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Analysis the Transient Process of Wind Power Resources When there are Voltage Sags in Distribution Grid

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Abstract

Vietnam has many advantages of wind power resources. Time by time there are more and more capacity as well as number of wind power project in Vietnam. Corresponding to the increase of wind power emitted into national grid, It is necessary to research and analyze in order to ensure the safety and reliability of win power connection.In national distribution grid, voltage sag occurs regularly, it can strongly influence on the operation of wind power. The most serious consequence is the disconnection. The paper presents the analysis of distribution grid's transient process when voltage is sagged. Base on the analysis, the solutions will be recommended to improve the reliability and effective operation of wind power resources.

Keywords: wind power, transition process, reliability.

1. Introduction

Wind power is renewable and green energy in Vietnam. According to accounting data, Vietnam has rich wind power capacity with 8,6 % area that is applicable to build up big wind power stations, among that 41 % area in urban area is suitable to build small stations. Total capacity of wind power is about 513.360 MW (Do Nhu Y, Le Xuan Thanh, 2016).

Voltage sag is a popular phenomenon in power system that makes wind power parameters changed. Therefore analyzing the transient of wind power sources at voltage sag moments, in order to recommend suitable operation for power system containing wind power, plays an important meaning.

2 Research method

Nowadays, most of wind power stations utilize Double-feed-Induction-Generator (DFIG) because they have the prior advantages when stator is directly connected to the grid whereas rotor is connected to the grid through controllable power electronic devices. Because the controller in rotor, therefore its power is much smaller than the power of generator; power flows directly from stator to grid, especially with big capacity generator. In the limit range of speed, the power of converter is only 30 % grid transmitting power. The structure of wind power generator DFIG is shown in figure 1 (Lai et al., 2010; Dami et al., 2010; Youcef Bekakra, Djilani Ben Attous, 2011).

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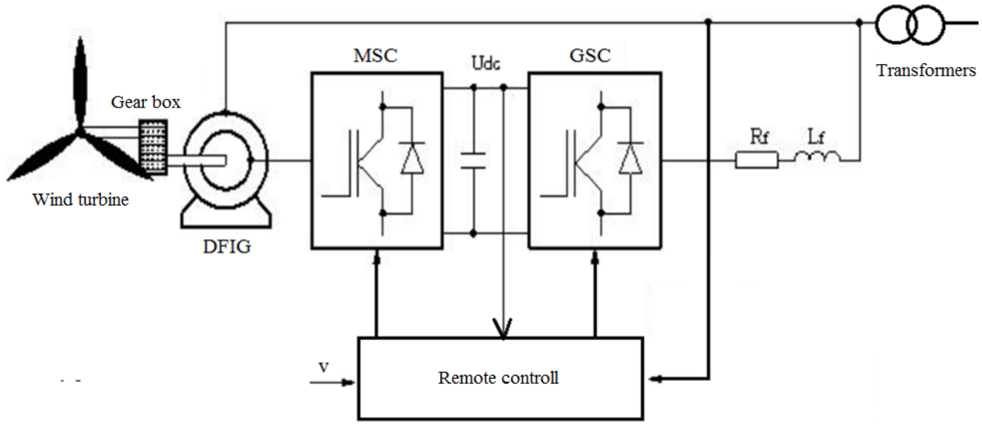

Fig. 1. Structure of wind power DFIG

In figure 1 (MSC) is the converter on generator side used to control generator's speed in order to get maximum power. Input signals of speed controller is deducted from wind velocity. Output signals of speed controller is the ref signal for power loop controller. Grid source converter (GCS) controls DC voltage (U_{dc}). It is also used to control reactive power Q.

To analyze the transient occurred in wind power when there is voltage sag, power system is simulated on Matlab-Simulink. Power generator DFIG is simulated on dq axis as figure 2.

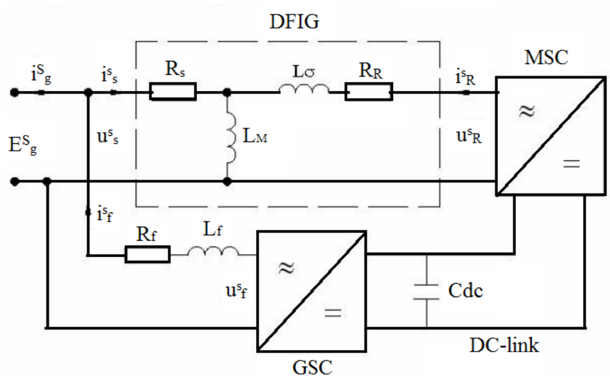

Fig. 2. Simulation of DFIG generator on space vectors

Replacing equivalent model of DIFG is expressed in stator's space vectors as shown in figure 3.

