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.

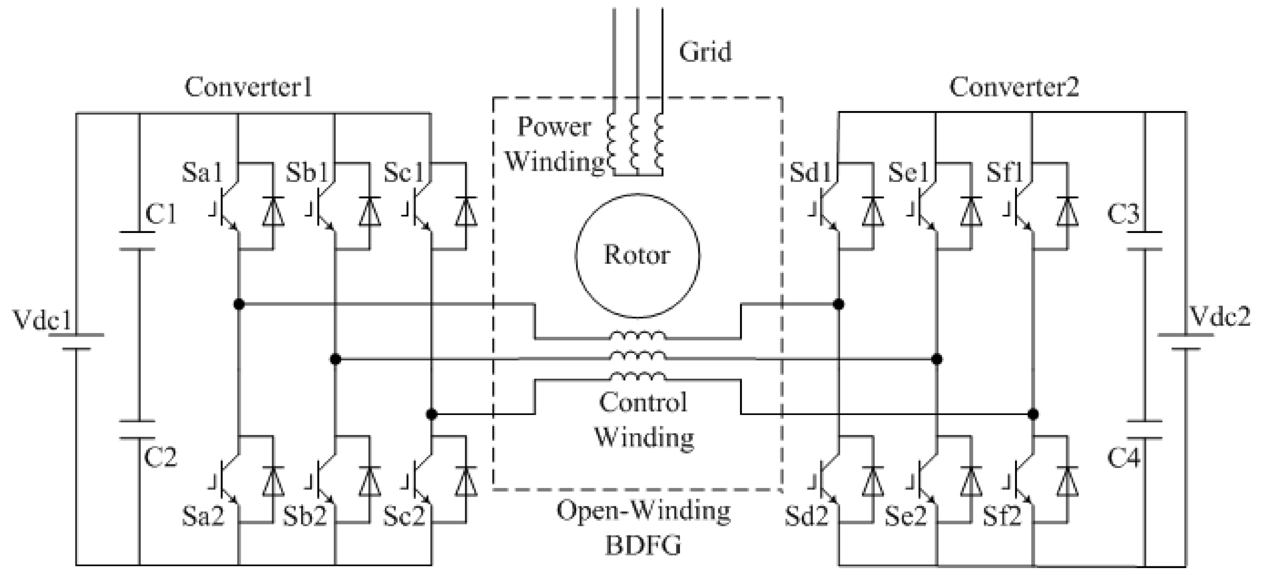
Objectives

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.

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.



BDFG Model

$$u_p = R_p i_p + \frac{d\psi_p}{dt} + j\omega\psi_p$$

$$u_c = R_c i_c + \frac{d\psi_c}{dt} + j(\omega_r - \omega)\psi_c$$

$$\psi_p = L_p i_p + L_{pc} i_c^*$$

$$\psi_c = L_c i_c + L_{pc} i_p^*$$

$$T_e = \frac{3(p_p + p_c)L_p}{2(L_p L_c - L_{pc}^2)} |\psi_c| |\psi_{pc}| \sin\delta$$

