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Application of Induction Machine in Wind Power Generation System

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ABSTRACT

Power generation due to fossil fuel is not eco friendly and economical. Non conventional sources are the option to overcome the problems due to fossil fuels. Power generation by wind is one of the option which is eco friendly and economical in long term. This paper deals with application of induction machine as a wind generator. Simulation is carried out in MATLAB environment and results are investigate for no load, load and load with STATCOM condition. STATCOM is suggested at load bus to improve the system stability.

Keywords

Fixed speed induction generator, STATCOM, voltage stability.

1. INTRODUCTION

Electrical energy is a very crucial issue as its demand is more than the generation. Energy has been the important driving force of the continual progress of human application. According to the current energy sources about 86% of total energy is generated from fossil fuels, 8% is generated from nuclear plants, and remaining 6% comes from renewable sources(mainly wind power, hydro and biomass). Unfortunately the world has limited amount of fossil fuel and nuclear power resources. Besides our overdependence on fossil and nuclear fuels is causing environmental pollution and safety problems, which are now becoming dominating issues in our society. In various countries like Europe wind power development dominates the global market for ex. Denmark produces 20% of total energy from wind power and they are targeting 50% of total share of energy from wind power by 2025[1]. The installed capacity of wind power in India was 17967 Mw in 2011. It is estimated that 6000 Mw of additional wind power capacity will be installed in India in coming 2-3 years. Wind power accounts for 60% of India's total installed power capacity and it generates 1.6% of country's power.

Wind power has many advantages that makes it a lucrative source of power for both utility-scale and small distributed power generation applications. Wind power is a clean and endless fuel as it doesn't produce any emissions and is not run down with time. The thermal power plants use fossil fuels like coal, oil as the fuel for producing electricity but wind power plant doesn't need any fuel. They use atmospheric wind which is available abundantly and freely. Also the size of plant and cost of generating electricity is more as compared to wind power plant.

Although the use of variable speed wind turbines with power electronics interfaces is the trend, many grid directly connected induction generator based wind turbine are still in operation, such as Fixed speed induction machine (FSIM) or wounded rotor induction machine. Voltage instability problems and collapse typically occur on power system that is not able to meet demand of reactive power, for considering heavy loads and fault conditions. When wind farms are connected to a weak network, the voltage stability is one of the most important factors that affect wind farm's stable operation. The common types of wind turbine are fix-speed turbine with induction generator directly connected to the grid. An induction generator connected with a wind turbine to generate electricity is sink of reactive power. Therefore, the compensation of reactive power is necessary in order to maintain the rated voltage on network to which the wind farm is connected.[2] This paper deals with the application of induction machine as a generator. Fixed speed induction generator(FSIG) is used as a wind generator and is carried out in MATLAB environment. Results are investigate for no load, load and with STATCOM condition. STATCOM is suggested at load bus to improve system stability.

2. MODELLING

The working principle of the wind turbine includes the following conversion processes: the rotor extracts the kinetic energy from the wind creating generator torque and the generator converts this torque into electricity and feeds it into the grid. Presently there are three main turbine types available

They are

- Fixed speed induction generator
- Doubly fed induction generator.
- Direct-drive synchronous generator.

In this paper in order to investigate the effect of voltage on the stability of the system fixed speed induction generator is considered.

The mechanical power and the aerodynamic torque developed by a wind turbine are given by:

$$P_W = \frac{\pi \rho r^2}{2} v_{wind}^3 c_p(\lambda . \beta) \quad (1)$$

$$T_W = \frac{\pi \rho r^3}{2} v_{wind}^2 c_p(\lambda . \beta) / \lambda \quad (2)$$

Where,

P_W - Mechanical output power of the turbine (W)

T_W - the aerodynamic torque (N/m),

c_p -Performance coefficient of the turbine

ρ- Air density (kg/m^3)

v_{wind} - Wind speed (m/s)

λ -Tip speed ratio of the rotor blade

β - Blade pitch angle (deg).

3. FIXED SPEED INDUCTION GENERATOR

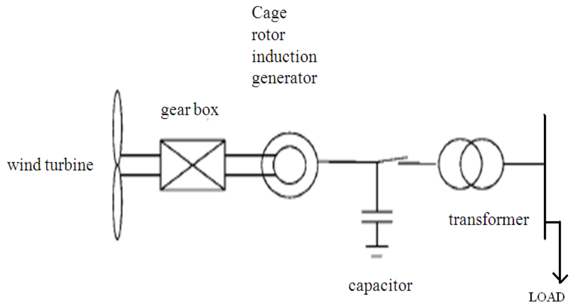

Fig.1. Fixed speed induction generator

An induction generator or asynchronous generator shown in fig 1. 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.