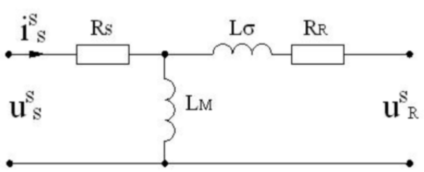

Fig. 3. Equivalent diagram of DFIG on space vector

Where: R_S – stator winding resistor; L_M – Magnetic induction; Lσ – Induction of stator and rotor converted into stator side; R_R – Rotor resistor converted to stator. Letter s means space vectors ref on stator of DFIG.

According to (Do Nhu Y, 2016; Doh, Chung, 2003; Cho, Lai, 2013), Kirchhoff equations for loop circuits:

$$u_S^s = R_S i_S^s + \frac{d\Psi_S^s}{dt}$$
$$u_R^s = R_R i_R^s + \frac{d\Psi_R^s}{dt} \quad (1)$$

The fields of stator, rotor, and electromagnetic torque are computed by the following equations:

$$\Psi_S^s = L_M\left(i_S^s + i_R^s\right)$$
$$\Psi_R^s = L_\sigma i_R^s + L_M\left(i_S^s + i_R^s\right) \quad (2)$$
$$T_e = 3Z_p I_m\left[\Psi_s i_R^*\right]$$

Where: L_M–Magnetizing induction; $L\sigma$ - Convert induction

$$L_S = gL_{sl} + \lambda^2 L_{rl}$$
$$\lambda = \frac{L_{sl} + L_M}{L_M} \quad (3)$$

Where: λ-Convert factor; L_{sl}; L_{rl}–Induction ofstator, rotor; Z_p– generator pole pair.

Mechanical equation of system is expressed by:

$$\frac{J}{Z_p}\frac{d\omega_r}{dt} = T_e - T_s \quad (4)$$

Where: J –Inertia torque; ω_r–rotor rotating velocity; T_e–electromagnetic torque; T–mechanic torque on rotor's shaft.

Maths expression of filter on grid side includes R_f and L_f, replace models is shown in figure 4.

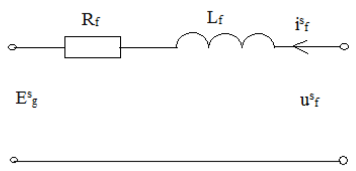

Fig. 4. Model of filter on grid side in space vector

According to (Do Nhu Y, 2016), Kirchhoff equation on dq axises:

$$E_g^s = -R_f i_f^s - L_f \frac{di_f^s}{dt} + u_f^s \quad (5)$$

Maths expression of DC – Link, replaced model is shown in figure 5.

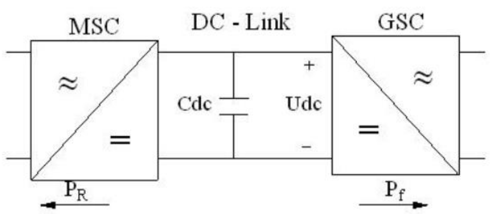

Fig. 5. Model of DC – Link

Energy W_{dc} is deducted from capacitor C and is computed by the following equations:

$$W_{dc}=\frac{1}{2}C_{dc}U_{dc}^{2}$$
$$\frac{dW_{dc}}{dt}=\frac{1}{2}C_{dc}\frac{d}{dt}u_{dc}^{2}=-P_{f}-P_{r} \qquad (7)$$
$$C_{dc}u_{dc}\frac{d}{dt}u_{dc}=-P_{f}-P_{r}$$

Output power of wind generator is calculated by:

$$P_{m}=C_{p}(\lambda,\beta)\frac{\rho A}{2}v^{3} \qquad (8)$$

Where:P_m–Output power of wind turbine; $C_p(\lambda,\beta)$ –power conversion factor (ratio of wing velocity λ and wing angle β); A –cross section of; ρ - air density; ν -wind velocity.

Power conversion factor Cpis determined as:

$$C_{p}(\lambda,\beta)=0{,}5176\left(\frac{116}{\lambda}-0{,}4\beta-5\right)e^{\frac{21}{\lambda_i}}+0{,}0068\lambda$$
$$\frac{1}{\lambda_{i}}=\frac{1}{\lambda+0{,}08\beta}-\frac{0{,}035}{1+\beta^{3}} \qquad (9)$$

Ratio of wing velocity and wind velocity is determined by:

$$\lambda=\frac{R\omega}{v} \qquad (10)$$

Where: ω- Turbine rotating velocity; R –Turbine radious

On other hand wind turbine can be operated by different controlling rules base on wind velocity. Figure 6 is the expression of relation between wind turbine's power and wind velocity.

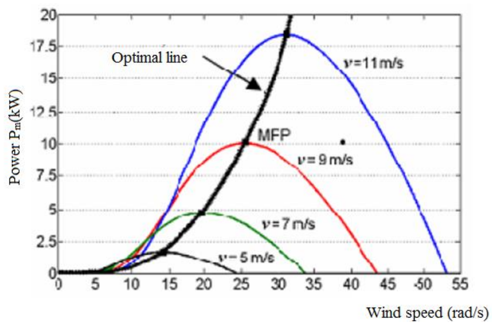

Fig. 6. The relation of wind turbine's power and wind velocity

Utilizing the simulation on Matlab-Simulink, above mentioned equations are expressed in figure 7 (Do Nhu Y, 2016).

