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POD Based FACTs Controller for Power Quality Enhancement in Wind Integrated System

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Abstract: ***In remote areas or in a region where the grid cannot provide supply the only solution is by generating power using renewable resources. Among renewable resources wind energy has its mark among other sources. The power generation by wind faces many challenges one among those is the fault. It is a critical parameter while considering power generation so there is a need of compensating devices like FACTS. Different types of FACTS devices are available they are shunt connected device and series connected device. STATCOM is well known among shunt connected facts devices and SSSC among series connected device. Combination of both shunt and series connected device is Unified Power Flow Controller (UPFC). By connecting these devices on the load side of Induction generators the problem during the fault that is the sag in voltage can be eliminated. A detailed study among these devices and their effect on the load side of induction generator are presented in this paper.***

Keywords: STATCOM, SSSC, UPFC, Induction Generators

1. Introduction

In remote areas the power generation can be achieved with the help of renewable energy sources like wind. For generation of power with wind the commonly used generators are Induction Generators and synchronous generators. Among these two induction generators [1] are more preferred because it is much cheaper than the other for power generation. But the main problem for the induction generator is the fault. So it is to be considered when power is generated with the help of wind in remote areas where the grid cannot provide supply.

The key factor which is to be considered during the connection of a wind turbine system to grid is the voltage control [2]. For connection of an induction generator to grid two main requirements need to be satisfied they are a) during normal operating condition reactive power control, and b) Fault ride through (FRT) capability during fault condition. The connection of wind turbine generators to the grid is ensured by FRT capability. During the occurrence of fault on the load side of Induction generator there will be a sudden drop in voltage which is an undesirable condition which affects the fault ride through capability. In order to ensure FRT capability induction generators are connected to the grid with the help of FACTS devices on its load side. When a fault occurs the facts devices will inject a voltage or current to provide necessary compensation.

Based on their connection FACTS Controllers can be classified in to two; shunt connected compensating devices and series connected compensating devices. STATCOM and SSSC are the shunt and series connected devices whereas UPFC is a combination of two with a common dc link capacitor between the shunt and series devices. Shunt converter which constitutes IGBTs. Different control methods are used to control the gate pulse of IGBTs. The commonly used controllers for the control of gate pulses are proportional controller, proportional plus integral controller, proportional plus integral plus derivative controller. In this paper, a new control strategy for control of gate pulse for IGBT is introduced with POD controller. Design of controllers has a significant role in the modeling of FACTS controllers.

2. System Description

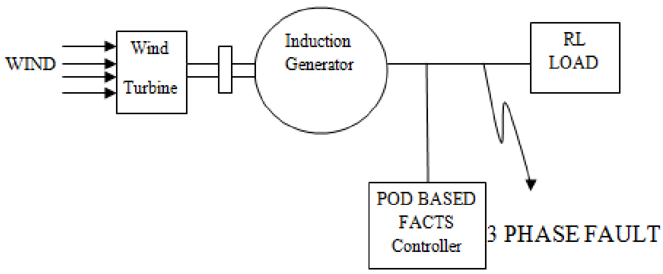

Figure 1: Induction Generator with FACTS

Wind integrated system consist of a wind turbine which is coupled to the induction generator. The stator winding is connected directly to the grid and the rotor is driven by the wind turbine. In this mechanical energy is converted in to electrical energy, the power captured by the wind turbine is converted into electrical power by the induction generator and is transmitted to the grid by the stator winding. In order to generate power the induction generator speed must have a speed slightly above the synchronous speed. But when a fault occurs there will be a sudden dip in voltage occurs and harmonics will dominate during this period also it will affect the load which is connected to the system. So we need a compensating device for solving this problem

The main purpose of FACTS devices is to provide necessary compensation at the load side of induction generators during fault. The FACTS devices used are STATCOM, SSSC and

