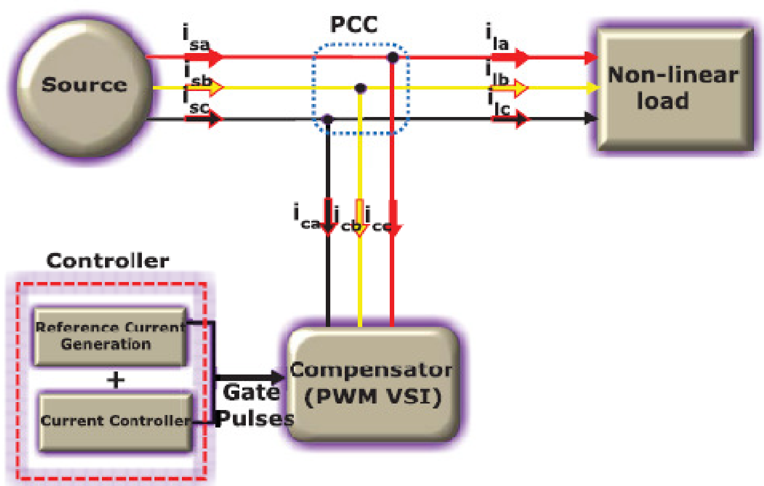

Figure.3:Shunt Active Filters

3.1.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.Thewindfarm voltages and currents are transformed from three phase to two phase and then fed to dual second order generalized integrators(DSOGI-PLL) to separate the positive and negative sequence voltages and currents. 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.

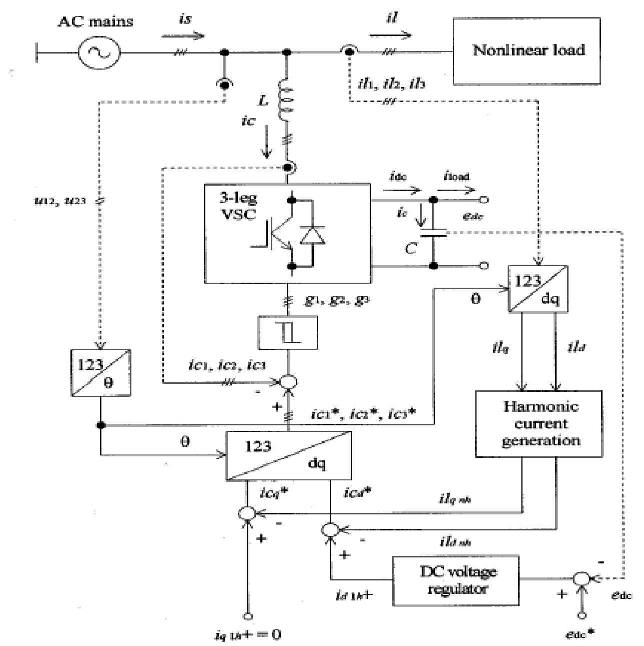

Figure.4: Instantaneous Active and Reactive Current Control

4. DYNAMIC VOLTAGE RESTORER

4.1.Principles of DVR Operation

A DVR is a solid state power electronics switching device which comprises of either gto or igbt, a capacitor bank as energy storage device and injection transformers. From the figure it can be seen that DVR is connected in between the distribution system and the load. The basic idea of DVR is that by means of an injecting transformer a control voltage is generated by a forced commuted convertor which is in series to the bus voltage. A regulated dc voltage source is provided by a dc capacitor bank which acts an energy storage device.

Under normal operating conditions when there is no voltage sag, DVR provides very less magnitude of voltage to compensate for the voltage drop of transformer and device losses. But when there is a voltage sag in distribution system, DVR will generate a required controlled voltage of high magnitude and desired phase angle which ensures that load voltage is uninterrupted and is maintained. In this case the capacitor will be discharged to keep the load supply constant[10].

