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Stability enhancement of doubly fed induction generator equipped wind farm using facts device

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Abstract- The current scenario of the world is that the power demand in the world is increasing at a very fast rate, to get an economical source of the power; renewable energy sources are proving out to be a reliable option. Hence wind energy systems are very much important for the power system engineers. In order to meet the demand of the world the wind energy is injected into the electric power grid. Along with the increase of power, the main issue arises due to power injection from wind a turbine is that the power quality of the present electric grid falls from its standards. The main reason for the substandard power quality of wind power system is that the generation of power from wind turbine is not constant as the power generation is dependent on the flow of wind which is not always constant, so we face many challenges like variable frequency throughout the generation, variation in active and reactive power. Due to this poor quality of power the problems of voltage fluctuations, flickering, harmonics and transients etc. arises. Now in order to mitigate this problem FACTS devices are injected with the wind generation system. These FACTS devices will provide reactive power compensation and also will provide voltage regulation. Due to this the demand of reactive power from load and generation will decrease and hence burden on supply side will be reduced. Hence the power quality will be enhanced.

Keywords- DFIG, stability, FACTS, power quality, STATCOM.

1. Introduction

Nowadays globally people are concerning about environmental pollution and energy shortage is increasing the interest in electrical energy generation using renewable energy resources. In dispersion of various renewable energy sources, wind energy is briskly growing non - conventional energy source. In modern power electronic, the perception of fixed speed wind turbine along with induction generator is getting more popular.

Wind force is extricated from wind employing wind turbines or drift to create mechanical or electrical power. Wind control is a distinct option for conventional fuels, and source of power from wind is inexhaustible, renewable, and clean, emits no flue gas or any sort of waste into environment and uses small share of land. The net consequences for nature are for the most part less tricky than those from non-renewable force sources. Extensive wind homesteads can constitute of many single or respective wind turbines which are associated with the electric force transmission system.

Doubly Fed Induction Generator (DFIG) is basically utilized for the wind turbines. These DFIG's comprise of a rotor sort actuation generator and IGBT based PWM converter. The stator slowing down supplied by the 50 HZ settled recurrence through the network and the variable recurrence is supplied to the rotor through AC/DC/AC converter.

The converter utilized here is an AC/DC/AC converter which utilizes PWM converter in which sinusoidal PWM strategy is utilized to decrease the sounds which are accessible in the wind turbine driven DFIG system. Gear boxes or else electronic control are utilized to control the velocity of the winder turbine. The stator is sustained by the AC mains and the rotor is supplied by the AC/DC/AC converter through the slip rings to allow DFIG to capacity at a different rate reaction as indicated by the change in wind speed. A recurrence converter must be incorporated in the middle of variable recurrence impelling generator and the matrix. A DC capacitor is utilized as a connection in the middle of stator and rotor side converter with the end goal of stream of force from affectation generator to continue further. The DC join voltage must be kept more prominent than the plentifulness of line-to-line voltage of lattice to get full control of system current. The slip force can stream in both the bearings i.e. from supply to the rotor furthermore from rotor to supply in sub-synchronous velocity ranges. Due to this themachine can go about as a generator and an engine in both sub-synchronous and super working modes.

In this paper rotor flux oriented VC scheme is presented for both GSC and RSC by different conditions rotor currents and its effect on grid are measured. Results obtained enlighten the effectiveness of controller.

2. DFIG Modeling

Doubly Fed Induction Generator (DFIG) is basically utilized for the wind turbines. These DFIG's comprise of a rotor sort actuation generator and IGBT based PWM converter. The stator slowing down supplied by the 50 HZ settled recurrence through the network and the variable recurrence are supplied to the rotor through AC/DC/AC converter. By enhancing the pace of the wind turbine, the most extreme accessible vitality is taken from the wind amid low wind speeds and the mechanical anxieties are diminished in the turbine amid tempests.

