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SSSC WITH POD CONTROLLER FOR REACTIVE POWER COMPENSATION IN INDUCTION GENERATORS

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ABSTRACT

One of the main problems faced by the Induction generator during fault is voltage sag. This phenomenon is really an undesirable one. The main aim is to introduce SSSC as a solution for this problem. It is connected in series for necessary compensation on its load side. To remove this problem it should be compensated by injecting a voltage in series so that it can provide necessary compensation. For that purpose we are using reactive power compensative devices (FACTS devices). Among the series connected FACTS devices SSSC is more preferred. It consists of a voltage source inverter (VSI). The series VSI is connected via a DC link, which includes a DC capacitor. The Induction generator is modeled using MATLAB SIMULINK is used for modeling of Induction generator. At that time of fault, power quality problems will dominate and active power is reduced. SSSC is used which will supply the necessary reactive power and thus the problem can be eliminated. This paper utilizes a SSSC with PWM generator and POD Controller for providing necessary control and thus for mitigation of power quality problems and hence reactive power compensation can be done which is the main objective.

KEYWORDS: FACTS, SSSC, VSI, POD.

INTRODUCTION

While considering wind turbine generation system (WTGS) to grid one of the key factors to be considered is Voltage Control. When a wind turbine generation system (WTGS) is connected to grid it should satisfy two main requirements they are a) reactive power control during normal operating condition, and b) Fault ride through (FRT) capability during fault condition. Wind turbine generators must remain connected to the grid which is ensured by (FRT). In order to achieve optimum conversion efficiency from wind's kinetic energy to the electrical energy, modern variable speed wind turbines (VSWT) with the help of power electronic converters they are capable of varying their speed. The converters can be used to provide Voltage support/Control can be used to at the level of generator grid interface with an adequate control. In spite of modern VSWT installed in wind farms, there are large amounts of fixed speed wind turbine (FSWT) still in use. Induction generator draws reactive power during fault that is the reason why FSWT exhibits poor FRT performance. A sudden voltage drop occurs at the Induction generators terminal at the time of occurrence of fault. The electrical torque abruptly decreases to zero as the induction generators terminal voltage is reduced and as a result of this rotor speed began to increase. After clearance of fault, the reactive power consumption increases resulting in a period of voltage reduction at the IG terminal. Thus, transient period follows after the fault as induction generator's voltage will not recover immediately. This will lead to unstable operation and it tends to accelerate. Hence, by providing the required reactive power it improves voltage regulation also helps in damping rotor speed oscillations. The solution that can be used to improve the FRT of WECS is the FACTS Controllers.

FACTS controllers can be classified into two based on their connection they are shunt connected devices and series connected compensating devices. The static synchronous series compensator injects a balance voltage in series with the transmission line. It is also connected near industrial loads to improve power quality. But SSSC is more preferred than other series connected. Dc link capacitor will act as a source for compensation.

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Different types of controller can be employed. The SSSC is additionally equipped with a Power Oscillation Damping (POD) control function. Different controllers commonly used are proportional controller, proportional plus integral controller, proportional plus integral plus derivative controller. The controller parameters are optimized using parameter identification.

Design of controllers has a significant role in modeling of SSSC. The SSSC is applied with the DC link voltage with the help of designed controllers and depending on spikes and overshoot responses a suitable DC link voltage is applied. Based on the values of DC link voltage passive components are designed.

This paper utilizes a model of SSSC to study about stability phenomenon and the performance of Induction generator. The SSSC is equipped with a Power Oscillation Damping (POD) control function. Parameter identification is used for optimization of controller parameters

MATERIALS AND METHODS

Static Synchronous Series Compensator (SSSC)

SSSC consist of a voltage source converter with a dc storage capacitor which is connected in series to a transmission line for compensation. It will inject a voltage to the transmission line thus it can provide necessary compensation.

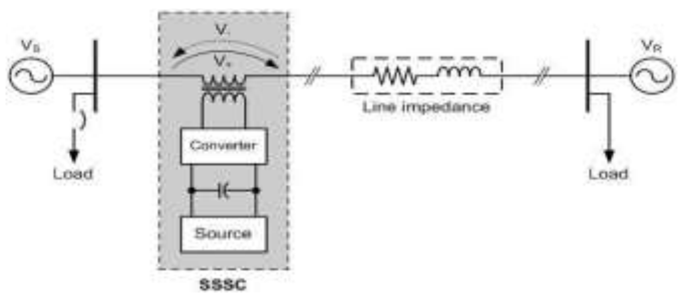

Fig.1. SSSC single line diagram

Working of a Static synchronous series compensator is similar to STATCOM, only difference is that it is serially connected instead of shunt. It can transfer both active and reactive power to the system, permitting it to compensate for the resistive and reactive voltage drops – maintaining high effective X/R that is independent of the degree of series compensation; this is costly as a relatively large energy source is required. A smaller supply will be required if control is limited to reactive compensation. In this case only parameter that can be controlled is the voltage because the voltage vector forms 90º with the line intensity. The SSSC can be uniformly controlled in any value i.e. the serial injected voltage can advance or delay the line current.

