Available online at www.sciencedirect.com
SciVerse ScienceDirect
Physics Procedia 24 (2012) 253 – 260
Physics Procedia

2012 International Conference on Applied Physics and Industrial Engineering

Simulation for Grid Connected Wind Turbines with Fluctuating

Ying Ye,Yang Fu, Shurong Wei
Shanghai University of Electric Power
Shanghai, China

Abstract

This paper establishes the whole dynamic model of wind turbine generator system which contains the wind speed model and DFIG wind turbines model .A simulation sample based on the mathematical models is built by using MATLAB in this paper. Research are did on the performance characteristics of doubly-fed wind generators (DFIG) which connected to power grid with three-phase ground fault and the disturbance by gust and mixed wind. The capacity of the wind farm is 9MW which consists of doubly-fed wind generators (DFIG). Simulation results demonstrate that the three-phase ground fault occurs on grid side runs less affected on the stability of doubly-fed wind generators. However, as a power source, fluctuations of the wind speed will run a large impact on stability of double-fed wind generators. The results also show that if the two disturbances occur in the meantime, the situation will be very serious.

Keyword: DFIG; fluctuating; simulation of grid connected wind farm ;MATLAB

1. Introduction

Due to concerns about emissions from fossil and the depletion of fossil fuel resources, renewable energy systems have been becoming a topic of great interest and investment in the world. In particular, wind energy has been the subject of much recent research and development. This paper aims to explore the transient stability of the wind farm which consist of doubly-fed wind generators in the case of the wind speed is variable.

This work was supported by:
1.Shanghai key Scientific and Technical Project(08dz1200604).
2.Leading Academic Discipline Project of Shanghai Municipal Education Commission, Project Number(J51303)

 doi:10.1016/j.phpro.2012.02.038

2. The mathematical model of wind speed

The model of wind speed changing in time and space is usually simulated as the following four components: the basic wind V_{WB} , the gust V_{WG}, the gradient wind V_{WR} and the random wind V_{WN} .

2.1 The basic wind

There has been the basic wind when the wind turbines are working, it can basically reflect the average wind speed .The basic wind can be determined approximately by Weibull distribution parameters which can be obtained from the measurement of wind in the wind farm.

$$V_{WB} = A \bullet \Gamma(1 + 1/K)$$

Where: V_{WB} is the basic wind speed. A, K is respectively scale parameter and shape parameter of the Weibull distribution. $\Gamma(\bullet)$ is the gamma function. It's generally believed that the speed of the basic wind does not change , so in the simulation it can be taken constant as its value.

2.2 Gust

The gust describe the characteristics of sudden change in wind speed.

$$V_{WG} = \begin{cases} 0 & t < T_{1G} \\ V_{\cos} & T_{1G} \le t < T_{1G} + T_G \\ 0 & t \ge T_{1G} + T_G \end{cases}$$

$$V_{\cos} = (\max G / 2)\{1 - \cos 2\pi[(t / T_G) - (T_{1G} / T_G)]\}$$

Where: $V_{WG}, T_G, T_{1G}, \max G, t$ stand for the speed of gust (m/s),the duration of the gust (s),the starting time of gust(s),the maximum speed of gust(m/s) and time(s). $V_{\cos}$ express that the Wind speed in the time period that has the cosine characteristics.

2.3 The gradient wind

Gradient wind is used to describe the characteristics of gradual change in wind speed.

$$V_{WR} = \begin{cases} 0 & 0 < t < T_{1R} \\ V_{ramp} & T_{1R} \le t < T_{2R} \\ \max R & T_{2R} \le t < T_{2R} + T_R \\ 0 & t \ge T_{2R} + T_R \end{cases}$$

$$V_{ramp} = \max R[1 - (t - T_{2R}) / (T_{1R} - T_{2R})]$$

where： $V_{WR}, \max R, T_{1R}, T_{2R}, T_R$ stand for the speed of gradient wind(m/s), the maximum speed of gradient wind(m/s), the starting time of gradient wind (s), the terminating time of gradient wind (s) and the duration of gradient wind (s)。

2.4 The random wind

Random wind describes the random nature of wind speed in the relative height which is designated. It can be represented by the random noise component in the simulation of wind speed.

$$V_{WN} = 2\sum_{i=1}^{N}[S_v(\omega_i)\Delta\omega]^{1/2}\cos(\omega_i t+\varphi_i)$$

$$\omega_i = (i-1/2)\Delta\omega$$

$$S_v(\omega_i) = \frac{2K_N F^2 \mid \omega_i \mid}{\pi^2[1+(F\omega_i/\mu\pi)^2]^{4/3}}$$

where： φ_i is a random variable which distributed uniformly between 0 and 2π， it is the initial phase of i th component. ω_i is the angular frequency of i th component, $\Delta\omega$ the discrete space of the random component, K_N surface roughness coefficient， F disturbed areas (m^2)， μ is the average wind speed in the relative height(m/s)， $S_v(\omega_i)$ is the amplitude of the i th random component .