UPFC[3] to provide necessary compensation. When a sudden fault occurs there will be sudden voltage sag which will affect badly the devices connected to it on the load side so by injecting a voltage or current the necessary compensation can be done. Fig-1 shows the induction generator with FACTS devices a POD controller is used to control the gate pulses to the IGBTS of FACTS devices. The STATCOM[4] which is a shunt converter will inject a current to the system to provide necessary compensation whereas SSSC will inject a voltage to the system as it is a series converter for the purpose of compensation. UPFC is a combination of shunt converter and series converter the shunt converter will provide necessary reactive power demand for charging the capacitor which will act as a source for series converter. Thus by providing these FACTs devices on the load side of Induction generator necessary compensation can be obtained and will ensure the safe operation of the equipments connected to it on the load side

3. POD Controller

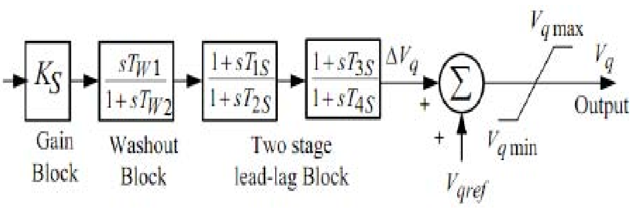

Figure 2: POD Controller

A general gain, a low-pass filter, a washout high pass filter, a lead compensator, and an output limiter constitute a Power Oscillation Damping (POD) controller [7]. But it seem that there is no effect with lag lead filters and on eliminating the system is reduced with a transfer function which is composed of a transducer with a gain which is followed by a washout filter. The main purpose is to remove unnecessary ripples. The signal obtained at the output is limited. The parameters are K, T_1, T_2, T_3 which is used for the control of gate pulse. The controller is tuned with the values for the voltage source converter. The values are K= 1.1058PU, T_1=0.068Sec,T_{W1}=0.145Sec, T_{W2}= 0.385Sec.

4. Modeling of Induction Generator

Device which helps to convert mechanical energy into electrical energy is Induction Generator. It consists of a stationary element called stator and a rotating element called rotor. Insulated copper windings within the stator laminations constitute the stator whereas rotor consists of an aluminum or copper „squirrel cage" within the rotor laminations. Here there is no need for an exciter or voltage regulator.

Table 1: Rating of Induction Generator

Rated Power	5 HP
Voltage	415 V
Frequency	50 Hz
No. Of Poles	4

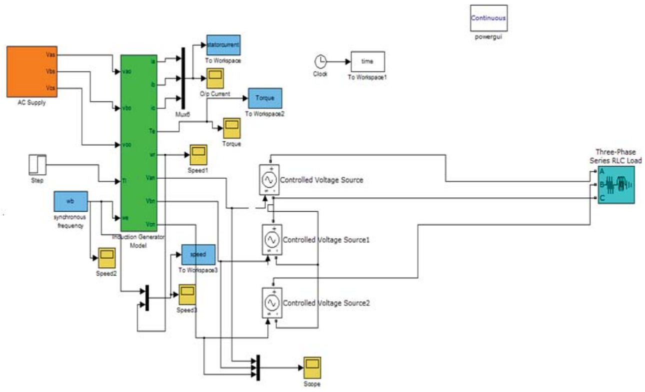

Figure 3: Modeling of Induction Generator in Wind Integrated System

Induction generator [8] is modeled with the help of flux equations in MATLAB/ SIMULINK
The equations for flux linkages [2] are:

$$\frac{dF_{qs}}{dt} = \omega_b[V_{qs} - \frac{\omega_e}{\omega_b}F_{ds} + \frac{R_s}{X_{ls}}\left(\frac{X_{ml}^{*}}{X_{lr}}F_{qr} + \left(\frac{X_{ml}^{*}}{X_{ls}} - 1\right)F_{qs}\right)] \quad (1)$$

$$\frac{dF_{ds}}{dt} = \omega_b[V_{ds} + \frac{\omega_e}{\omega_b}F_{qs} + \frac{R_s}{X_{ls}}\left(\frac{X_{ml}^{*}}{X_{lr}}F_{dr} + \left(\frac{X_{ml}^{*}}{X_{ls}} - 1\right)F_{ds}\right)] \quad (2)$$

$$\frac{dF_{qr}}{dt} = \omega_b[-\frac{(\omega_e - \omega_r)}{\omega_b}F_{dr} + \frac{R_r}{X_{lr}}\left(\frac{X_{ml}^{*}}{X_{ls}}F_{qs} + \left(\frac{X_{ml}^{*}}{X_{lr}} - 1\right)F_{qr}\right)] \quad (3)$$

$$\frac{dF_{qr}}{dt} = \omega_b[\frac{(\omega_e - \omega_r)}{\omega_b}F_{qr} + \frac{R_r}{X_{lr}}\left(\frac{X_{ml}^{*}}{X_{ls}}F_{ds} + \left(\frac{X_{ml}^{*}}{X_{lr}} - 1\right)F_{dr}\right)] \quad (4)$$

