Stability Improvement of Wind Generation Using FACTS Device

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Abstract: ***Wind energy is gaining the most interest among a variety of renewable energy resources, but the disadvantage is that wind power generation is intermittent, depending on weather conditions. Energy storage is necessary to get a smooth output from a wind turbine. This paper presents the impact of fault on the system stability by using the fixed speed induction generator (FSIG) based wind farm connected to interconnected power system. Consequently, the stable operation of wind turbine systems is very important for power system stability.***

Keywords: fsig; wtig; voltage stability; statcom; faults

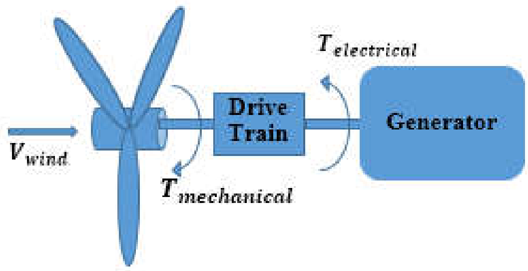
1. Introduction

The increasing number of renewable energy sources and distributed generators requires new strategies for the operation and management of the electricity grid in order to maintain or even to improve the power-supply reliability and quality[1].Wind power continuously give variable output power, when combined with induction generators like the fixed-speed squirrel-cage induction generator (SCIG). .Sometime these induction generators which are usually connected at weak end of a grid or at distribution networks inject large amount of reactive currents during disturbances such as faults[4]. Compared with the wind turbines based on synchronous generators, the squirrel cage induction generator (SCIG) based wind generation technology has several advantages such as flexible active and reactive power control capabilities[3] When a fault occurs in the external power system, the blade-angle control orders the mechanical system to reduce the wind turbine mechanical power to improve stability[6].]. It is necessary to examine the responses of SCIG wind farm during the faults and possible impacts on the system stability the part of STATCOM to support the windfarm during different fault locations and durations are studied.

2. Objective of Work

1) Study under standard IEEE 9 bus system
2) Simulation of bus system with wind generation
3) Simulation of bus system with wind generation with fault
4) Simulation of bus system with wind generation with fault and compensated by FACTS device.

3. Model of Wind Turbine



Wind turbines is the system where electricity produced by using mechanical components and electrical generator. Wind passes over the blades of WT. Lift and exerting a turbine force are generating. In nacelle, the rotating blades turn a shaft that goes into a gearbox. The drive train is increasing the rotational speed that appropriate for wind turbine generator and rotational speed converted into electricity. Wind power extract from the wind by the rotor which is limited by the Betz limit (maximum 59%), Therefore, the mechanical power is expressed in Equation. (1)

$P = 0.5.\ Cp.\ (\lambda, \beta).\ \rho.\ A.\ v3$ (1)

Where Cp(λ, β) is the power coefficient, ρ is the air density (1.25kg/m2), Vw is wind speed(ms−1), and A swept area A is given the equation $A = \pi R2$.Where R is the radius of blade(m). Figure 1 shows the global scheme of variable speed wind turbine.

Aerodynamic model
The blades of wind turbine extract the kinetic energy from the wind and converted mechanical energy. The kinetic energy is equal to the mass of air m and the wind speed in Equation. (2)

$E = 1/2.\ m.\ v2$ (2)
The moving air power is equal to
$Pw = dE/dt = /12.\ m.\ v2$ (2) (3)
Where m is the mass flow rate per second. The air passes across an area A. From the Equation. (3)
$Pw = 12m.\ A.\ \rho.\ v2$ (4)
Where ρ is the air density ($\rho = 1.225 kg/m2$)

The power extracted from the wind by the blades

$PBlade = Cp(\lambda, \beta).\ Pw = Cp(\lambda, \beta).1/2m.\ A.\ \rho.\ v3$ (5)

where Cp is the power coefficient. The power coefficient given two function. β (in degree) is the pitch angle of the rotor blades. The theoretical value of power coefficient isCp = 0.593. λ is defined the tip speed

$\lambda = \omega mR/v$ (6)

Where ωm is the angular velocity of the rotor and R is the length of the rotor blade. The rotor torque given the Equation.

