SCIG In Wind Farm System

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Abstract- *Large number of wind turbines are being installed and connected to power systems. In some of the countries the penetration of wind power is significant high so as to affect the power quality, system operation and control and power system stability. This paper studies the dynamic behaviour of system parameters with wind variation and three phases to ground fault condition in the wind farm having SCIG as wind turbine generator (WTG). The results were obtained from simulation in PSCAD/EMTDC environment.*

Keywords- Squirrel Cage Induction Generator (SCIG), PSCAD, Wind Turbine Generator (WTG)

I. INTRODUCTION

With the development of wind turbine technology, large scale wind farms of hundreds of MW level being developed in many countries. These modern wind farms are usually connected to the power grid. The global annual installation capacity is increased with the rate of 30 % in recent years (1). One of the major concerns related to high level wind power penetration is the impact on power system stability.

A. Wind Variation

Grid connected wind turbines often produce active power with significant fluctuations due to wind speed variations, the wind gradient and the tower shadow effect. The output power variations can cause fluctuations of the voltage (also called flicker, which is a measure of voltage fluctuations) at the connection point. Because of the power quality requirements from the utilities, flicker emission may become a major limiting factor for integrating wind turbines, especially the fixed-speed wind turbines (FSWTs), into weak power grids where the wind power penetration levels are high (2).

B. Fault Condition

Another important issue related to the FSWTs equipped with squirrel-cage induction generators (SCIGs) is the fault ride-through (FRT) capability. When connected to a weak power grid and during a grid fault, the over-speeding of the wind turbines can cause voltage instability. As a result, utilities typically disconnect the wind turbines immediately from the grid when such a contingency occurs. With the rapid increase in penetration of wind power in power grids, tripping of many wind turbines in a large wind farm during grid faults may begin to influence the overall power system stability (2).

II. SQUIRREL CAGE INDUCTION GENERATOR

Although there is a growing interest in the usage of doubly fed induction generators, squirrel-cage rotor type induction generators are still in use due to their simplicity, robustness, low cost and low maintenance, which can be very advantageous for small and medium size wind farms Moreover, in Europe there are large wind power plants composed by squirrel-cage rotor (3).

A Squirrel cage induction generator may be directly connected to grid. The frequency of grid determines the air gap flux speed ωs, the synchronous speed. The rotor speed ωr of induction machine is made slightly higher synchronous speed to operate the machine as induction generator. The features SCIG driven wind farms are simple, cheap and no synchronization required.

The SCIG in this WTG concept can only operate within a narrow range of the rotational speed slightly above the synchronous speed. Because of these very small rotational speed variations, this type of WTG is considered to operate at fixed speed.

Grid connected wind turbine generator based on SCIG gave the following results for active power (P), reactive power requirement (Q) and reactive power supplied by grid (O) when simulated using PSCAD/EMTDC environment. Simulated results are obtained for mean wind speed (*Wms*) variations.

Table 1: Active power generation

P	5 sec	10 sec	15sec	20 sec
5	0.04587	-0.2677	-0.1344	-0.1344
10	-0.3686	-0.5327	-0.5856	-0.5952
15	-0.4127	-0.3908	-0.5373	-0.5415
20	-0.2284	-0.1777	-0.2785	-0.2785
25	-0.0819	-0.0521	-0.0973	-0.0973
30	-0.0124	-0.0003	-0.0166	-0.0166

Table 2: Reactive power requirement

Q	5 sec	10 sec	15sec	20 sec
5	0.5	0.5212	0.5085	0.5
10	0.5326	0.5589	0.5689	0.5707
15	0.539	0.5359	0.5597	0.5604
20	0.5164	0.5119	0.5216	0.5213
25	0.5051	0.5035	0.506	0.506
30	0.5018	0.5013	0.5019	0.5019