Equations for mutual flux linkages are given below

$$F_{mq} = X_{ml}^{*}[\frac{F_{qs}}{X_{ls}} + \frac{F_{qr}}{X_{lr}}] \quad (5)$$

$$F_{md} = X_{ml}^{*}[\frac{F_{ds}}{X_{ls}} + \frac{F_{dr}}{X_{lr}}] \quad (6)$$

Thus the machine is modeled in SIMULINK using the above equations and on the load side of induction generator a 3 phase voltage is applied.

5. PWM Generator

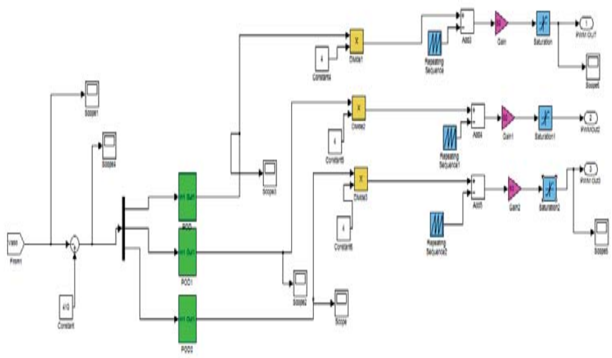

Figure 4: PWM Generator

For controlling the gate pulse of IGBTs in the VSC PWM Generator with POD controller is used the sinusoidal voltage coming out of POD controller is used to compare with triangular wave. The figure shows the modeling of PWM generator for Voltage source converters. Here the voltage is compared with reference signal and given to POD controller and the signal is compared with triangular wave of 20 KHz to produce the gate pulses for the converters. Thus the gate pulse can be controlled