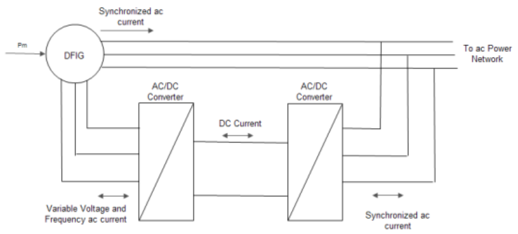


Fig: 1 Block diagram of DFIG

The stator is sustained by the AC mains and the rotor is supplied by the AC/DC/AC converter through the slip rings to allow DFIG to capacity at a different rate reaction as indicated by the change in wind speed. A recurrence converter must be incorporated in the middle of variable recurrence impelling generator and the matrix. A DC capacitor is utilized as a connection in the middle of stator and rotor side converter with the end goal of stream of force from affectation generator to continue further. The DC join voltage must be kept more prominent than the plentifulness of line-to-line voltage of lattice to get full control of system current. The slip force can stream in both the bearings i.e. from supply to the rotor furthermore from rotor to supply in sub-synchronous velocity ranges. Due to this the machine can go about as a generator and an engine in both sub-synchronous and super working modes.

The mechanical power and the stator electric power output are computed as follows:

$$P_r = T_m * w_r \quad (1)$$

$$P_s = T_{em} * w_s \quad (2)$$

For a lossless generator:

$$j\frac{dw_r}{dx} = T_m - T_{em} \quad (3)$$

In steady state at fixed speed for a loss less generator

$$T_m = T_{em} \quad (4)$$

$$P_m = P_s + P_r \quad (5)$$

And

$$P_r = P_m - P_s = T_m w_r - T_{sm} w_s = -sP_s \quad (6)$$

Where

$$s = (w_s - w_r)/w_s \quad (7)$$

Now the machines works as a generator, which converts the mechanical power of the turbine into electrical power which is delivered to the load connected to the stator terminals. The machine will feed power into the grid, if it is connected to the grid. Therefore, at the speed higher than the synchronous speed, the induction machine can work as the electrical generator. This condition, during which the generator operation occurs at this speed, is called as super-synchronous speed operation of the induction machine.

3. Statcom Model

Typically a STATCOM is introduced to support power organizes that have a poor force element and frequently poor voltage regulation. There are then again, different uses, the most well-known utilization is for voltage dependability. A STATCOM is a voltage source converter (VSC)-based gadget, with the voltage source behind a reactor. The voltage source is made from a DC capacitor and consequently a STATCOM has almost no dynamic force ability. On the other hand, its dynamic force ability can be expanded if a suitable vitality stockpiling gadget is associated over the DC capacitor. For instance, if the terminal voltage of the VSC is higher than the AC voltage at the purpose of association, the STATCOM produces responsive current; then again, when the adequacy of the voltage source is lower than the AC voltage, it assimilates receptive force. The reaction time of a STATCOM is shorter than that of a SVC, predominantly because of the quick exchanging times gave by the IGBTs of the voltage source converter. The STATCOM likewise gives better responsive force support at low AC voltages than a SVC, since the receptive force from a STATCOM diminishes straightly with the AC voltage (as the current can be kept up at the evaluated esteem even down to low AC voltage).

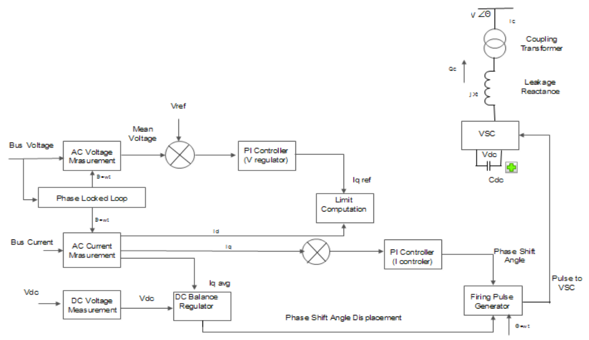


Fig: 2 Basic Block diagram of STATCOM

STATCOM is installed to increase the stability of electric networks having poor power factor and poor voltage regulation. STATCOM has low active power capability as the voltage source is created from a DC capacitor and if suitable energy storage device is connected across the DC capacitor; its active capability can be increased.

Its model describes the utilization of most exceptional innovation for element VAR remuneration. It is otherwise called DSTATCOM when apply in distribution side. STATCOM is joined parallel in force system and acts as responsive current source. Its responsive current can be adaptable controlled and repay receptiveforce for system consequently. It tackles issue of sounds meddle exchanging parallel capacitor banks. In another hand, it can limit harmonics and enhance power quality as indicated by clients' necessities.