Table 3: Reactive power supplied by grid

Q	5 sec	10 sec	15sec	20 sec
5	0.1935	0.2019	0.1969	0.1969
10	0.2066	0.2171	0.221	0.2218
15	0.2093	0.2078	0.2174	0.2177
20	0.2001	0.1983	0.2022	0.2022
25	0.1956	0.1949	0.1959	0.1959
30	0.1942	0.194	0.1943	0.1943

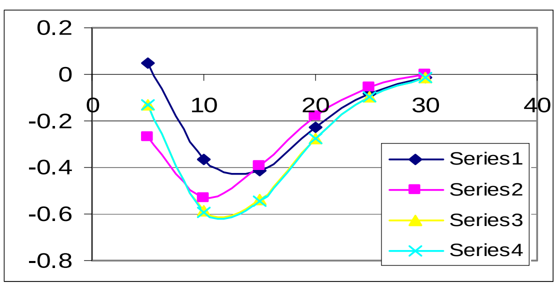

Figure1: Active power generated

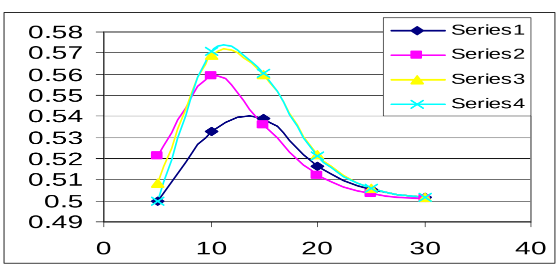

Figure2: Reactive power absorbed

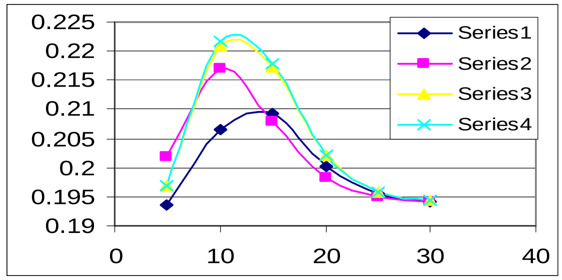

Figure 3: Reactive power supplied by grid

A. Wind farm operation and control during fault condition

Fixed speed wind turbines have a high sensitivity to voltage sags due to the fact that a generator is directly connected to the main grid. In case of a voltage drop, resulting from a fault on the main grid, the electromagnetic torque of the generator reduces significantly while mechanical torque is still applied. This leads to the unbalanced torque, accelerating the rotor, which may, in turn, result in the rotor instability.

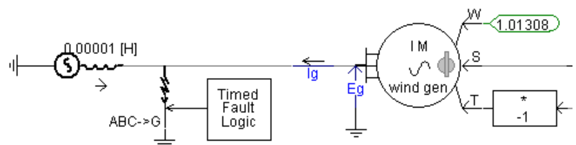

Figure 4: Three phase grid fault simulation

Furthermore, induction generators absorb reactive power from the grid. They will consume more reactive power to recover their air gap flux when a voltage drop occurs. This effectively prevents voltage recovery after fault clearance. If voltage does not recover quickly enough, the rotor may continue to accelerate and the generator's absorption of reactive power becomes larger. Voltage may reduce further and the induction generator may become unstable, requiring disconnection of the wind turbine from the power system (4).

B. Simulation Model for Wind Turbine Generator

The network shown in Fig. 05 was to investigate the stability of Wind Turbine Generator (WTG). A three phase fault is introduced near to CB3 and then fault was removed by isolating the faulty circuit using half breaker scheme.

When the fault is cleared the generator will only be able to return to its normal operation if the generator speed does not exceed its so called critical speed (*Wcrt*) (5).

The advantages of this one half breaker scheme are flexible operation and high reliability, isolation at either bus without service disruption and bus fault doesn't interrupt service. All switching is done by circuit breakers. More complicated relaying is required as CB has to act on faults for either the two circuits it is associated with and each circuit isolated have its own potential source of relaying.