In this paper(asynchronous) fixed speed induction generator is used to convert mechanical energy into electricity. An induction generator may be directly connected to the grid. Wind turbines produce electricity by using the power of the wind to drive an electrical generator. Passing over the blades, wind generates lift and exerts a turning force. The rotating blades turn a shaft inside the nacelle, which goes into a gear box. The gearbox adjusts the rotational speed to that which is appropriate for the generator, which uses magnetic fields to convert the rotational energy into electrical energy[2].

The features of this type of system are simple and cheap construction and no synchronism device is required. The demand for reactive for the reactive power is normally met by capacitor banks that may be switched in or out according to the real power production. The reactive power demand will increase when the machine speed is diverted from synchronous speed, and will reduce if the machine terminal voltage get dropped. For this kind of generators, the steady state generated active Pe and reactive power Qe are approximated as:

$$Pe = \frac{p}{2}\frac{Rr}{S\omega_e}\frac{V^2\Omega_r}{(R_s + R_r/S)^2 + (\omega_e)^2(L_{LS} + L_{Lr})^2} \tag{3}$$

$$Q_e = \frac{V^2}{\omega_e L_m S} + \frac{V^2\omega_e(L_{LS} + L_{LR})}{(R_s + R_r/S)^2 + (\omega_e)^2(L_{LS} + L_{Lr})^2} \tag{4}$$

Where,

P = the number of poles,

L_m is the magnetizing inductance,

Rr and Rs are the rotor and stator side resistance,

Ω_r is the electrical rotor speed

ω_e is the line frequency

V is the stator voltage

Ls and Lr are the leakage inductance

S is the slip

All the electrical quantities are referred to the stator side.

STATCOM OPERATION

4. STATCOM OPERATION

STATCOM is a power electronics device based on the voltage source converter principle. The technology typically in use is a two level voltage source converter with a DC energy storage device, a coupling transformer connected in shunt with the power system, and DSP based control circuits.[4] The main advantage of the STATCOM over thyristor type of static var compensators is that the compensating current does not depend on the voltage level of the connecting point and thus the compensating current is not lowered as the voltage drops. However, in the light of the new grid codes for wind generation, the most relevant feature of the STATCOM will be its inherent capability to increase the transient stability margin and thus contribute with ride through handling. STATCOM configuration is shown in fig .2

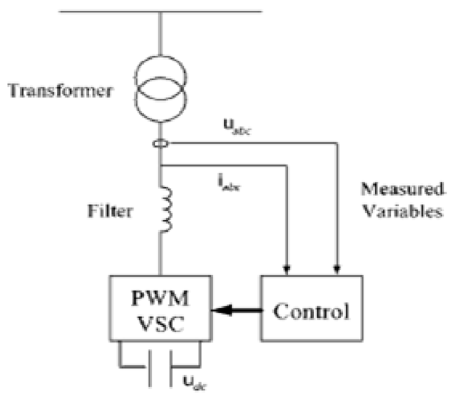

Fig .2. STATCOM configuration

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FSIM is used as a wind generator. Simulation is carried out in MATLAB environment and the results are verified for no load, load and load with STATCOM. STATCOM is assigned at load to improve the stability. The basic block diagram is shown in fig 3.

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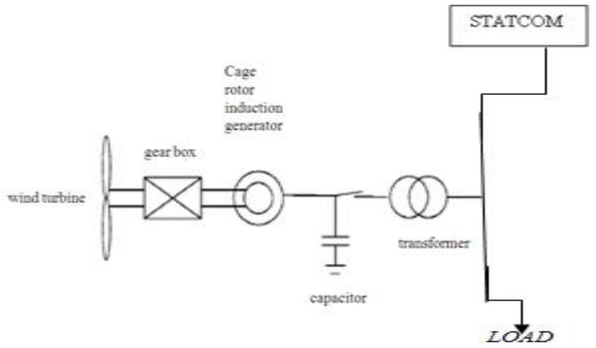

Fig. 3 Block diagram of FSIG with STATCOM

System parameters are reported in table 1, 2 and 3. Simulation is carried out for no load, load and load with STATCOM in terms of voltage, speed and torque. Results are investigated and are shown in table 2.

Table . 1: Wind turbine parameters

Rated power , mw	2
Rated voltage kV	0.96
Rotor diameter, m	76
Moment of inertia kgm^2	9.0x10^6

Table . 2: Transformer parameters

Rated capacity, MVA	2
High voltage, kV	11
Low voltage, kV	0.96
Magnetizing current, %	1
Positive sequence leakage reactance, p.u.	0.1

Table . 3: Fixed speed induction generator

Rated power MW	2
Rated voltage kV	0.96
Angular moment of inertia (2H), s	1.0094
Mechanical damping, p.u.	0.01
Stator resistance, p.u.	0.0063
Rotor resistance, p.u.	0.0113
Stator leakage inductance, p.u.	0.1574
Rotor leakage inductance, p.u.	0.1181
Mutual inductance, p.u.	5.9043

