PERFORMANCE ANALYSIS OF SQUIRREL CAGE INDUCTION GENERATOR USING STATCOM

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Abstract: *Electricity generation by wind is eco-friendly, cheap and hence the best option over conventional power generation system. Induction generator is preferred in wind power generation but has synchronization issues hence its performance analysis is essential. This paper deals with voltage stability of Squirrel cage induction generator in wind power generation. Analysis of voltage stability is made for steady state and fault condition. STATCOM is connected at load bus to improve voltage stability. Simulation is carried out in MATLAB environment assuming constant wind velocity and load. Analysis is also made for power flow.*

Key words: *Squirrel cage induction generator, STATCOM, voltage stability.*

I. INTRODUCTION

Electrical energy is a very crucial issue as its demand is more than the generation and increases day by day. Energy has been the important driving force of the continual progress of human application and the development of country. 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 by wind, hydro, solar biomass, etc. Unfortunately the world has limited amount of fossil fuel and Power generation due to fossil fuel is not eco friendly and economical. Generation by fossil fuels and by nuclear source causes environmental pollution which is very harmful for human being and environment and also responsible for global warming.

Non conventional sources are the option to overcome the problems due to fossil fuels. Power generation by non-conventional source like wind is one of the options which is eco friendly and economical in long term.

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 make 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. It doesn't run down with time. The installation cost of wind power plant is comparatively more but it compensate in long term [5], [6].

Induction generators are used as a wind generator with power electronic interfaces to improve the performance. Squirrel cage, wound rotor type, dynamic slip control type, doubly fed Induction generators etc. are widely used. As wind velocity changes, voltage stability and voltage collapse occurs in the power system and not able to meet demand of reactive power. 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. 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. Power electronics based advanced compensations i.e

Flexible AC Transmission systems (FACTS) are generally preferred [2].

This paper deals with the performance analysis of induction generator for voltage stability for steady state and fault condition. Squirrel cage induction machine is used as a wind generator and simulation is carried out in MATLAB environment. Results are investigated for steady state and fault condition with and without STATCOM. In the simulation STATCOM is suggested at load bus to improve system stability and overall performance [9].

II. 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,

- Cage rotor induction generator
- Doubly fed induction generator.
- Direct-drive synchronous generator.

In this paper in order to investigate the performance, Squirrel cage induction generator is considered.

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

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

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

Where,

P_W - Mechanical output power of the turbine (W)

T_W - 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)

III. SQUIRREL CAGE INDUCTION GENERATOR

Basic wind generation system with squirrel cage induction generator is shown in fig 1. Squirrel cage induction generator is a type of AC electrical generator. It operates mechanically by wind turbine with proper gear box. Squirrel cage induction generator operates in generator mode, giving negative slip [8].

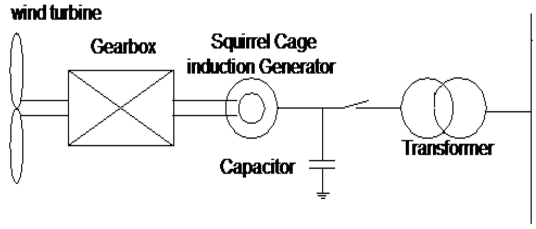

Fig.1. Basic wind generation system with squirrel cage induction generator

When wind 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 gearbox. The gearbox adjusts the rotational speed to that which is appropriate for the generator. Wind turbines produce mechanical energy in proportion with the wind velocity. Squirrel cage induction generator convert mechanical energy into electricity. An induction generator may be directly connected to the grid. Step up transformer is used to step up voltage as per the requirement of grid [7]. The features of this type of system are, simple in construction and cheap[10]. The demand of 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 gets dropped. For this kind of generators, the steady state generated active power Pe and reactive power Qe is 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 is 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.