$Tw = PBlade/\omega m = \pi Cp(\lambda,\beta)\rho R2Av3/2\omega m$ (7)

The power coefficient Cp is defined as a function of the blades angle and the tip-speed ratio

$Cp(\lambda, \beta) = c1(c2.1\gamma - c3.\ \beta - c4.\ \beta x - c5)e{-}c61/\gamma$ (8)

With γ defined as

$1/\gamma = 1/\lambda + 0.08\beta - 0.035/\ 1+\beta 3$ (9)

Where the coefficients are equal to $C1$ = 0.5, $C2$ = 116, $C3$ = 0.4, $C4$ = 0, $C5$ = 5, $C6$ = 21 (C4 = 0 that why x is not used)

4. Induction Generator Model

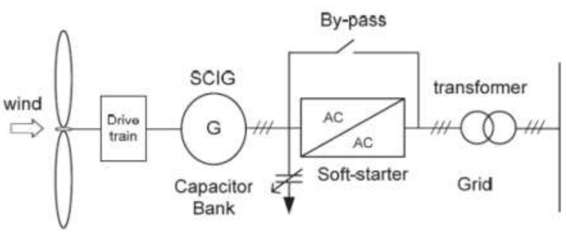


Fig 3.1: fixed speed wind turbine with directly grid connected squirrel-cage induction generator

An induction generator or asynchronous generator is a type of AC electrical generator that uses the principles of induction motors to produce power. Induction generators operate by mechanically turning their rotor in generator mode, giving negative slip. This system stator is connected to grid and rotor is driven by pith of variable wind turbine. In this configuration rotor of SCIG is directly connected to the turbine through the multistage gearbox. . The low rotational speed of the turbine rotor is translated into the high generator rotational speed by a gear box.

Stator voltage equation

Vds = -Rsids – Ws Ψqs +1/wb*d/dt Ψds

Vqs = -Rsiqs – Ws Ψds +1/wb*d/dt Ψds

Rotor equation

Vdr = -Rridr – sWs Ψqr +1/wb*d/dt Ψdr

Vqr = -Rriqr + sWs Ψdr +1/wb*d/dt Ψdr

Flux equation

Ψds = -Xssids +Xm idr

Ψqs = -Xssiqs +Xm iqr

Ψdr = Xrridr -Xm ids

Ψqs = Xrrids -Xm iqs

Active power

Ps = Vds Ids +Vqs Iqs

Reactive power

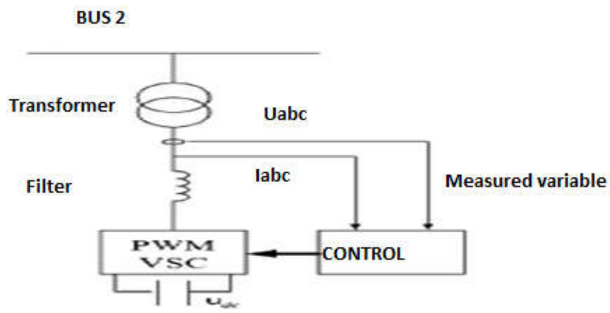
Qs = Vqs Ids –Vqs Iqs

Torque and speed equation are given as follows

Te = Ψds ids –Vqs Iqs

Dwm/dt = 1/2H (Tm-Te)

5. STATCOM



STATCOM with transformer

A STATCOM consists of a PWM voltage source converter (VSC). The VSC can provide a controllable voltage matching the grid voltage in frequency, with the amplitude and phase being continuously and rapidly controlled, so that the VSC can absorb or generate reactive power to control the voltage at the wind farm terminal. The converter can be multiple level or multiple pulses for high power and low harmonic operation. However, only a simple six-pulse PWM voltage source converter is presented here to illustrate the principle. A STATCOM may be applied at any voltage level with a coupling transformer. In the studied system, the STATCOM is connected in shunt to the point of common coupling (bus 2) through a transformer as shown in Fig. Usually, the STATCOM is applied to voltage support goals. At system voltage is a decrease, the STATCOM inject reactive power (STATCOM capacitive). At system voltage is increases; it absorbs reactive power (STATCOM inductive). Statcom is installed to support electricity network that have poor power factor and poor voltage regulation.

6. Simulation and Result

6.1: Standard 9 bus with wind generation without fault

Table-2: Generator Data

Generator	1	2	3
Rated MVA	247.5	192.0	128.0
KV	16.5	18.0	13.8
Power Factor	1.0	0.85	0.85
Type	Hydro	Steam	Steam
Speed	180 r/min	3600r/min	3600 r/min
X_d	0.1460	0.8958	1.3125
X'_d	0.0608	0.1198	0.1813
X_q	0.0969	0.8645	1.2578
X'_q	0.0969	0.1969	0.25
X_l (leakage)	0.336	0.0521	0.0742
T'_{d0}	8.96	6.00	5.89
T'_{q0}	0	0.535	0.600
Stored Energy at rated speed	2364 MW/s	640 MW/s	301 MW/s