$$\Delta P_p \propto \Delta T_e$$

u_p, u_c : power, control winding voltage vectors

i_p, i_c : power, control winding current vectors

ψ_p, ψ_c : power, control winding flux vectors

ω: power winding reference frame angular frequency

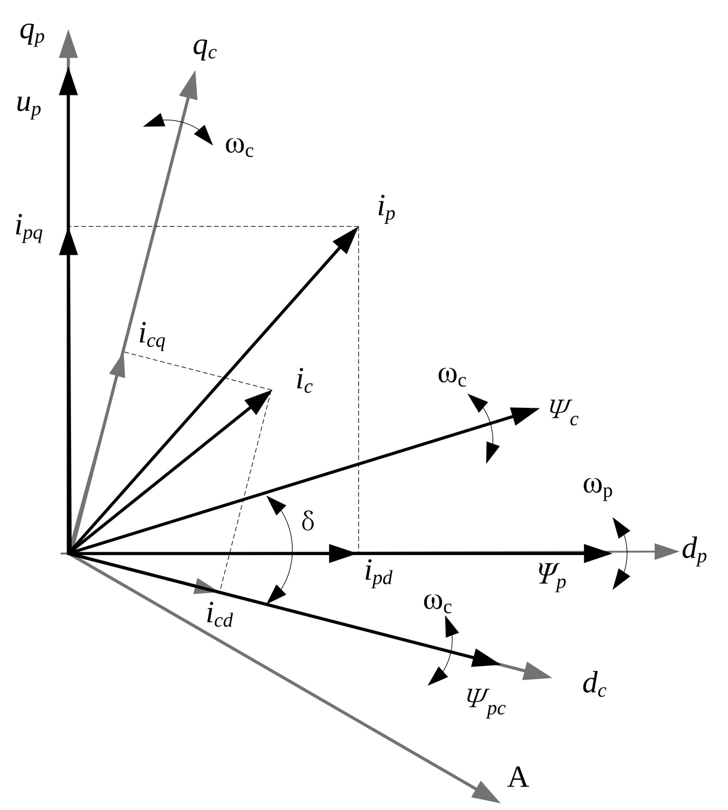
ω_r : rotor angular frequency

L_p, L_c : power, control winding self-inductance