This paper studies the impact on the operation of wind turbines by gust and mixed wind(as shown in Figure 1, Figure 2).

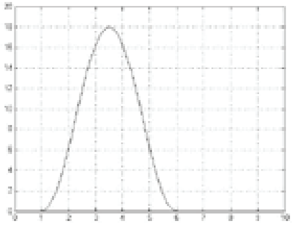
Figure 1 waveshape of gust

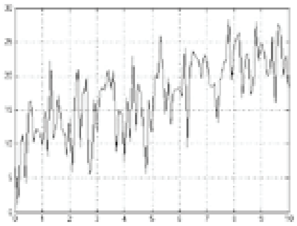
Figure 2 waveshape of mixed wind

3. Building the Smulation for grid connected wind turbines by using matlab

3.1 The establishment of the gust module and mixed wind module

This paper establishes the gust module and mixed wind module based on the mathematical model by using the SIMULINK in MATLAB. The figures of the module are shown below.

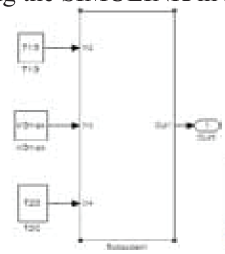
Figure 3 the gust module

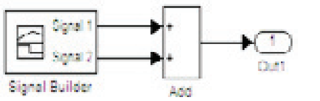

Figure 4 the mixed wind module

3.2 The establishment of the grid connected wind far, module

As a wind farm which connected to the grid, the disturbance may come from two sides: one is the wind disturbance, the other is the disturbance of the grid side. In this paper, the wind disturbances are gust and mixed wind, the disturbance from the grid side is three-phase ground fault. This paper analyzes the influence on the operation of wind turbines from these types of disturbance.

In this simulation, the capacity of the wind farm is 9MW which consist of 6 doubly-fed wind generators (the per-capacity is 1.5MW), the wind farm is connected to infinite bus system after a length of 30 km of overhead line. Simplified equivalent diagram is shown in figure 5,and the diagram of the simulation in MATLAB is shown in figure 6.

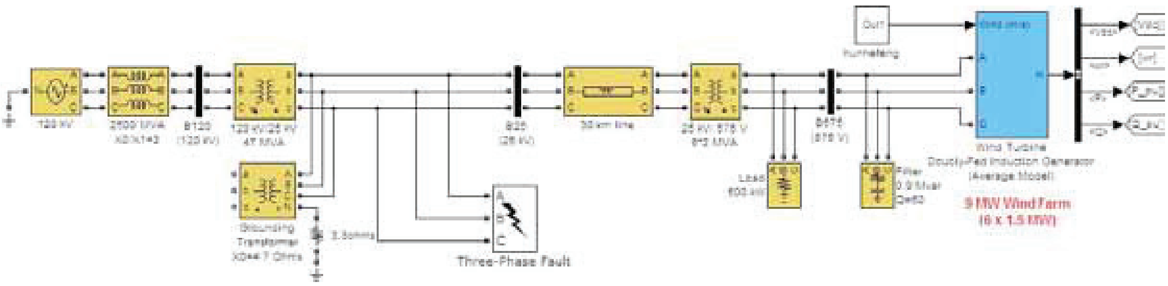

Figure 6 diagram of the simulation in MATLAB

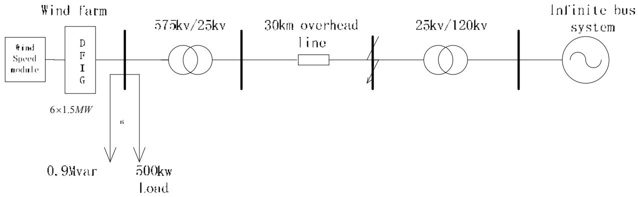

Figure 5 Simplified equivalent diagram

4. Simulation and Analysis

The process of the simulation is as follows: Firstly, the simulation is without any disturbance, make sure that the whole system is under stability in the case of the wind speed is constant (10m/s) and there is no failure in the grid side. Secondly, three-phase ground fault occurs on the grid side, the position is some bus of the grid, then contrast the results of the simulation. Finally the basic wind speed module is replaced by the gust and mixed wind module, with and without failure in grid side is analyzed. The whole simulation lasts for 20 seconds, the fault clearing time is 0.083s.