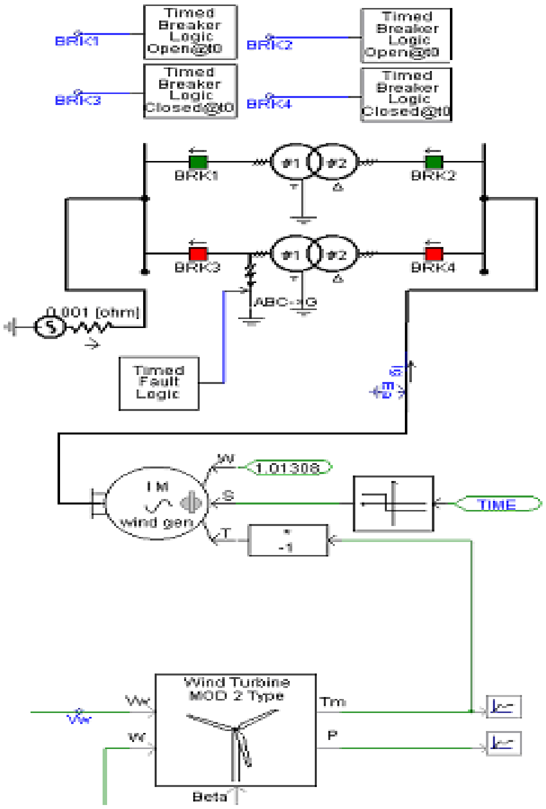

Figure 5: Simulation Model for Wind Turbine Generator

To preventing an over-speeding phenomenon and supplying reactive power are necessary to improve the fault ride through capability of SCIG-based wind turbines. In order to deal with generator acceleration, pitch angle (β) control is often used to reduce mechanical power input and then reduce the accelerating rate of rotor speed when voltage drops. However due to the physical limitations of the blades and the pitch regulation mechanism the method is not so effective (5). Simulation results obtained during three phase grid fault.