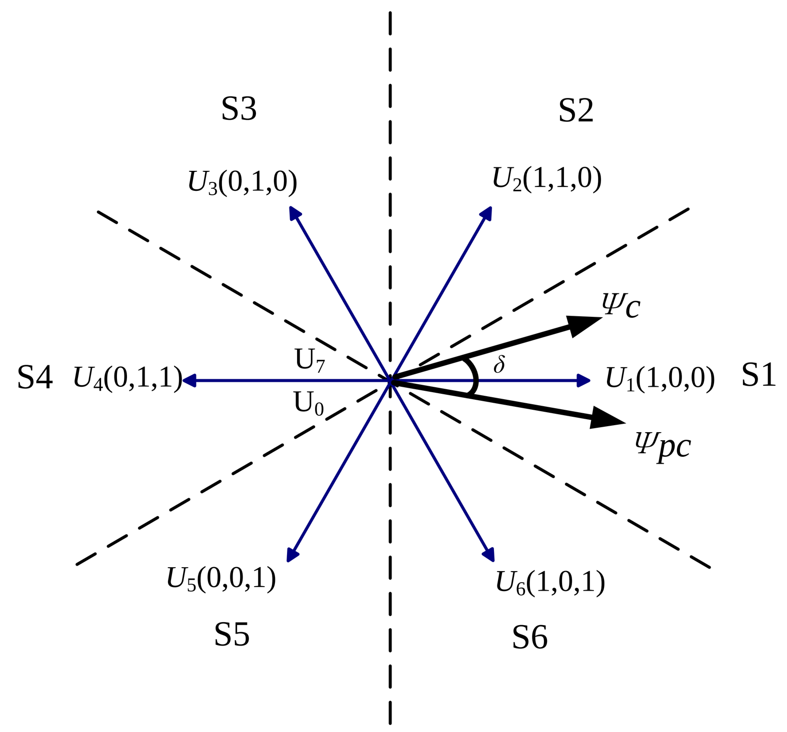
L_{pc} : mutual inductance

p_p, p_c : pole-pairs number of power, control winding

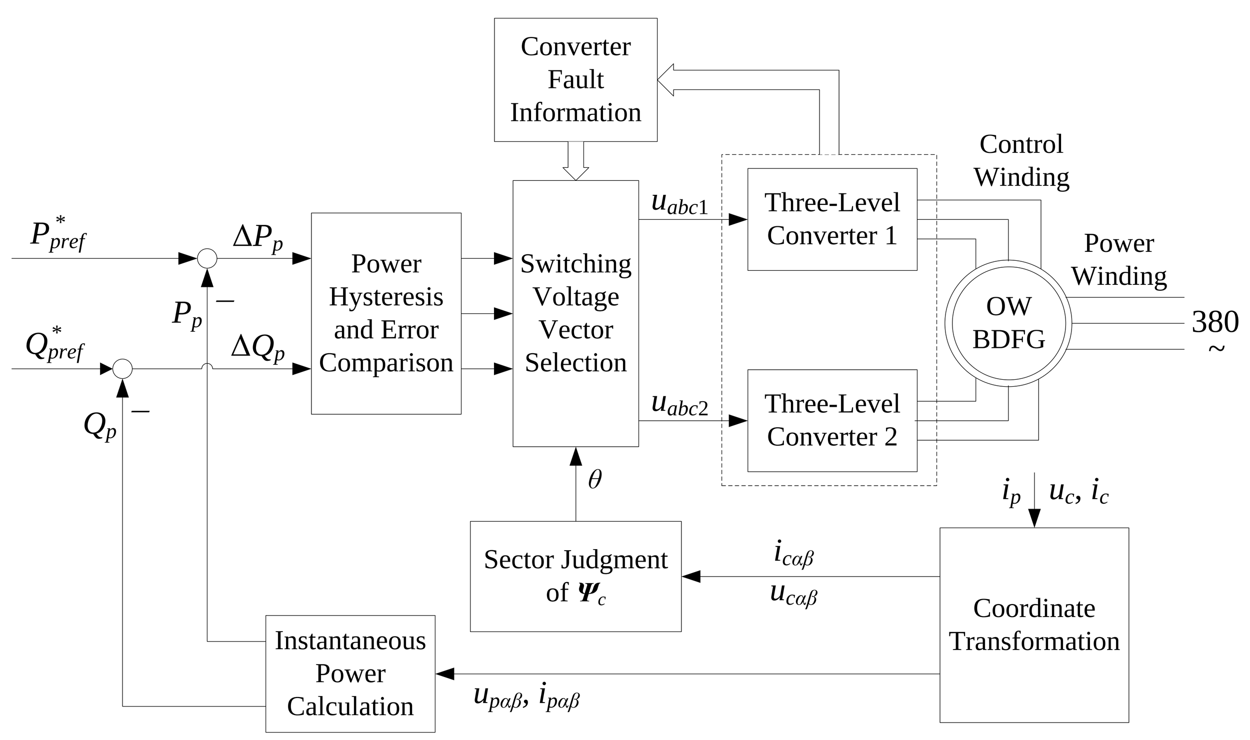
Reference Frames



Vector Distribution of Converter1/2



Control System

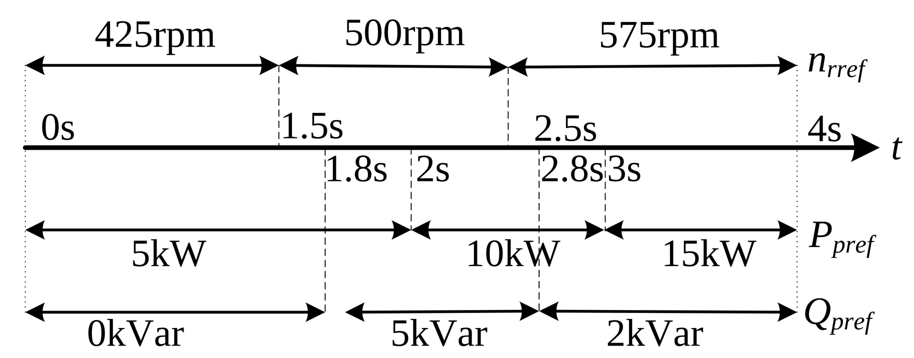


Conclusion

- 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.