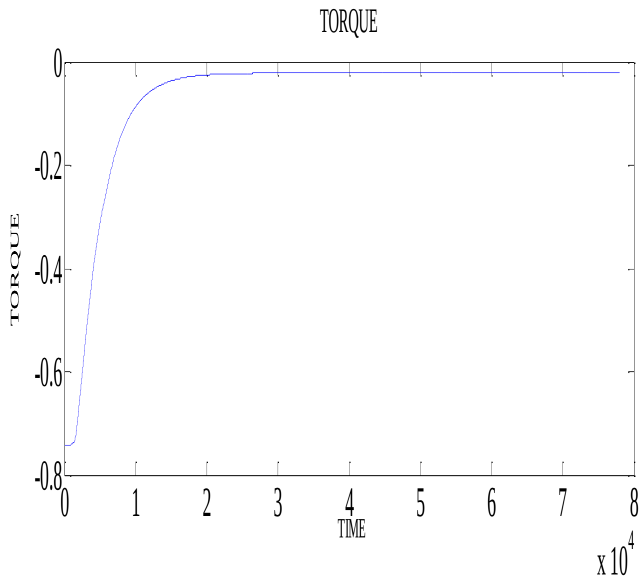

Fig.4. Torque of generator (without load)

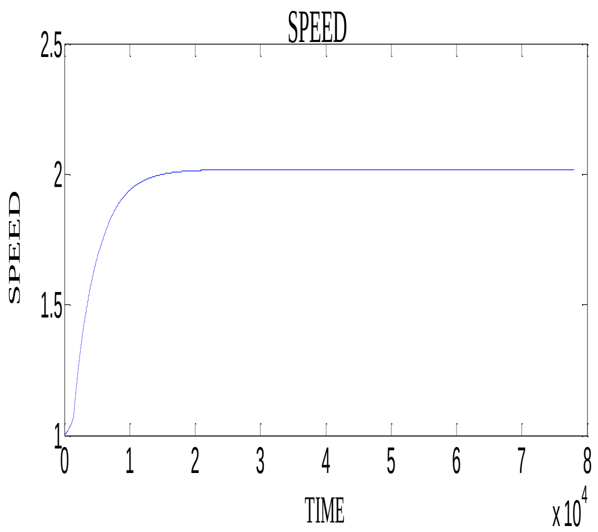

Fig. 5. Rotor speed (without load)

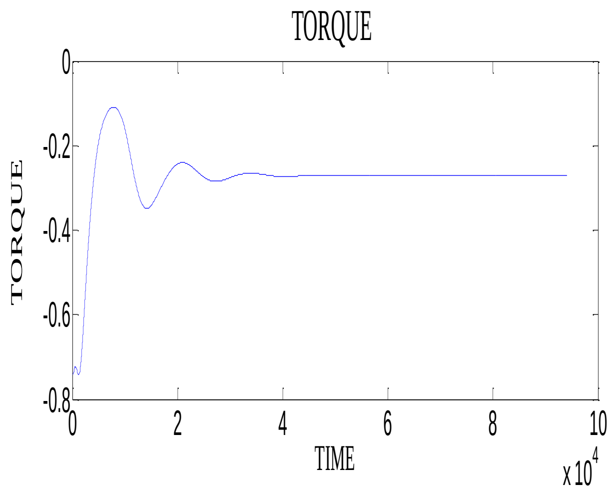

Fig.8. Torque of generator (with load)

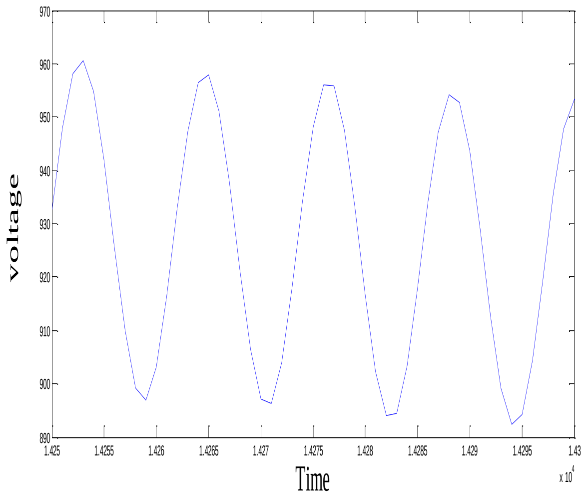

Fig.6. Primary voltage (without load)