4.1 Smulation and analysis with the basic wind

The curves of the active power, reactive power and the rotor speed which are the outputs of the wind farm are shown in Figure 4 and Figure 5. After analysis and comparison ,we can conclude that, when the three-phase ground fault occurs in time 4s, much loss of load lead to a sharp decline in electromagnetic torque, and the active power output is decreased, while the input mechanical torque is kept constant. So the rotor speed increase. When the rotor speed increase over synchronous speed the doubly-fed wind generators started outputting reactive power. The fault is cleared in 4.083s, and then the load is restored, active power output increase and rotor speed is decreased, finally the doubly-fed wind generators stabilize at near rated.

From the simulation, we can find that, when the wind speed is constant, the three-phase ground fault occurs on grid side runs less affected on the stability of doubly-fed wind generators.

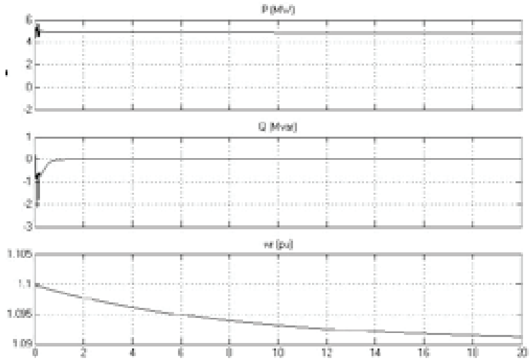

Figure 7 Curves of active power, reactive power and rotor speed without grid side fault (the basic wind)

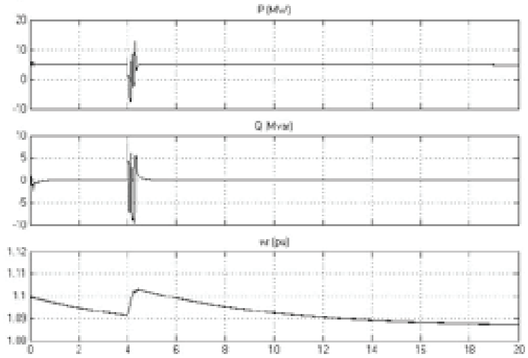

Figure 8 Curves of active power, reactive power and rotor speed with grid side fault (the basic wind)

4.2 Smulation and analysis with the gust

The gust starts at time 1s, the period of the gust is 5s,the maximum speed of the gust is 18m/s. As shown in figure 9, with the gust, the rotor speed of wind turbines start running faster, and active power grow up in the meantime. As the wind speed increase to a peak value, active power output of wind turbines also reaches the top. At time 5s, the gust stops, the rotor speed decrease to the speed with the basic wind, and the active power output of the wind farm also decrease to the value with the basic wind.

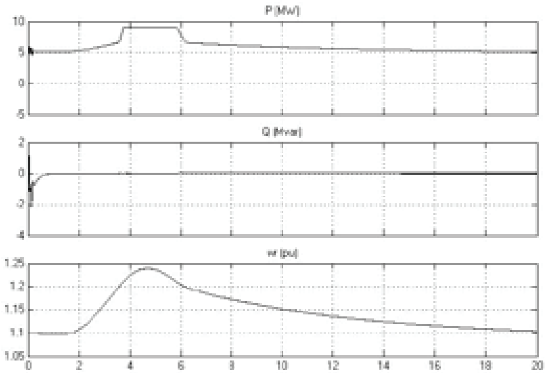

Figure 9 Curves of active power, reactive power and rotor speed without grid side fault (the gust)