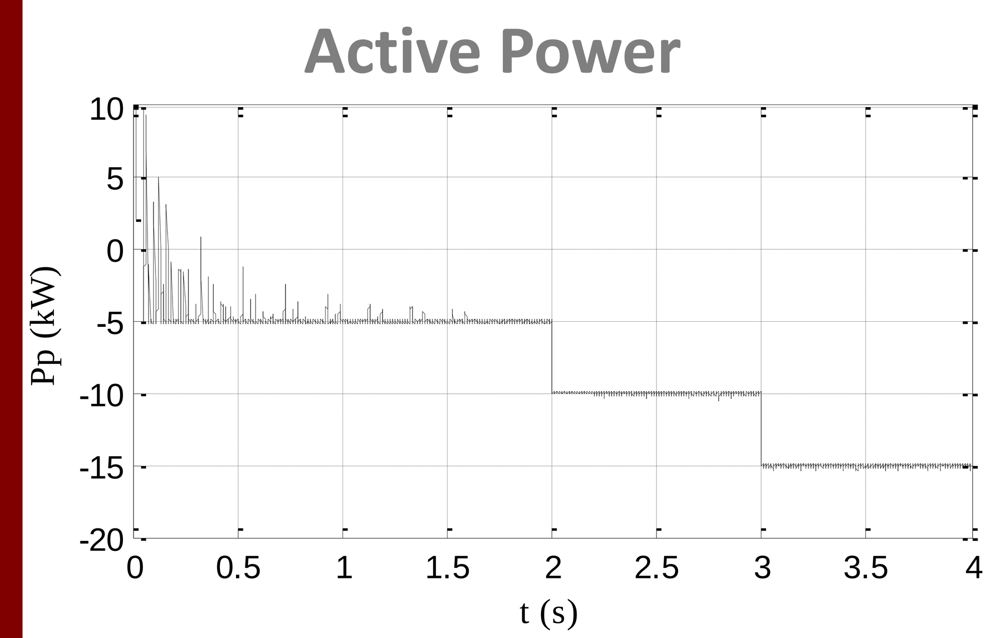
Results

Step Changes of Given Parameters

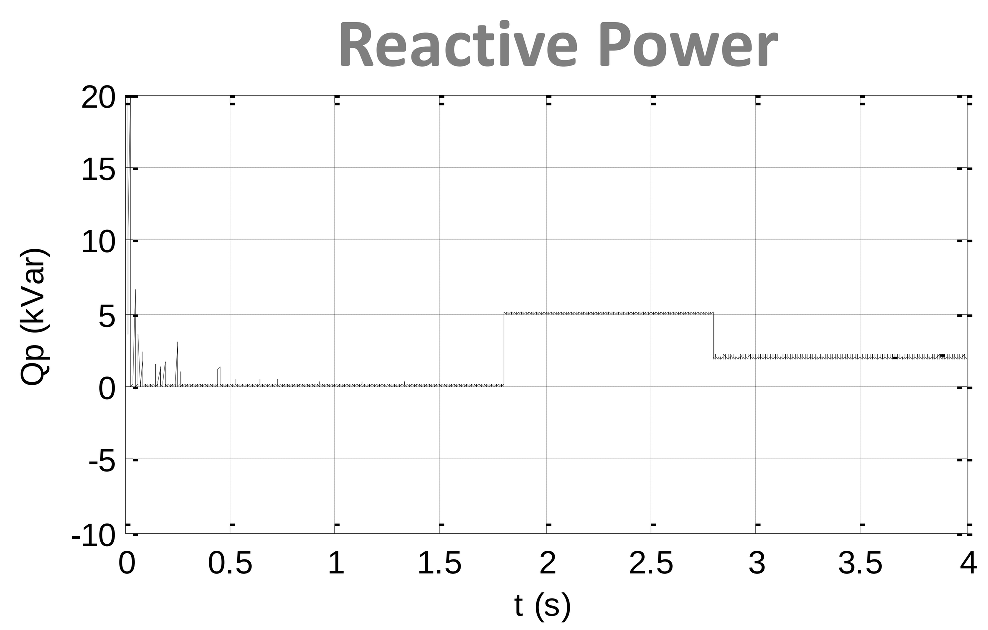


In the simulation process, the brushless doubly fed generator is operated at sub-synchronous, synchronous and super-synchronous speed respectively. Active and reactive powers are given a step change in different moments.

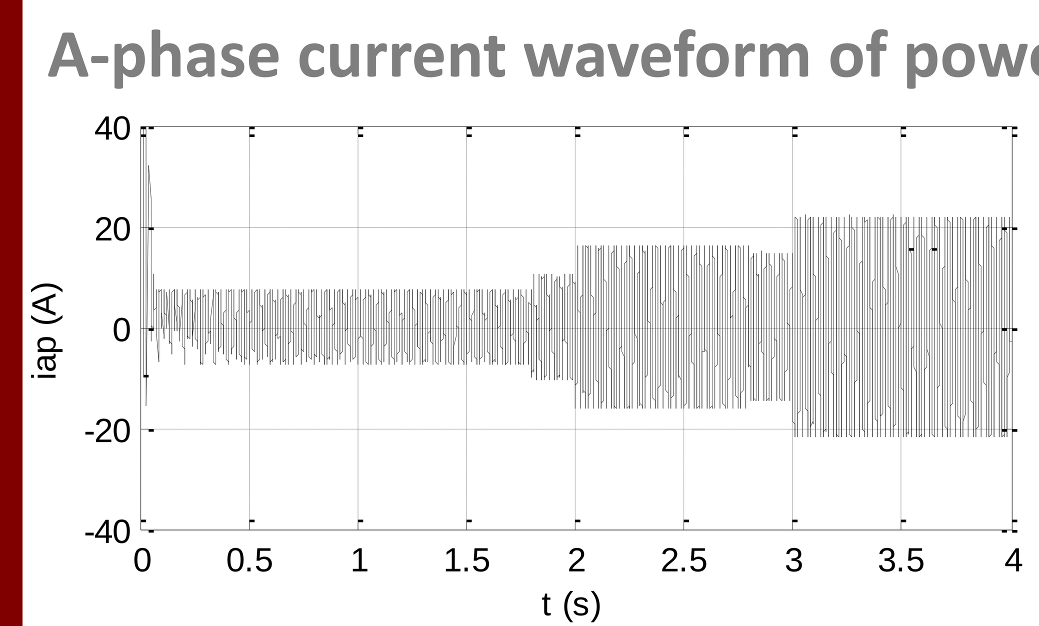
Active Power



Reactive Power



A-phase current waveform of power winding



Both active and reactive power vary with the given value. The power winding current is in good sinusoidal shape, and the frequency remains constant at 50HZ when the speed, active or reactive power is changed.

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