The SSSC can inject a voltage component, which is of the same magnitude but opposite in phase angle with the voltage developed across the line. As a result, the effect of the voltage drop on power transmission is offset. The static synchronous series compensator provides fast control and is inherently neutral to sub-synchronous resonance. Generally, the line reactance is constant but its net effect can be controlled through voltage injection. As the inductive reactance compensation level increases from 0% to 100% the line current decreases. Meanwhile, the line current increases with the capacitive reactance compensation level from 0% to 33%.

It can be noted that the static synchronous series compensator does not only increase the transferable power but also decrease it, by simply reversing the polarity of the injected voltage. This reversed polarity voltage is fed directly to the line voltage drop as if the line impedance was increased. In short, the effects of reactance compensation on normalized power flow in the transmission line are as follows:

When the emulated reactance is capacitive, the active and reactive power flow increases and the effective reactance decreases as the reactance compensation increases in the positive direction.

When the emulated reactance is inductive, the active and reactive power flow decrease and the effective reactance increases as the reactance compensation increases in the negative direction

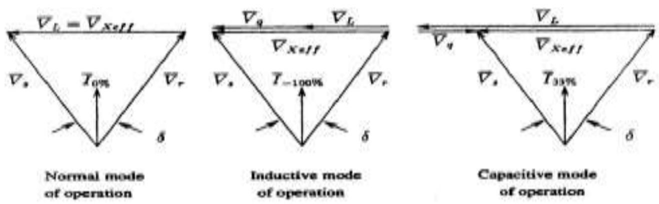

Fig.2. Basic modes of operation of SSSC

Modeling of Induction generator

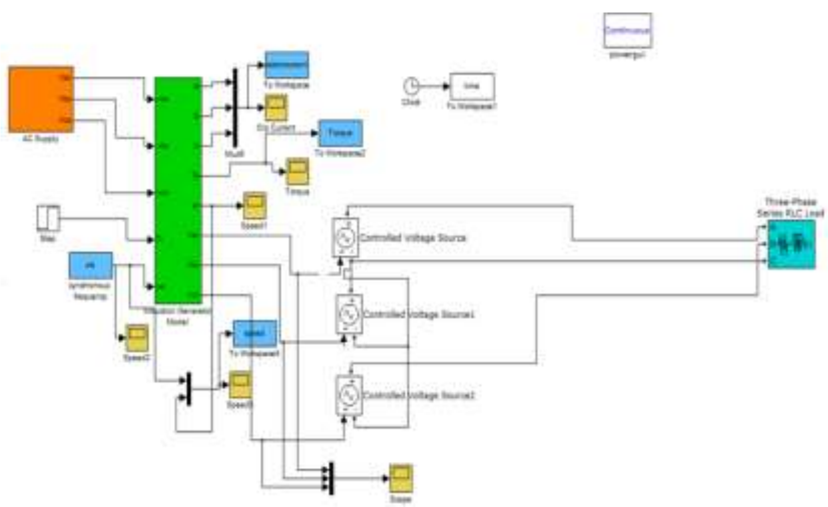

Fig.3. Induction generator model

The above figure shows the simulink model of induction generator in MATLAB/SIMULINK. The induction generator is modelled with the help of flux equations given below:
The equations for flux linkages[2] are:

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

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

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

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

Equations for mutual flux linkages are given below

$$F_{mq} = X'_{ml}[\frac{F_{qs}}{X_{ls}} + \frac{F_{qr}}{X_{lr}}] \ldots (5)$$

$$F_{md} = X'_{ml}[\frac{F_{ds}}{X_{ls}} + \frac{F_{dr}}{X_{lr}}] \ldots (6)$$

Thus the machine is modeled in simulink using the above equations

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POD Controller

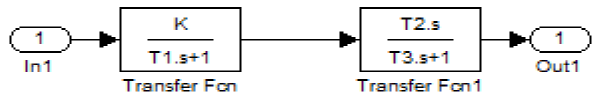

Fig.4. POD controller

The SSSC controller parameters are shown in Table 1. The POD controller constitutes a transfer function which is composed of a transducer with a gain which is followed by a washout filter. The signal obtained at the output is limited. The transfer function constitutes lead-lag filters which can be used for phase compensation of POD controllers. A POD controller is developed which is tuned to provide necessary damping to stabilize the power system after severe disturbances