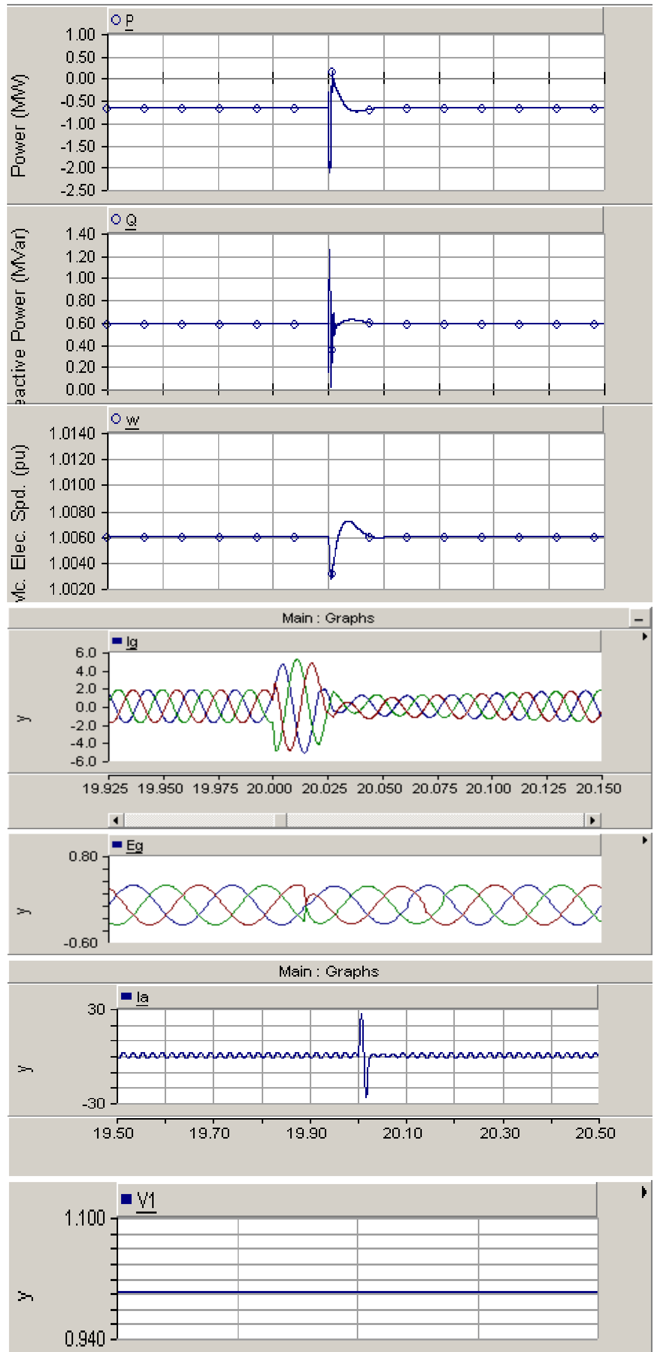

Figure 6: Simulation results during the faulty grid

III. CONCLUSION

The impact of the wind power integration is felt more at the PCC than other part of the network. Reactive power during the gust and ramp period the result shows that more reactive power is absorbed by the wind farm when the wind speed is not constant and the impact increase with increase in wind power penetration. It is again seen that the generator closer to the PCC is more affected. It could be inferred here that the generator closer to PCC is more likely to be more vulnerable to voltage instability than other generator.

When the fault is cleared the generator will only be able to return to its normal operation if the generator speed does not exceed its so called critical speed (*Wcrt*).

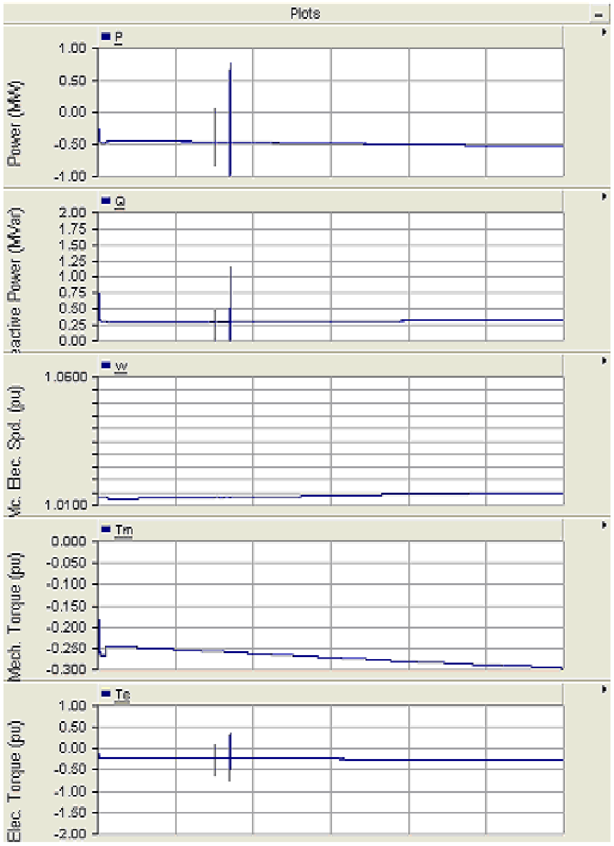

Figure 7: Simulation results after bypass the faulty grid.

By maintaining circuit breaker switching time less than the critical fault clearance time (*Tcrt*), the generator was prevent from over speeding and hence stability is maintained.

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Prof. Kadam D.P graduated in Electrical Engineering from Govt. College of Engineering, Amaravati in 1997, Master's Degree in Electrical Engineering from Walchand college of Engg., Sangli, Shivaji University, Kolhapur with Power System and Ph.D (Electrical) from Savitribai Phule Pune University, Pune in 2015. He is working as a Professor at MET-IOE, Nashik, Maharashtra, India. His research area includes Power Quality, Optimization of Reactive Power & FACTS. His total experience spans over 18 years.