4. System Description

Single line diagram of variable speed wind power plant under study is shown in below diagram. This Simulink model shows a 9 MW wind farm employing Doubly Fed Induction Generator driven by a wind turbine. Generator data is shown below in Table 2. It comprises of six 1.5MW wind turbines associated with 25 kV distribution system which distributes power to 120 kV grid over 30 km, 25kV feeder. Turbine data is shown below in Table 1. Wind turbine using DFIG comprises of an AC/DC/AC IGBT-based Pulse Width Modulation Converter and a wound rotor induction generator. Converter data is shown below in Table3. The rotor of DFIG is driven by variable frequency through AC/DC/AC converter of wind turbine and stator winding of DFIG is connected to 60 Hz grid. During gusts of wind Doubly-Fed Induction Generator technique permits to pull out maximum energy from wind whereas minimizes mechanical stress on the turbine. A STATCOM is connected in the system to keep the system under stable conditions. And to figure out the performance of STATCOM a three-phase to ground fault is introduced into the system.

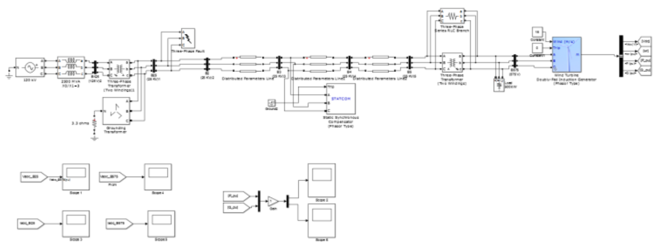


Fig: 3Diagram of studied system

5. Simulation Results and Analysis

The Simulink model is carried out using MATLAB SimPowerSystem Toolbox. The behaviour of wind farm is observed throughout fault events and after fault clearance. The system is studied twice: once with STATCOM connection and the other without STATCOM connection.

A. Experimental Work:

Initially the doubly fed induction generator equipped wind farm produces 9MW of power. Equivalent turbine speed is 1.2 p.u of generator synchronous speed.

The DC Bus voltage is kept at 1150V and reactive power is kept 0 Mvar. And suddenly at t=0.03s there is a drop in positive-sequence voltage to 0.5 p.u. which causes oscillation on Doubly-Fed Induction Generator output power and on DC Bus Voltage. During the occurrence of fault the STATCOM tries to stabilize the system by regulating the reactive power and DC Bus Voltage at their set points. Due to the effect of STATCOM the system recovers the steady state in approximately 4 cycles.

Table 1: Turbine data

Turbine Data	
Nominal output power	6*1.5e6W
Mech. Power	0.73pu
Wind speed	12m/s
Pitch angle controller gain	500kp
Rate of change of pitch angle	2 deg/s

Table 2: Generator Data

Generator Data	
Nominal power	1.5e6/0.9VA
L-L voltage	575 Vrms
Frequency	50Hz
Stator resistance	0.00706pu
Stator inductance	0.156pu
Rotor resistance	0.005pu
Rotor inductance	0.156pu
Magnetising inductance	2.9pu
Inertia constant	5.04
Friction factor	0.01
Pairs of pole	3

Table 3: Converter Data

Converter Data	
Converter maximum power	0.8pu
Grid-side coupling inductor	L 0.3pu R0 0.003pu
Nominal DC bus voltage	1150 V
DC bus Capacitor	10000e-6F
Reference grid voltage	1.0pu (Vref)
Droop (Xs)	0.02pu

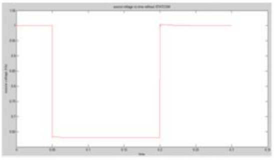
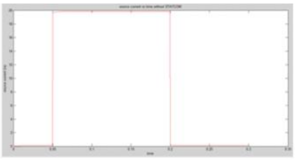
Table 4: STATCOM Parameters

STATCOM Parameters	
System nominal voltage (Vrms L-L)	500e3
Frequency (f)	60Hz
Converter rating (VA)	100e6
Converter resistance (Rpu)	0.22/30
Converter inductor (Lpu)	0.22
Converter initial current (Mag.(pu) Pha(deg.))	0
DC link nominal voltage (V)	40000
DC link total equivalent capacitance (F)	750e-6/2
Reference voltage Vref (pu)	1.00
Maximum rate of change of reference voltage Vref (pu/s)	10
Droop (pu)	0.03
Vac regulator Gain [Kp]	5
Vac regulator Gain [Ki]	1000
Vdc regulator Gain [Kp]	0.1e-3
Vdc regulator Gain [Ki]	20e-3
Current Regulator Gain [Kp]	0.3
Current Regulator Gain [Ki]	10
Current Regulator Gain [Kf]	0.22