Table.1. POD Parameters

PARAMETER	VALUE	UNIT
K	1.1058	PU
T1	0..068	Sec
T2	0.145	Sec
T3	0.385	Sec

PWM Generator for SSSC

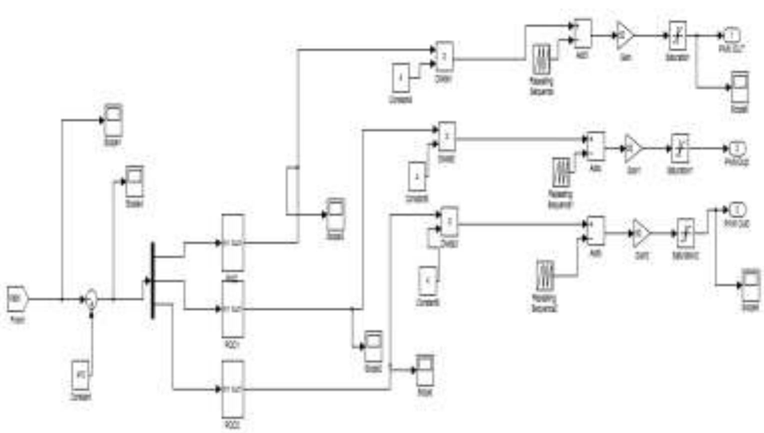

Fig.5. PWM generator with POD controller

The figure shows the modelling of PWM generator for SSSC. 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.

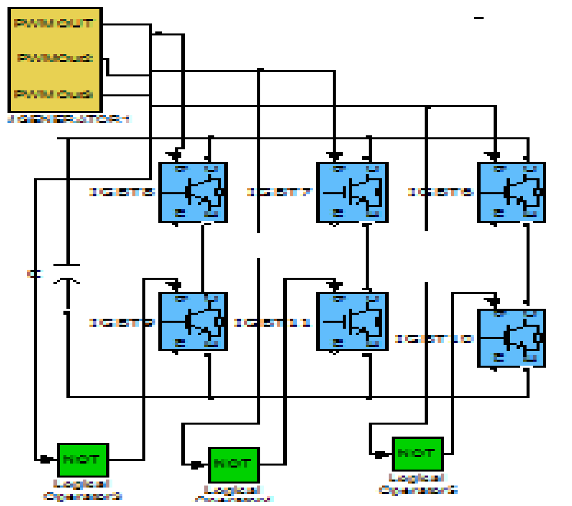

Fig.6. Modeling of SSSC with POD controller in MATLAB/SIMULINK

SSSC is an important device among FACTS family. It is connected in series with transmission line, also it has a superior performance in lot of aspects such as fast responding speed, voltage stabilization and it also limits the transient voltage.