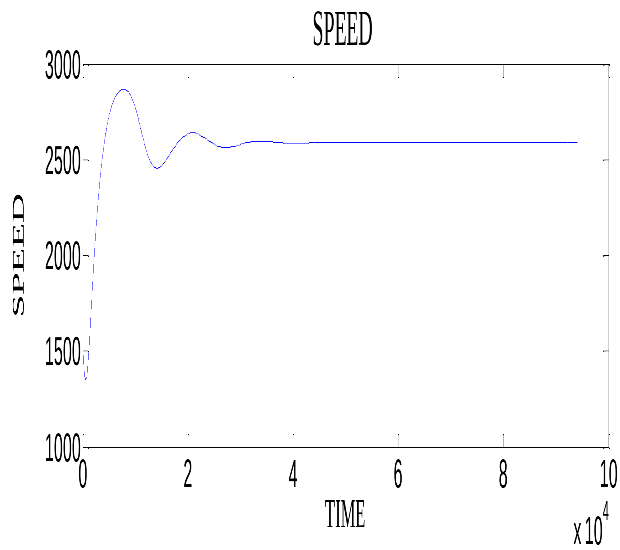

Fig.9. Rotor speed (with load)

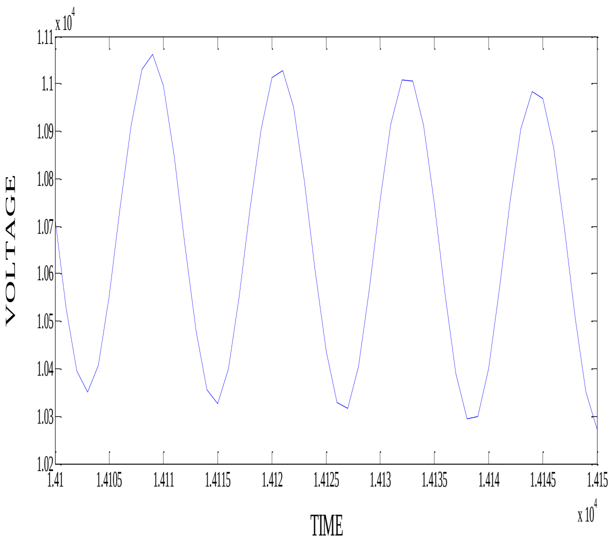

Fig.7. Generated voltage (without load)

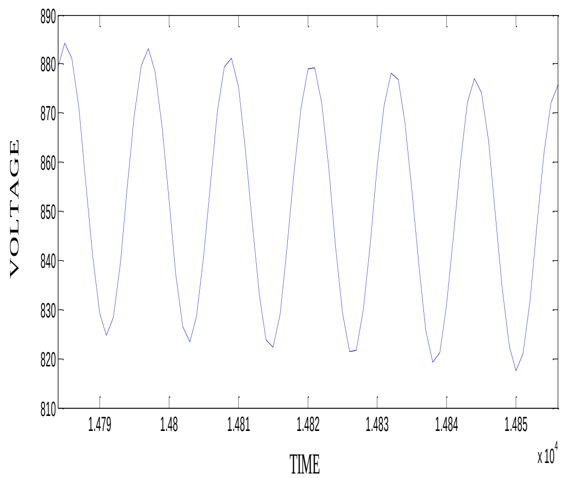

Fig.10. Primary voltage (with load)

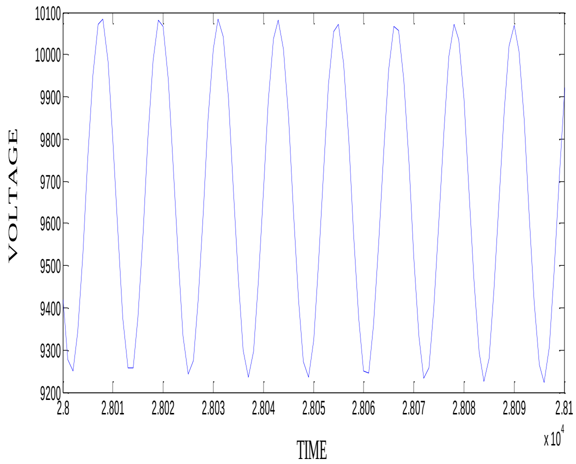

Fig.11. Generated voltage (with load)

Table . 4: Comparison at NO-load and load with STATCOM

PARAMETER	AT NO LOAD	AT LOAD	AT LOAD WITH STATCOM
Primary voltage(kV)	961.2	874.7	964.8
Busbar voltage(kV)	11.06	10.11	11.22
Speed(pu)	2.01	1.72	1.01
Torque(N-M)	-0.021	-0.27	-0.74

5. RESULT AND CONCLUSION

Simulation is carried out for induction machine as a FSIG in MATLAB environment. It is carried out for no load and load with STATCOM. Results are investigated for voltage, speed, torque etc. Comparative results are reported in table (4) with the application of STATCOM. The performance of FSIG has been improved and enhance the system stability. This paper also suggests that induction machine is the best option as a wind generator which is eco friendly and economical for long term.

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