IV. 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[3].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.[4] 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

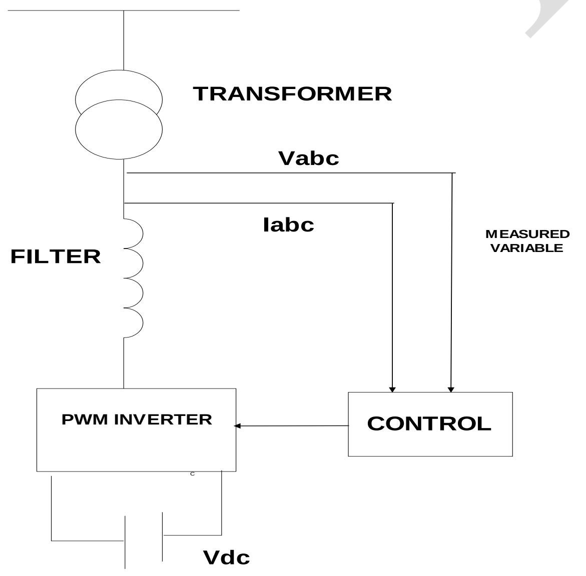

Fig .2. STATCOM configuration

V.SIMULATION

Squirrel cage induction machine is used as a wind generator. Simulation is carried out in MATLAB environment considering constant wind velocity and load. Results are investigated for steady state condition and for three phase to ground fault condition with and without STATCOM. Wind turbine parameters, transformer parameters and squirrel cage induction generator are reported in Table I, Table II and Table III respectively.

Table . I: Wind turbine parameters

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

Table . II: Transformer parameters

Prameters	Values
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 . III: Squirrel cage induction generator

Prameters	Values
Rated power MW	2
Rated voltage kV	0.96
Angular moment of inertia (2H),	1.0094
Mechanical damping, p.u.	0.01
Stator resistance, p.u.	0.0063
Rotor resistance, p.u.	0.00113
Stator leakage inductance, p.u.	0.1574
Rotor leakage inductance, p.u.	0.1181
Mutual inductance, p.u.	5.9043

The basic block diagram of SCIG with STATCOM of rating 0.5 Mvar at load bus is shown in fig 3. STATCOM improves the system performance in terms of voltage stability and power handling capacity.

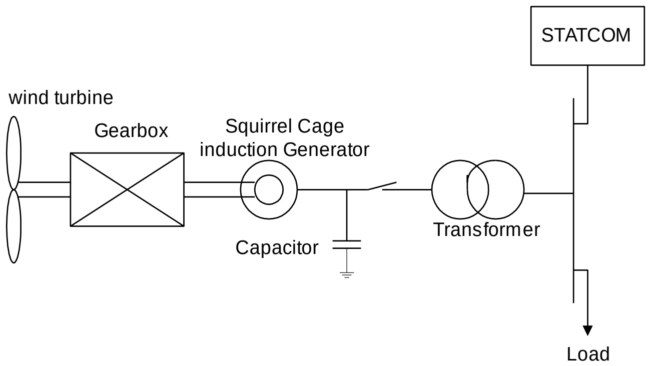

Fig. 3 Block diagram of SCIG with STATCOM

Simulation is carried out for a constant load of 2 MW, with and without STATCOM for steady state condition, i.e pre fault condition, during fault and for post fault condition. Fault duration is considered as 0.1 sec i.e fault begins at 4 ses and it is cleared at 4.1 sec.

During pre fault condition, without STATCOM, voltage at load bus is 10.94 Kv and it improves to 11 kv with the application of STATCOM. Power supplied by SCIG is 2.2 MW and 2.1 MW without and with STATCOM respectively. Results are reported in Table IV.

Table.IV: Comparison at fault condition with and without STATCOM

PARAMETERS	WITHOUT STATCOM	WITH STATCOM
Busbar Voltage(kV)	10.94	11
Power(Mw)	2.2	2.1

During fault condition, more oscillations are observed without STATCOM and these are minimized with the application of STATCOM. During Post fault condition, without STATCOM voltage at load bus is drop and it regains with STATCOM. All the results for voltages and power generated are reported in fig 4,5,6,7 resp.

