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Sensorless Machine Parameter-Free Control of Doubly Fed Reluctance Wind Turbine Generator

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Abstract : The brushless doubly-fed reluctance generator (BDFRG) is an emerging, medium-speed alternative to a conventional wound rotor slip-ring doubly-fed induction generator (DFIG) in wind energy conversion systems (WECS). It can provide competitive overall performance and similar low failure rates of a typically 30% rated back-to-back power electronics converter in 2:1 speed ranges but with the following important reliability and cost advantages over DFIG: the maintenance-free operation afforded by its brushless structure, 50% synchronous speed with the same number of rotor poles (allowing the use of a more compact, and more efficient two-stage gearbox instead of a vulnerable three-stage one), and superior grid integration properties including simpler protection for the low voltage ride through compliance of the fractional converter due to the comparatively higher leakage inductances and lower fault currents. Vector controlled pulse-width-modulated converters generally feature a much lower total harmonic distortion relative to hysteresis counterparts with variable switching rates and as such have been a predominant choice for BDFRG (and DFIG) wind turbines. Eliminating a shaft position sensor, which is often required for control implementation in this case, would be desirable to address the associated reliability issues. This fact has largely motivated the recent growing research of sensorless methods and developments of various rotor position and/or speed estimation techniques for this purpose. The main limitation of all the observer-based control approaches for grid-connected wind power applications of the BDFRG reported in the open literature is the requirement for pre-commissioning procedures and prior knowledge of the machine inductances, which are usually difficult to accurately identify by off-line testing. A model reference adaptive system (MRAS) based sensor-less vector control scheme to be presented will overcome this shortcoming. The true machine parameter independence of the proposed field-oriented algorithm, offering robust, inherently decoupled real and reactive power control of the grid-connected winding, is achieved by on-line estimation of the inductance ratio, the underlying rotor angular velocity and position MRAS observer being reliant upon. Such an observer configuration will be more practical to implement and clearly preferable to the existing machine parameter dependent solutions, and especially bearing in mind that with very little modifications it can be adapted for commercial DFIGs with immediately obvious further industrial benefits and prospects of this work. The excellent encoder-less controller performance with maximum power point tracking in the base speed region will be demonstrated by realistic simulation studies using large-scale BDFRG design data and verified by experimental results on a small laboratory prototype of the WECS emulation facility.

Keywords : brushless doubly fed reluctance generator, model reference adaptive system, sensorless vector control, wind energy conversion
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