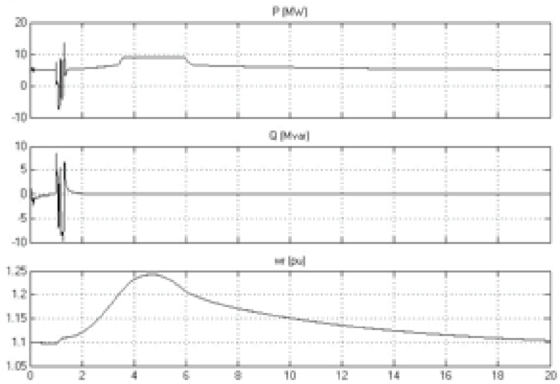

Figure 10 Curves of active power, reactive power and rotor speed with grid side fault happened at time 1s (the gust)

Three-phase ground fault occurs on the grid side when the gust starts. The curves in figure 10 shows that rotor speed in time 1s is increased significantly by comparing with figure 9. The active power output is decreased and the reactive power output is increased, the same as the situation in the basic wind. When the fault is cleared, the output of the wind farm come back to the situation that without fault. In this case, the failure in the grid side runs less affected on the stability of doubly-fed wind generators.

In the case that three-phase ground fault occurs on the grid side in time 4s when speed of the gust reaches to the peak value. As shown in the figure 11, the active power and reactive power outputs of the doubly-fed wind generators are with a violent oscillation .The oscillation lasts for a long while. It happens at time 4s,and stop at time 16s.There is a large-scale fluctuations in the rotor speed also. We can find that, when the fluctuation of the gust reaches to the peak, the failure in the grid side runs a large impact on the stability of doubly-fed wind generators.

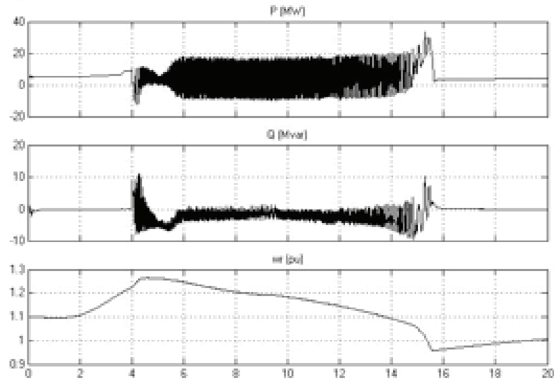

Figure 11 Curves of active power, reactive power and rotor speed with grid side fault happened at time 4s (the gust)

Three-phase ground fault occurs on the grid side at time 6s when the gust is going to leave. As shown in the figure 12, the active power and reactive power outputs of the doubly-fed wind generators oscillate. It's less serious than the situation in figure 11, but be much more serious than the situation in figure 10.In this case, the failure on the grid side also runs a large impact on the stability of doubly-fed wind generators.

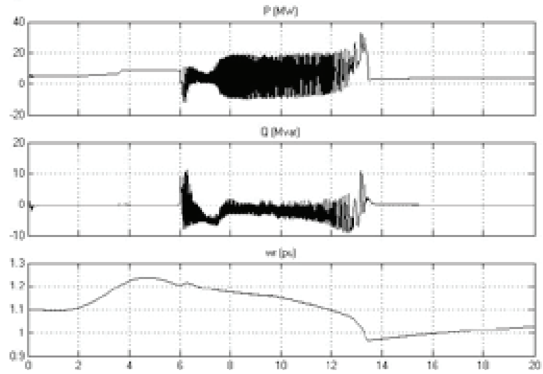

Figure 12 Curves of active power, reactive power and rotor speed with grid side fault happened at time 6s (the gust)

4.3 Smulation and analysis with the mixed wind

When the input of wind speed is the mixed wind, the curves of the active power, reactive power and the rotor speed which are the outputs of the wind farm without failure on the grid side are shown in Figure 13.The values of the active power and reactive power keep constant at time 4s.As shown in figure 14, when the failure occurs on the grid side at time 1s, the values of the active power and reactive power fluctuate. But if the failure occurs on the grid side at time 3s, we can find from the figure 14, it runs a large impact on the stability of doubly-fed wind generators. The stability of doubly-fed wind generators will be loss of stability when the failure occurs on the grid side after the time 4s.