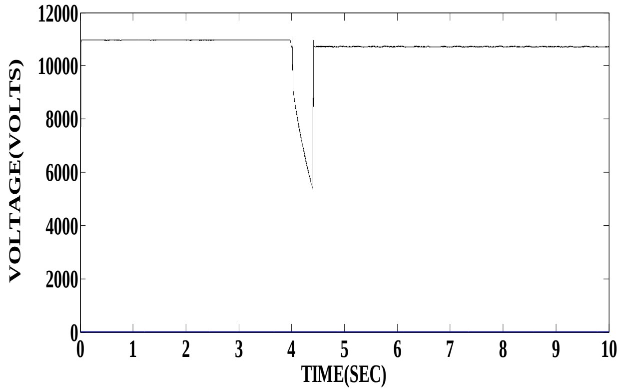

Fig.4. Voltage at load bus-without STATCOM

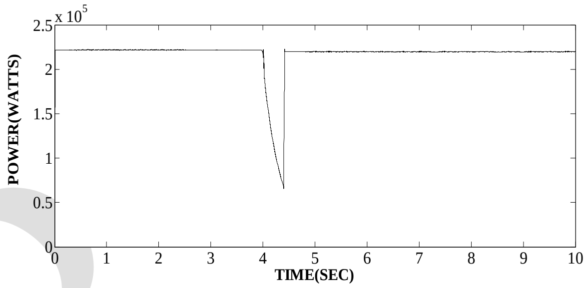

Fig.5.Power generated-without STATCOM

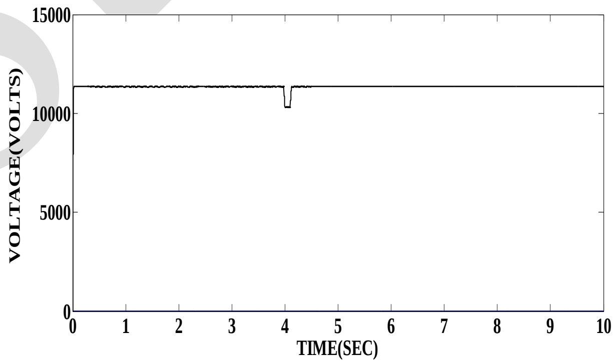

Fig.6. Voltage at load bus-with STATCOM

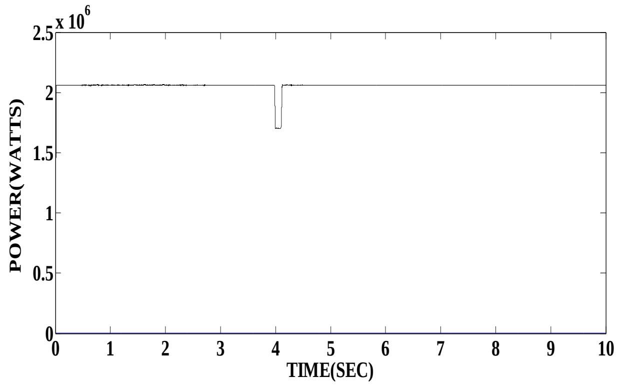

Fig. 7. Power generated-with STATCOM

VI. RESULTS AND CONCLUSION

Simulation is carried out for SCIG during pre and post fault condition with and without the application of STATCOM. Fault is created at 4 sec and cleared at 4.1 sec.

For a constant load of 2 MW during normal operating condition voltage at bus bar is 10,94 kV, during fault condition voltage drops to 5.6 Kv and it regains at 10.34 kV, it indicates the deviation in voltage (Drop in voltage) after the clearance of fault.

With the application of STATCOM it is observed that post fault voltage reaches to system rated value i.e. 11 kV which is shown in fig. 4 and 6 as well as table no. IV. With the application of STATCOM voltage drop of 7% is reduced.

Similarly power generated by Induction generator is 2.2 MW when STATCOM is not connected whereas power generation is 2.1 MW in presence of STATCOM. Saving of power is 0.1 MW is observed with the application of STATCOM and shown in fig. 5 and 7 as well as table no. IV.

The voltage stability and power saving is observed with the application of STATCOM. System performance is also improved during fault condition also. Post fault performance is also enhanced. Hence STATCOM is suggested for reliable operation of SCIG during steady state and fault condition.

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