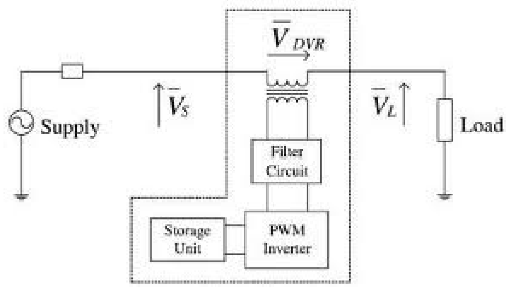

Figure.5: DVR structure

4.2. Controller

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system only measures the r.m.s voltage at the load point, i.e., no reactive power measurements are required. The vsc switching strategy is based on a sinusoidal pwm technique which offers simplicity and good response. Since custom power is a relatively low-power application, pwm methods offer a more flexible option than the fundamental frequency switching (ffs) methods favored in facts applications. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses. The controller input is an error signal obtained from the reference voltage and the value rms of the terminal voltage measured. Such error is processed by a hysteresis controller the output is the angle δ,which is provided to the pwm signal generator. It is important to note that in this case, indirectly controlled converter, there is active and reactive power exchange with the network simultaneously: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point. The hysteresis controller process the error signal generates the required angle to drive the error to zero, i.e., the load rms voltage is brought back to the reference voltage.the dc capacitor of the uncontrolled rectifier, the dc capacitor cdc and the inductor ldc of the dc-to-dc step up converter are designed based on single-phase voltage sag which induces a voltage fluctuation with twice the line frequency of the dc capacitor[6]. The parameters of the series and shunt transformers are the default parameters of the transformer model in matlab/simulink. Hysteresis band voltage control is used to control load voltage and determine switching signals for inverter switches.there are bands above and under the reference voltage. If the difference between the reference and inverter voltage reaches to the upper (lower) limit, the voltage is forced to decrease (increase).

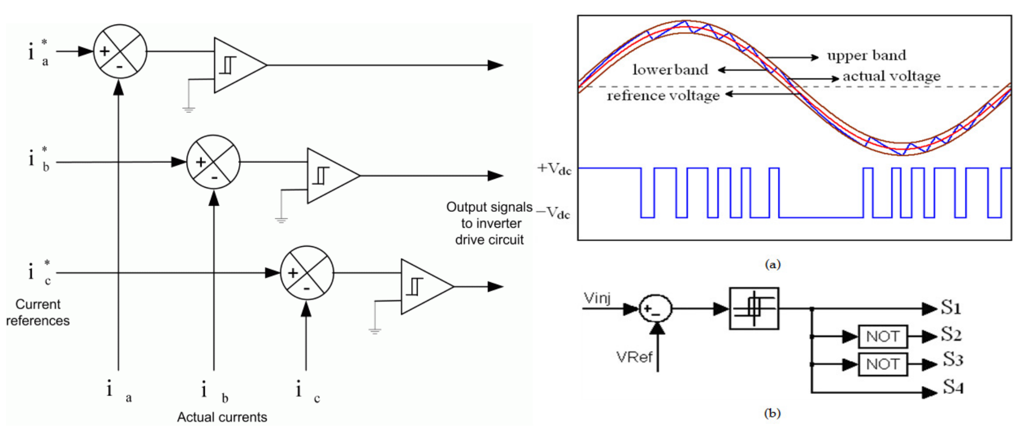

Figure.6: Hysteresis controller

5. SIMULATION RESULTS

In Figure.7, Tthe proposed system is implemented in MATLAB/SIMULINK consisting of windturbine connected to fixed speed induction generator under asymmetric fault of 1ph-50%- **without UPQC AND DVR**

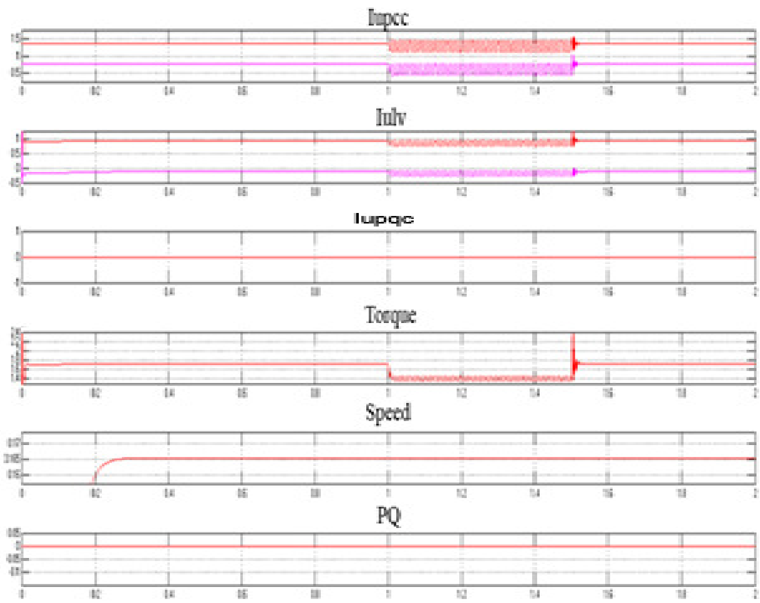

Figure.7: Wind Turbine Fed Fsig Without UPQC and DVR

In Figure.8, The proposed system is implemented in MATLAB/SIMULINK consisting of windturbine connected to fixed speed induction generator under asymmetric fault of 1ph-50%-