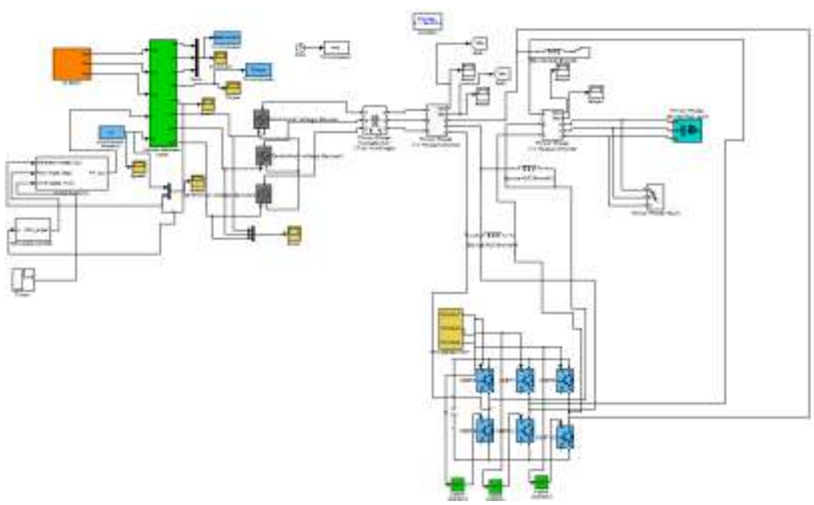

Fig.7. Modeling of Induction generator with SSSC

RESULTS AND DISCUSSION

Induction generator is modeled using MATLAB/ SIMULINK software. A fault with a resistance of 0.1 ohm is applied and fault transition time between 0.1 and 0.2sec At the time of fault and there will be a decrease in active power and increase in reactive power during this time and voltage sag will occur. Results obtained during the simulation shown below so we need to compensate this by using a SSSC so that the voltage can be improved and the quality of power produced is also improved. Here for better understanding simulation time is taken as 0.21. From the voltage waveform at instant of fault SSSC will inject voltage in to the system and thus necessary compensation occurs.

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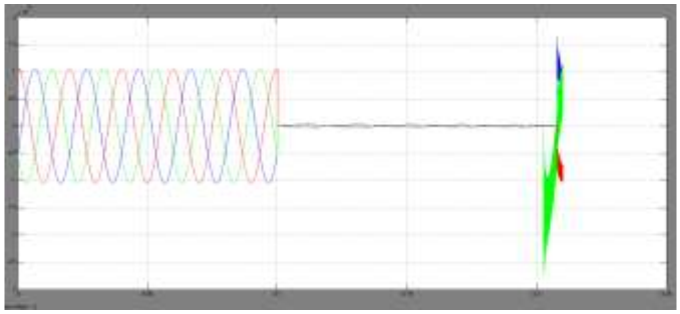

Fig.8. Output Voltage with fault

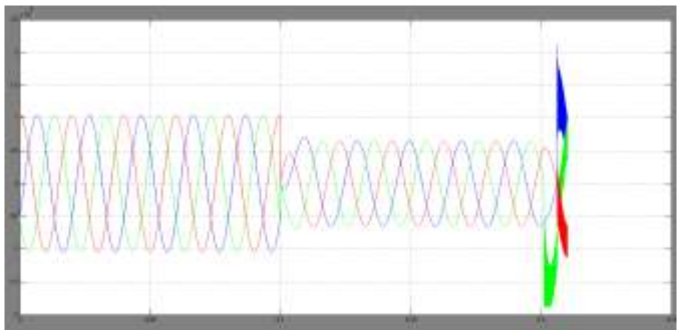

Fig.9. Output Voltage after compensation by SSSC

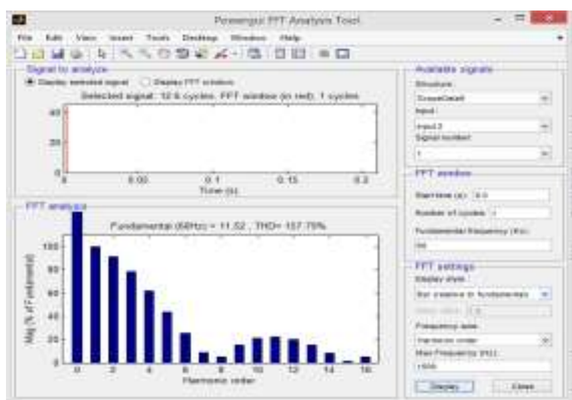

Fig.10.THD without compensation

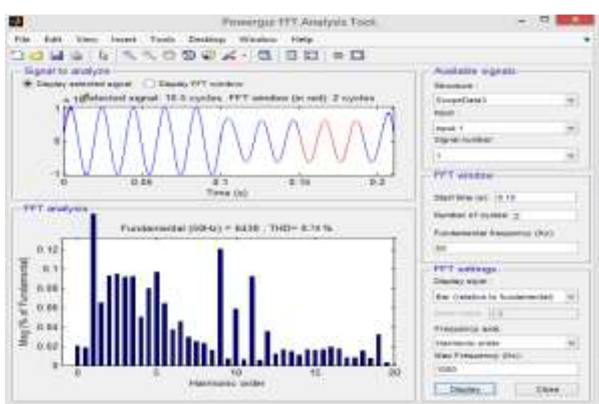

Fig.11. THD after compensation

CONCLUSION

Fault is one of the severe problems that Induction generators face. There is a sudden increase in reactive power which will cause a decrease in voltage during fault it will cause problems to the equipments connected to it. So we use SSSC to compensate by injecting a voltage in to the system 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. Hence the compensation is done with SSSC in SIMULINK platform and the problem is completely eliminated which is clear from output waveform and THD values.

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