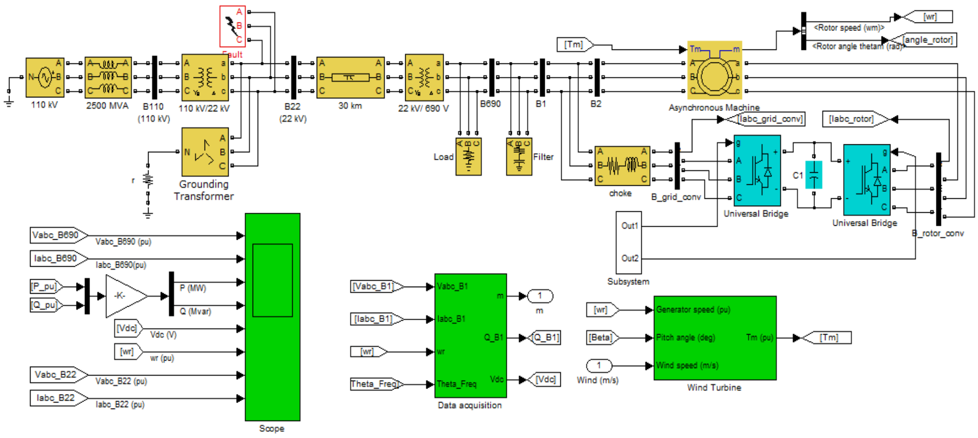

Fig. 7. Simulation diagram

3. Results

Simulation results are implemented on system with the following parameter: output voltage 690V, step-up transformer is 690V/22kV, the wind power system is connected with power system on 22kV bus bar. In the operation of the system, there is a voltage sag, consequently voltage on 22kV bus bar is reduced (as shown in figure 8 The transient process of output voltage of wind power is shown in figure 9, the current changing is presented in figure 10 and the transient velocity of motors is on Figure 11.

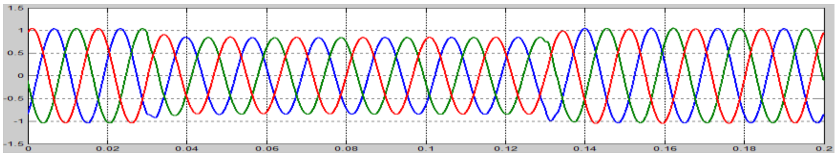

Fig. 8. Voltage on 22kV bus bar (B22)

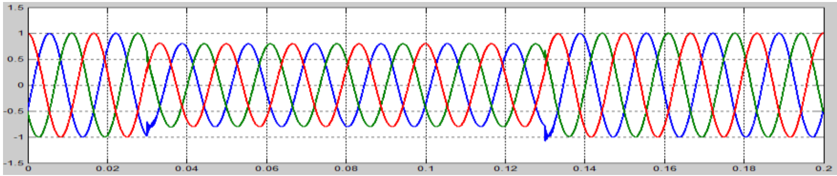

Fig. 9. Response voltage of wind power

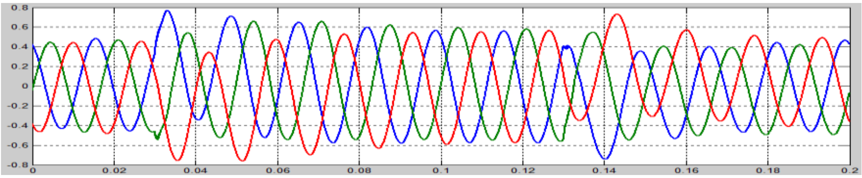

Fig. 10. Response current of wind power

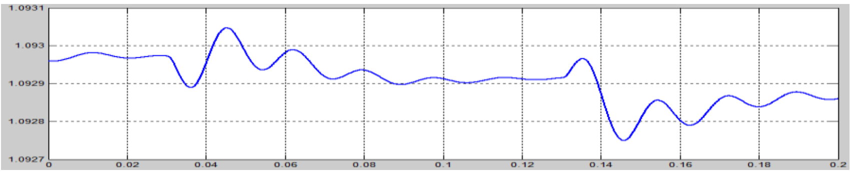

Fig. 11. The transient of generator velocity

4. Conclusion

The above simulations show that, when there is voltage sag on distribution grid (22kV bus bar) output voltage of generator is also down (fig. 9), consequently current of generator is increased (fig. 10). If the process is long lasting can cause over load or destroy the generator. At the moment of voltage recovery, wind power voltage is also recovered, but it is transient much over rated voltage. This cause to the transient of generator velocity (fig. 11).

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