WITH DVR- POSITIVE AND NEGATIVE SEQUENCE COMPENSATION

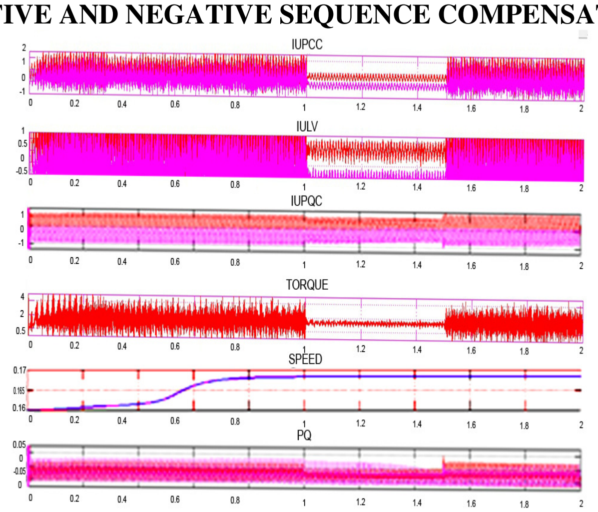

Figure.8: Wind Turbine Fed Fsig With DVR1Ph -50%

In Figure.9,The proposed system is implemented in MATLAB/SIMULINK consisting of windturbine connected to fixed speed induction generator under asymmetric fault of 1ph-50%-

WITH UPQC- POSITIVE AND NEGATIVE SEQUENCE COMPENSATION

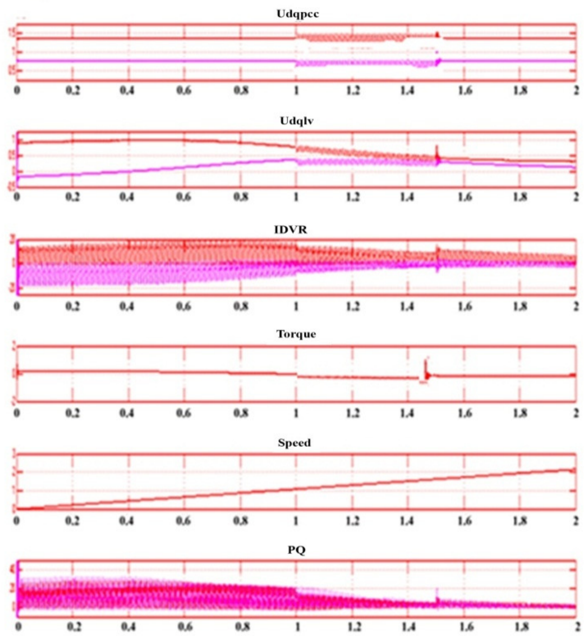

Figure.9: Wind Turbine Fed Fsig With UPQC 1Ph – 50 %

6. TABULATION

Sl. No	PARAMETERS	Vector Control	
		DVR	UPQC
	1 ph – Fault 50 %	(THD)	(THD)
1	Iupcc	20.44	6.82
2	Iulv	32.97	4.56
3	Istat	41.78	15.33
4	Torque	47.59	10.41
5	Speed	55.68	15.44
6	PQ	58.32	14.96

7. CONCLUSION

In this project a wind turbine fed fixed speed induction generator is modeled under asymmetric grid fault of1ph-50%. To mitigate these faults UPQC is injected into the wind turbine fed fixed speed induction generator and the same compensation is repeated for DVR. From the THD reduction it clearly shows the torsional oscillations and harmonics are reduced better in UPQC than DVR. Hence UPQC gives better performance than DVR in wind turbine fed FSIG under asymmetric faults.

7.1. Appendix

Table 1: 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

Table 1 :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

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I like to dedicate this paper to my family and to my friend Prakash.

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