Study on fault-tolerant control of open-winding brushless doubly-fed wind power generator

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Background

Brushless doubly-fed generator (BDFG) has the advantages of reliable structure, easiness in implementing variable-speed constant-frequency, small converter capacity, and so on, which has a broad application prospect in large offshore wind power generation. There are two sets of windings with different pole numbers on the BDFG stator, which are respectively called the power winding for generation and the control winding for excitation. The coupling relationship between the two sets of stator windings is implemented by the special rotor. For the high reliability requirement of offshore wind power generation system, the fault-tolerant ability has been paid more and more attention.

Objectives

The proposed fault-tolerant control strategy enable the brushless doubly-fed wind power generator system to be normal operation under the fault of dual converters, and implement the power tracking control at the same time.

BDFG Model

\[ u_p = R_i i_p + \frac{dv}{dt} + j \omega_p \psi_p \]

\[ u_c = R_i i_c + \frac{dv}{dt} + j \omega_c \psi_c \]

\[ \psi_p = L_{ip} i_p + L_c i_c \]

\[ \psi_c = L_{ic} i_c + L_p i_p \]

\[ \Delta \Psi = \Delta \frac{v_i}{\omega_c + \Delta \omega_c} \]

Where:
- \( u_p, u_c \): power, control winding voltage vectors
- \( i_p, i_c \): power, control winding current vectors
- \( \psi_p, \psi_c \): power, control winding flux vectors
- \( \omega_c \): rotor angular frequency
- \( L_{ip}, L_{ic} \): power, control winding self-inductance
- \( L_p, L_c \): mutual inductance
- \( \Delta \omega_c \): rotor angular frequency change
- \( P, P' \): pole-pairs number of power, control winding

Methods

Structural Diagram

The control winding of BDFG is designed as open winding structure, that is, all the six terminals of control winding are drawn out to connect with dual converters.

Control System

The control system for the BDFG is designed as a three-level converter structure. The control system consists of the following parts:
- Power winding flux control
- Control winding flux control
- Power winding current control
- Control winding current control
- Power winding voltage control
- Control winding voltage control
- Power winding angle control
- Control winding angle control
- Power winding current detection
- Control winding current detection
- Power winding voltage detection
- Control winding voltage detection
- Power winding real-time control
- Control winding real-time control
- Power winding fault detection
- Control winding fault detection

Vector Distribution of Converter1/2

Reference Frames

Step Changes of Given Parameters

Results

A-phase current waveform of power winding

Conclusion

- For the special structure of the open-winding BDFG, a fault-tolerant control strategy based on direct power control (DPC) is proposed.
- DPC can independently control the active and reactive powers of BDFG, and has simple structure, strong robustness and good real-time.
- The simulation results verify the feasibility and validity of the proposed fault-tolerant control strategy for the open-winding BDFG.