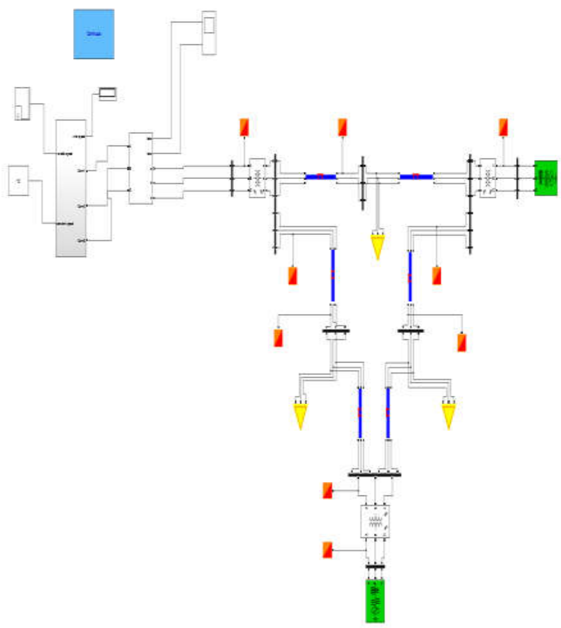
The generator internal voltage and their initial angles are given in pu by

$$E_1\angle\delta_{10} = 1.0566\angle 2.2717$$
$$E_2\angle\delta_{20} = 1.0502\angle 19.7315$$
$$E_3\angle\delta_{30} = 1.0170\angle 13.1752$$

5. DATA SHEET OF 9 BUS SYSTEM

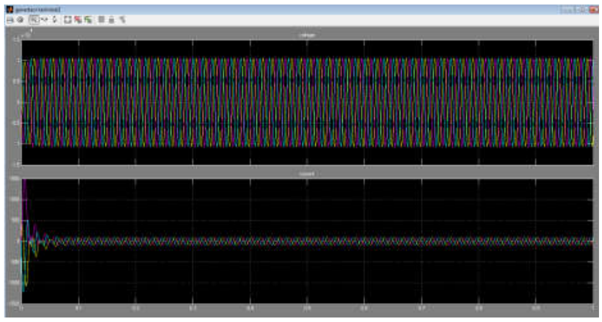
Table-1: Prefault Network Admittance including load Equivalents

	BUS No	Impedance		Admittance	
		R	X	G	D
Generator					
No 1	1-4	0	0.1184	0	-8.4459
No 2	2-7	0	0.1823	0	-5.4855
No 3	3-9	0	0.2399	0	-4.1684
Transmission Line					
	4-5	0.0100	0.0850	1.3652	-11.6041
	4-6	0.0170	0.0920	1.9422	-10.5107
	5-7	0.0320	0.1610	1.1876	-5.9751
	6-9	0.0390	0.1700	1.2820	-5.5882
	7-8	0.0085	0.0720	1.6171	-13.6980
	8-9	0.0119	0.1008	1.1551	-9.7843
Shunt Admittance					
Load A	5-0			1.2610	-0.2634
Load B	6-0			0.8777	-0.0346
Load C	8-0			0.9690	-0.1601
	4-0				0.1670
	7-0				0.2275
	9-0				0.2835

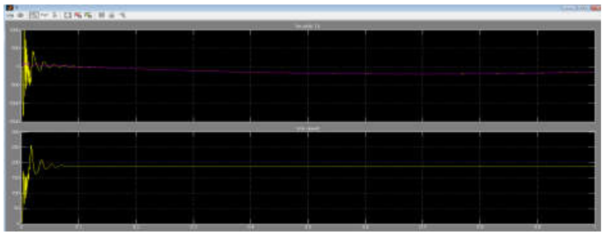


7. Result

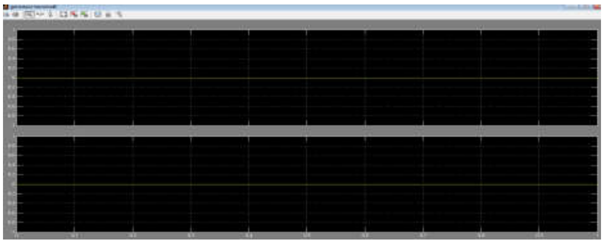
Voltage and current waveform without fault