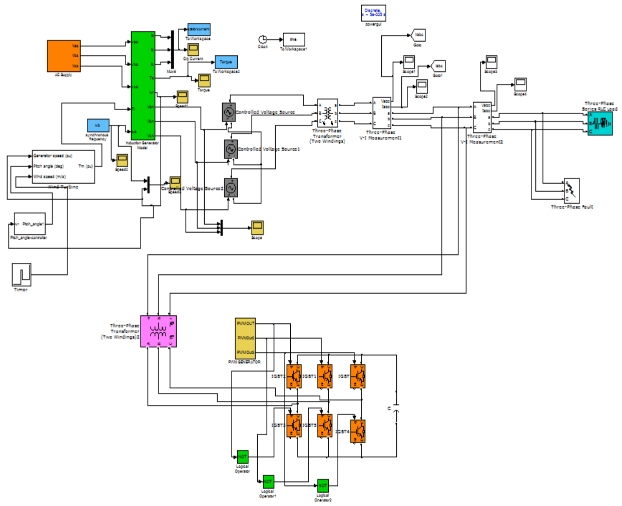

Figure 5: Wind Integrated System with STATCOM

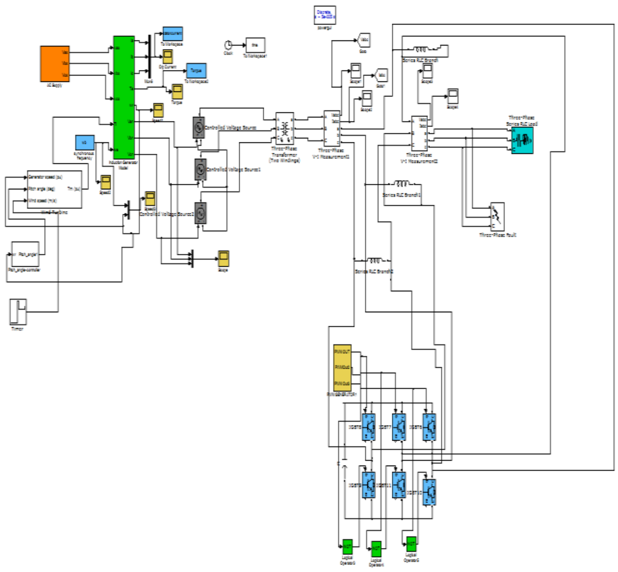

Figure 6: Wind Integrated System with SSSC

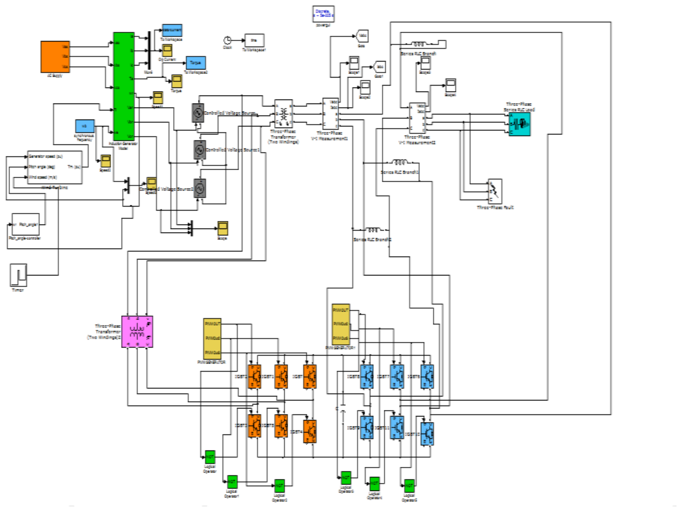

Figure 7: Wind Integrated System with UPFC

The above figure shows the induction generator with STATCOM, SSSC and UPFC. During the time of fault there will be a sudden dip in voltage which is compensated by these FACTs devices.

6. Results and Discussions

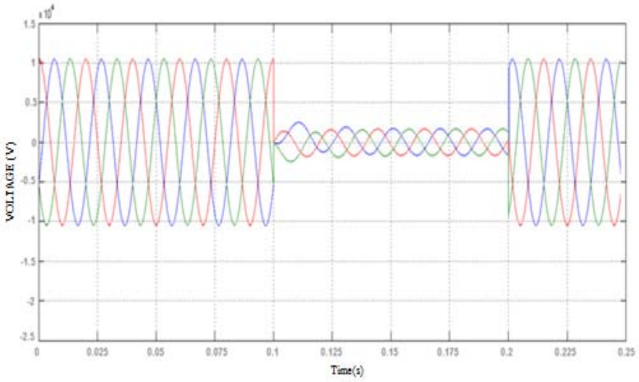

Figure 8: Voltage of Wind Integrated System with Fault

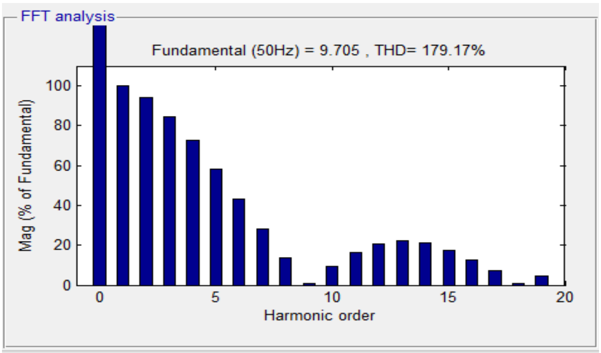

Figure 9: THD with Fault

The above waveform shows the instant of fault where there is sudden dip in voltage at instant between 0.1sec and 0.2sec and after the instant it will recover. At the time of fault Total harmonic distortion will increase and is about 179.17%, which is an undesirable phenomenon and it need to be compensated by FACTS devices on the load side.