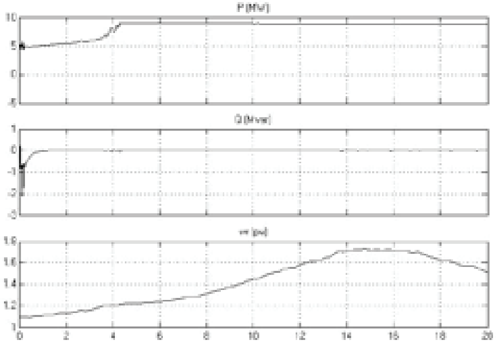

Figure 13 Curves of active power, reactive power and rotor speed,without grid side fault happened at time 6s (the mixed wind)

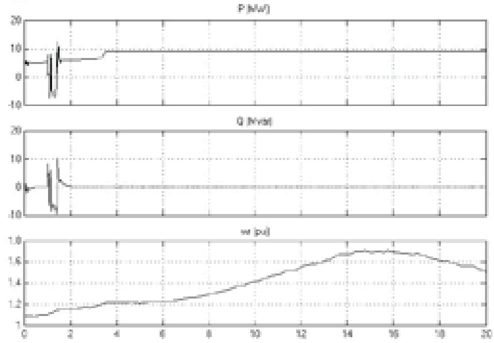

Figure 14 Curves of active power, reactive power and rotor speed, with grid side fault happened at time 1s (the mixed wind)

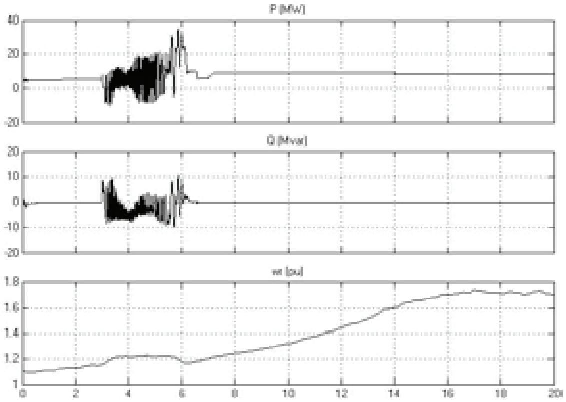

Figure 15 Curves of active power, reactive power and rotor speed with grid side fault happened at time 3s (the mixed wind)

Conclusion

The analysis of the simulation indicates that three-phase ground fault occurs on grid side runs less affected on the stability of doubly-fed wind generators. However, as a power source, fluctuations of the wind speed will run a large impact on stability of double-fed wind generators. The results also show that if the two disturbances occur in the meantime, Situation will be very serious.

Acknowledgment

Supported by Leading Academic Discipline Project of Shanghai Municipal Education Commission, Project Number：J51303

References

[1] S. M. Muyeen. Transient stability analysis of wind generator system with the consideration of multi-mass shaft model[J]. IEEE PEDS 2005,1:511-516.

[2] Tao Sun, Z. Chen, F. Blaabjerg. Transient stability of DFIG wind turbines at an external short-circuit fault [J]. Wind Energy, 2005, (8):345-360.

[3] J.G.Slootweg,W.L.Kling.Modeling of large wind farms in power system simulations.Power Engineering Society Summer Meeting,2002 IEEE,Vol.1．Pp:503-508.

[4] Andres,E.Feijoo,Jose Cidras.Modeling of wind farm in the load flow analysis.,IEEE Transactions on Power .

[5] G.Slootweg,Wind Power Modeling and Impact On Power System Dynamics,Ph.D thesis,2003.

[6] Ioannides M G.Doubly fed induction machine state variables model and dynamic response[J]． IEEE Trans on Energy.

[7] M.Martins,A.Perdana,P.Ledesma, E.Agnehom, O.Carlson. Validation of fixed speed wind turbine dynamic models with measured data[J]. Renewable Energy, 2007,32:1301-1315.Conversion,1991,16(1):55-61.

[8] K.C.Divya and P.S.Nagendra Rao.Study of dynamic behavior of grid connected induction generators[C].IEEE Power Engineering Society General Meeting, 2004:2200-2205.

[9] Holdsworth L.,Wu X .G,Ekanayake J.B.,Jenliins N. Comparison of fixed speed and doubly-fed induction wind turbines during power system disturbances [J]. IEE Proc. Generation,Transmission and Distribution, 2003,150(3):343-352.

[10] Daniel J. Trudnowski, Jawad M. Khan, Eric M. Petritz. Fixed-speed wind-generator and wind-park modeling for transient stability studies[J]. IEEE Transactions On Power Systems,2004,19(4):1911-1917.