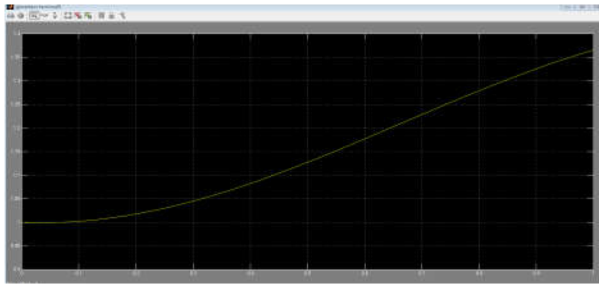
Mechanical electrical torque and wind speed without fault



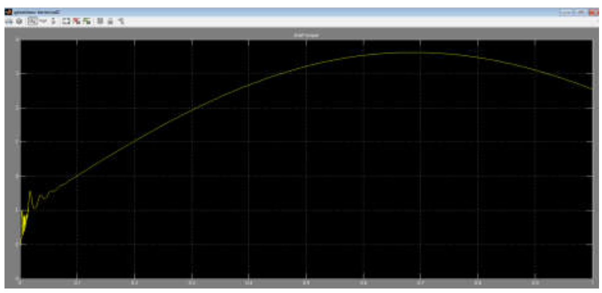
Pitch control without fault



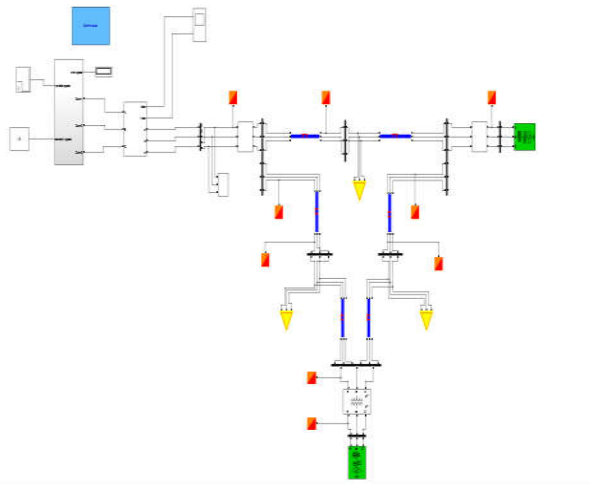
mass drive without fault



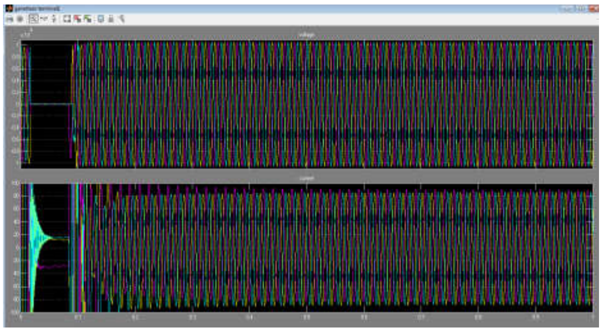
Shaft torque without fault



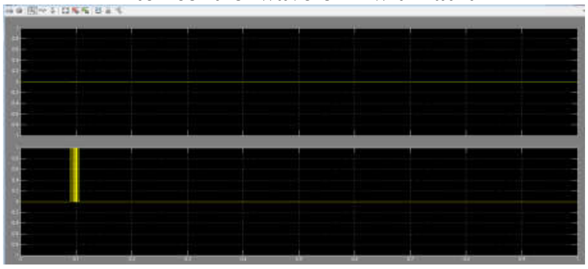
6.2: Standard 9 bus with wind generation with fault



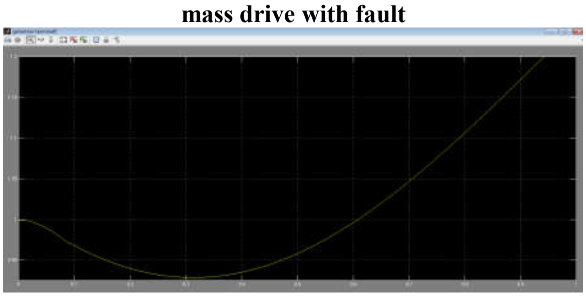
Voltage and current waveform of SCIG with fault