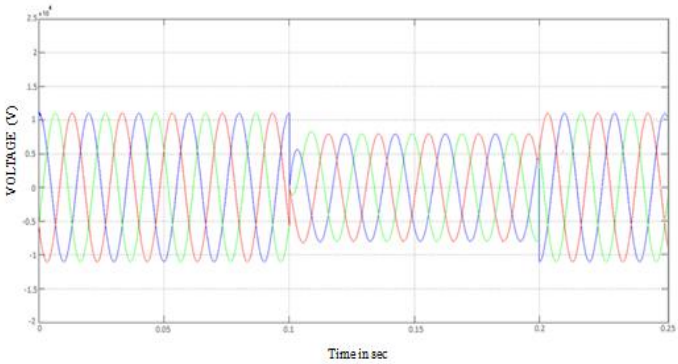

Figure 10: Voltage of Wind integrated system with STATCOM

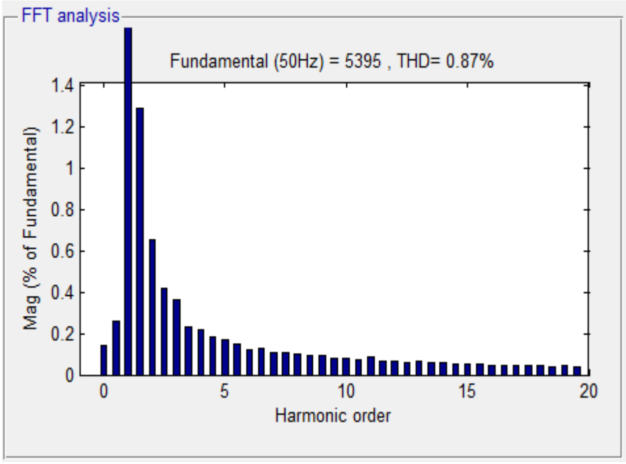

Figure 11: THD with STATCOM

From the above figures, with the help of STATCOM required compensation can be achieved which improves the FRT capability of induction generators and power quality is improved. At the instant of fault that is between 0.1 and 0.2 sec it will suddenly inject a current in to the system with the help of DC link capacitor. Thus at the time fault the total harmonic distortion was about 179.17% which has improved to 0.87% with the help of STATCOM with POD controller and voltage has improved which is the main objective

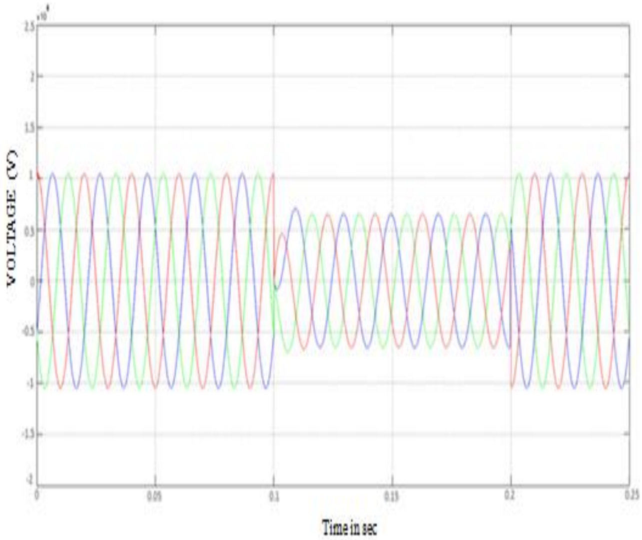

Figure 12: Voltage of Wind Integrated System with SSSC

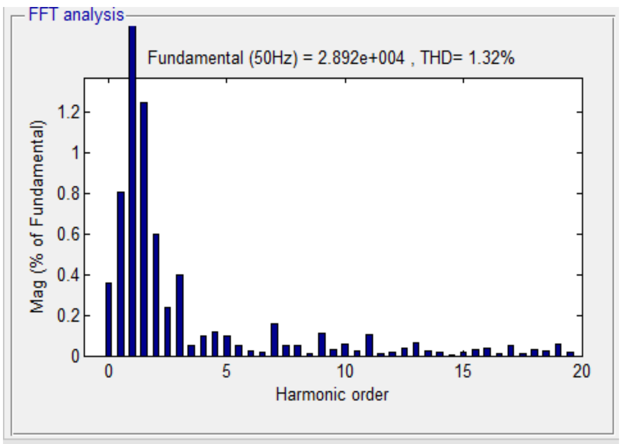

Figure 13: THD with SSSC

With SSSC at the instant of fault it will inject a voltage which will provide necessary compensation and from the voltage waveform and THD value it is seen that at the time of fault the value of voltage have fallen to 1kV now after compensation it has improved to 6.5kV and value of THD has improved from 179.17% to 1.32%. Hence necessary compensation is obtained.

