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Dynamic Characteristic Analysis of Doubly-fed Induction Generator Low Voltage Ride-through

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Abstract

For studying the impacts of wind turbines integrated into grid, the relation between the protection of doubly-fed induction generator (DFIG) during low voltage fault and the dynamic characteristic of grid is established from the points of generator operation constrains and district grid voltage stability. Then the resistance value and switching strategy of crowbar are discussed. Based on analyzing the electric characteristic of the voltage or current during the short-circuit fault in wind turbines with crowbar switching, the equation to estimate peak current of stator and rotor of DFIG with crowbar switching and the value range of crowbar resistance are derived. The numeric test analyzes the impacts of crowbar switching on district grid voltage stability with different fault types, crowbar switching time and crowbar resistance values. Also the interaction impact of crowbar switching on multi-wind farms is analyzed. The results show that reasonable crowbar resistance value and switching strategy can improve low voltage ride through (LVRT) ability of wind turbines and reduce bad impacts on district grid voltage stability with large-scale crowbar switching of wind farms.

Keywords: Low voltage ride through (LVRT); doubly fed induction generator (DFIG); crowbar; voltage stability.

1. Introduction

With large scale wind power integrated into grid, its impacts on gird stability has been an important issue. Now, more and more grid operators required that wind turbines must have LVRT ability [1]-[3].

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DFIG stator links with grid directly, so grid voltage sags will cause terminal voltage sags and rotor over-current which may damage generator and converter [4]. It is difficult to realize LVRT [5]-[6]. However, additional crowbar circuit provides a method. Crowbar resistance value selection has been studied in [7]-[9]. Physical process of DFIG LVRT has been studied in [7] and [10].

In fact, DFIG LVRT and grid impact with each other when grid voltage sags. LVRT control can make DFIG maintain connection with grid so that DFIG can supply reactive power to support grid voltage. But long duration will make DFIG absorb reactive power from grid.

From the point of mutual impacts between DFIG LVRT and grid, dynamic characteristic of DFIG LVRT will be studied in this paper. The analysis of short-circuit current is described in Section II, the analysis of LVRT characteristic in SectionⅢ, and the numerical analysis in Section IV. Finally, the conclusions are drawn in Section V.

2. Analysis of Short-circuit Current

2.1 Equivalent Model of DFIG

Equivalent model of DFIG is shown in Fig.1.

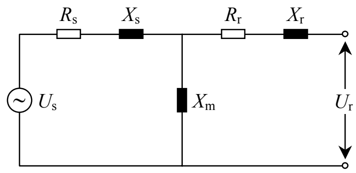

Fig. 1 Equivalent model of DFIG .

Rotor orientation method is used to analysis generator dynamic characteristic, so electromagnetic transient model is described as

$$\begin{cases} U_{ds} = \mathrm{D}\psi_{ds} - \omega_r \psi_{qs} + r_s I_{ds} \\ U_{qs} = \mathrm{D}\psi_{qs} + \omega_r \psi_{ds} + r_s I_{qs} \\ U_{dr} = \mathrm{D}\psi_{dr} + r_r I_{dr} \\ U_{qr} = \mathrm{D}\psi_{qr} + r_r I_{qr} \end{cases} \quad (1)$$

$$\begin{cases} \psi_{dr} = X_{rr} I_{dr} + X_m I_{ds} \\ \psi_{qr} = X_{rr} I_{qr} + X_m I_{qs} \\ \psi_{ds} = X_{ss} I_{ds} + X_m I_{dr} \\ \psi_{qs} = X_{ss} I_{qs} + X_m I_{qr} \end{cases} \quad (2)$$

Where, r_s is stator resistance, x_s is stator leakage reactance, r_r is rotor resistance, x_r is rotor leakage reactance, U_{ds} is stator voltage in d-axis, U_{qs} is stator voltage in q-axis, U_{dr} is rotor voltage in d-axis, U_{qr} is rotor voltage in q-axis, I_{ds} is stator current in d-axis, I_{qs} is stator current in q-axis, I_{dr} is rotor current in d-axis, I_{qr} is rotor current in q-axis, ψ_{ds} is stator flux in d-axis, ψ_{qs} is rotor flux in q-axis, ψ_{dr} is rotor flux in d-axis, ψ_{qr} is rotor flux in q-axis, ω_r is rotor angular velocity, X_m is excitation reactance, $X_{rr} = X_m + x_r$, $X_{ss} = X_m + x_s$, D is differential operator.

Considering transient flux change, the relation among rotor current, rotor voltage and stator current is