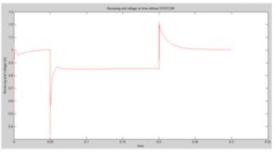
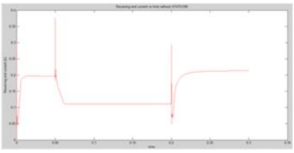
B. Simulation waveforms

The simulation results for the fault occurring in the system without and with STATCOM has been represented in Fig.4

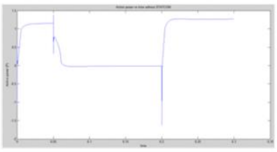
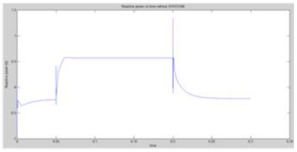
(a) to (f) and in Fig.5. (a) to (f) respectively. Fig.4 (a) and (b), it represents the source voltage current and voltage. It is observed that during fault, there is a voltage drop in magnitude from time period of 0.05sec to 0.2sec and during that time there is an increase in current. In Fig.5 (a) and (b), the source end voltage and current remains same after the connection of STATCOM. From Fig.4 (c) it is observed that there is a voltage drop to 0.9 pu and in (d) it is observed that the receiving end current drops to 0.2 pu. In Fig.5 (c) it can be seen that after connecting STATCOM, the voltage profile rises to full magnitude of 1 pu and in Fig.5 (d) it can be seen that the current rises to 0.2 pu after connecting STATCOM. In Fig.4 (e) the active power is 0 without STATCOM and it increases to 1 pu after connecting STATCOM in Fig.5 (e). In Fig.4 (f) the reactive power is 0.5 pu and it decreases to 0 after connecting STATCOM in Fig.5 (f).

(a) Sending end voltage (b) Sending end current

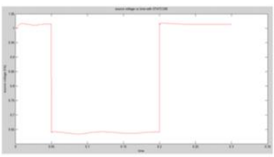
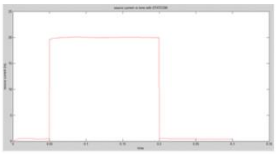



(c) Receiving end voltage (d) Receiving end Current

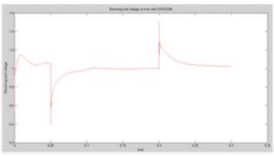
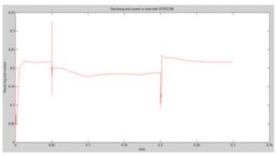



(e) Active power (f) Reactive power

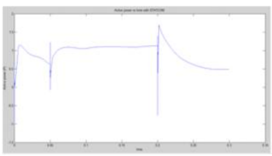
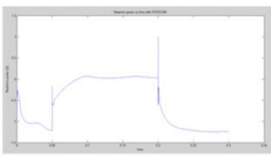
Fig.4. Simulation waveforms for fault without STATCOM

(a) Source voltage (b) Source current

(c) Receiving end voltage (d) Receiving end Current

(e) Active power (f) Reactive power

Fig.5. simulation waveforms for fault with STATCOM

6. Conclusion

In this thesis a Doubly-Fed Induction Generator wind farm under a three-phase to ground fault is been simulated and an appropriate controller is designed to supply required reactive power to the system to maintain stability. Initially there is dip in Active Power when fault occurs in the system but when STATCOM is introduced on the system it helps the active power to be under stable conditions. When the STATCOM is connected to the system, it can return back to steady state and DFIG wind farm can stay connected to the grid. In case of three-phase to ground fault when system operates without STATCOM the protection system trips the wind farm due to under-voltage condition. A Static VAR Compensator (SVC) can also be used for voltage stability. Even still, STATCOM has better characteristics than SVC. If the system voltage drops sufficiently to force the STATCOM output current to its ceiling, its maximum reactive output current will not be affected by the voltage magnitude. Because of this, it exhibits constant current characteristics when the voltage is low under the limit. SVC's reactive output is proportional to the square of the voltage magnitude.

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