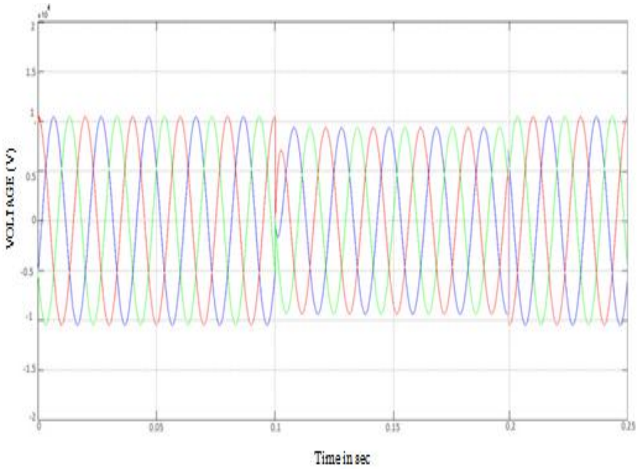

Figure 14: Voltage of Wind Integrated System with UPFC

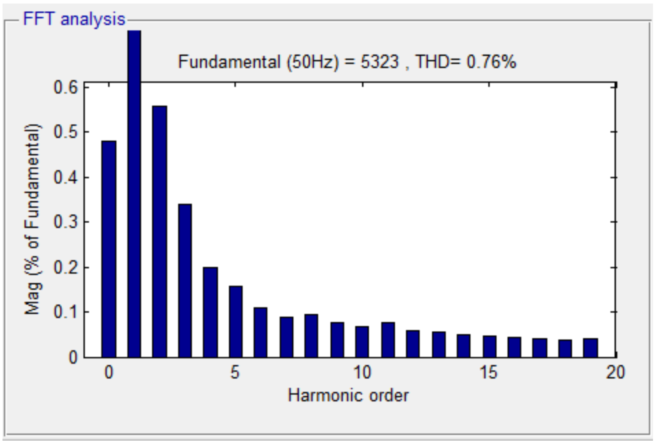

Figure 15: THD with UPFC

During the occurrence of fault power is i.e. the instant between 0.1sec and 0.2sec. UPFC is used to provide necessary compensation. Therefore the necessary reactive power need for dc link capacitor is provided by shunt converter whereas series converter will inject a voltage to the system for compensation. At the time of fault voltage has fallen to 1kV but after compensation by UPFC it has raised to 9kV and THD during fault has improved from 179.17% to 0.76%.

Table 2: Comparison of Results

Types of FACTs Devices	Type of fault	Percentage Improvement in Voltage	THD (%)
Without FACTs Devices	3 Phase	9	179.17%
STATCOM	3 Phase	68	0.87%
SSSC	3 Phase	59	1.32%
UPFC	3 Phase	82	0.76%

7. Conclusion

Fault is one of the severe problems that Induction generators face while generating power in remote areas with the help of wind.. There is a sudden increase in reactive power which will cause sudden voltage sag during fault it will cause problems to the load connected to it. So we use FACTs devices like STATCOM, SSSC and UPFC to compensate by injecting a voltage or current in to the system with the help of shunt converter and series converter and hence necessary compensation can be obtained. The gate pulse of IGBT is controlled by a PWM generator with POD controller. Thus by POD controller serves a major role in improving power quality by eliminating ripples. Hence the compensation is done with UPFC in SIMULINK platform is more effective than the compensation by FACTs devices like STATCOM and SSSC from the output voltage wave form and THD values obtained and the problem is completely eliminated with the help of these FACTS devices. Hence by reactive power compensation by FACTs devices the problem is eliminated which is the main aim of the paper.

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