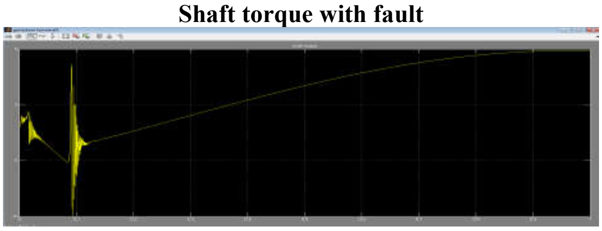
Pitch control waveform with fault



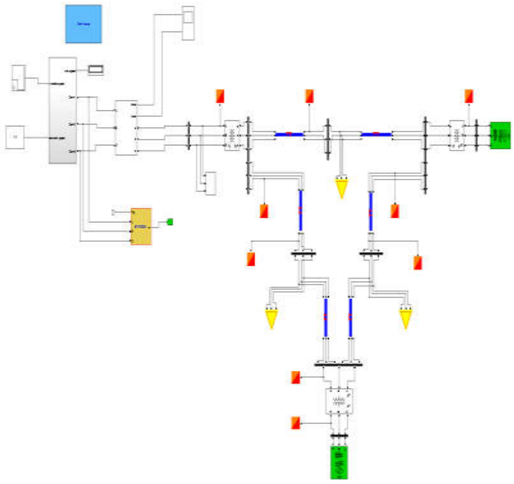
mass drive with fault

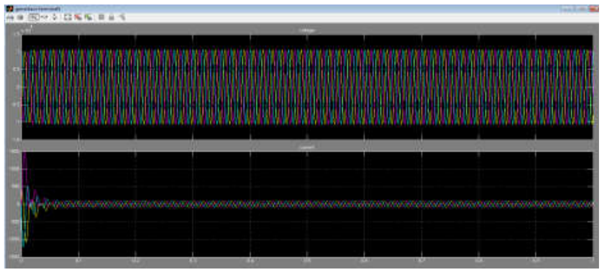


Shaft torque with fault

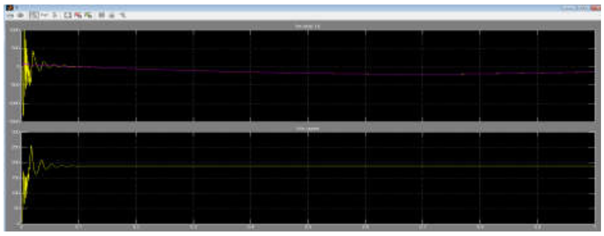


6.3 wind generation with standard IEEE 9 bus system with STATCOM

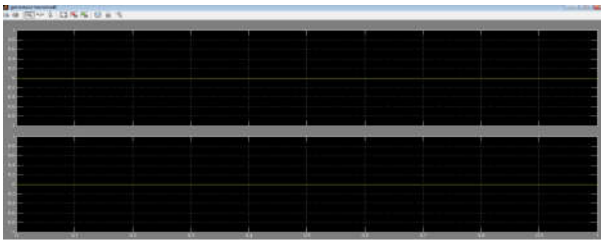




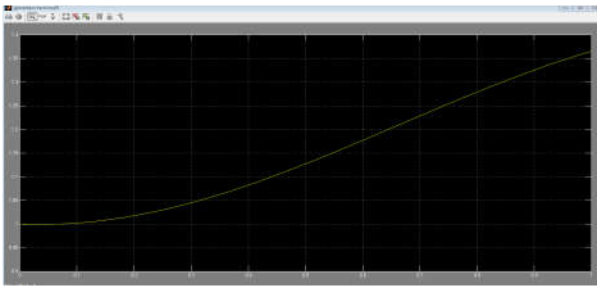
Mechanical electrical torque and wind speed with fault and STATCOM



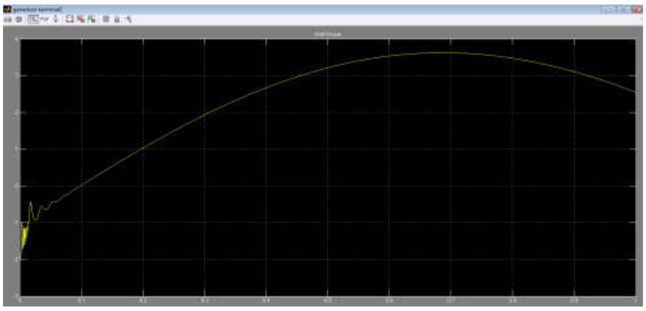
Pitch control with fault and STATCOM



mass drive with fault and STATCOM



Shaft torque with fault and STATCOM



8. Conclusion

This paper explains the basic concept of squirrel cage induction generator with wind turbine connected to grid. In this system many problems occur and this problem compensated by using STATCOM. It full fill the reactive power requirement of the system at the time of fault occur in the system. Because when fault occur on system then volage low and system get unstable so in that case STATCOM help the system.

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