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Advanced Doubly Fed Induction Machine Rotor Fault Diagnosis Based on Wavelet Analysis in Closed-Loop Operation Under Time–varying Condition

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Abstract. This paper introduces a new diagnostic technique for the detection of incipient electrical rotor faults in doubly fed induction Machine (DFIM) for wind power systems. In the considered application, the rotor is supplied by a static converter for the control of active and reactive power flows from the generator to the electrical grid. A new diagnostic method based on the rotor modulating signals pre-processing by Frequency Sliding (FS) and Discrete Wavelet Transform (DWT) thereby is here proposed to detect rotor faults dynamically over time. Experimental and simulation results demonstrate the effectiveness of the proposed approach under time-varying conditions.

Key words Doubly Fed Induction Machine (DFIM), rotor fault, Sliding Frequency (SF), Wavelet Decomposition (WD).

1. Introduction

Wind power generation has become the most accessible and efficient form of renewable energy during the past few years. Wind turbines equipped with Doubly Fed Induction Machine (DFIM) are emerging as the preferred technology in the field. Among different alternatives and for Variable Speed Constant Frequency (VSCF) generation systems, the DFIM can provide higher energy output with lower rating of power converter. Particularly in this type of application, monitoring the induction machine is crucial. The paper introduces a new monitoring and diagnostic technique for the detection of rotor electrical faults in DFIM for wind power systems. The main concern is that under time-varying conditions an efficient frequency transformation (Fourier Transform) cannot be made, since slip and speed vary and so the frequency components [1]. The above issues are enhanced in case of drives, where the control loop compensates the modulation of currents given by the faults. Hence fault signatures are masked by the regulators, and different variables must be monitored [2]-[3]. A new method based on the combined use of Discrete Wavelet Transform (DWT) and Frequency Sliding (FS), is here enhanced and optimized [4]-[5]. In order to detect rotor faults, rotor currents and voltages are analyzed by the proposed approach.

2. Control System Description

For a DFIM associated with a back-to-back PWM converter on the rotor side and with the stator directly connected to the grid, a stator flux oriented vector control is utilized in order to control separately the active and reactive power on the stator side [2].

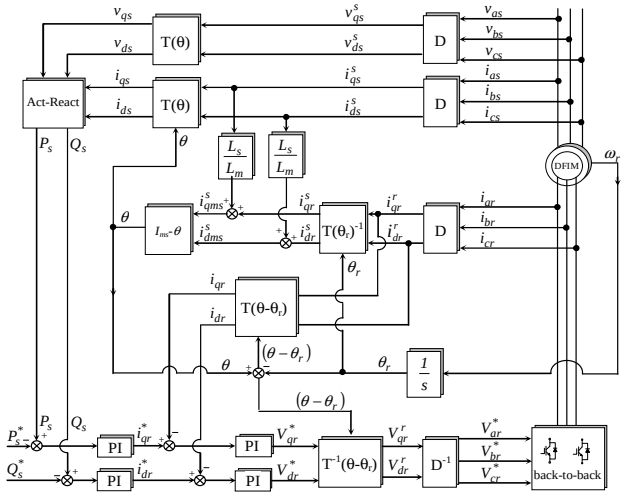

Fig. 1. Block scheme of the whole control system

3. Results

Simulation and experimental analysis were made to the proposed diagnostic procedure. In order to validate the results obtained in simulations a test bed was realized. A 5.5 kW 2 poles pair wound rotor induction machine was connected with a PWM back to back converter on the rotor side. The direct field oriented control for the DFIM was implemented on a d-SPACE DS1103 board. The generator was coupled with a 9 Kw DC motor fed by a

commercial DC/DC chopper converter. Experimental test bed photos are illustrated in Fig. 2. For the study of the phenomena caused by a rotor fault, an external resistance *Radd* has been inserted in series to one rotor phase in order to emulate rotor asymmetry.

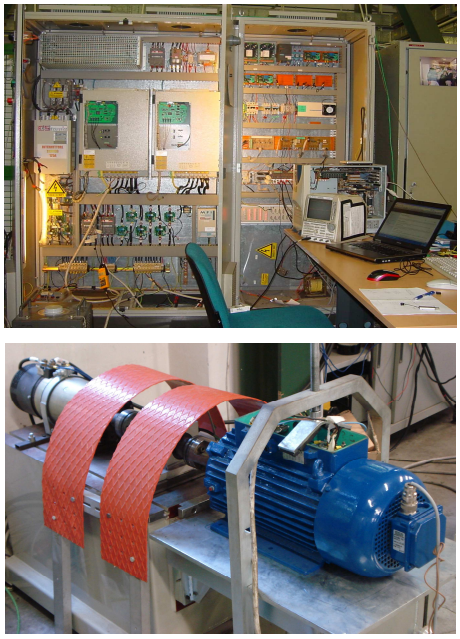

Fig. 2 Experimental test bed photos

Experimental and simulation results, under healthy and faulty conditions *(Radd=Rr)*, are depicted in Fig. 3 & 4 and Fig. 5 & 6 respectively. Experimental results corroborate simulation ones, although the magnitude evolutions in some cases are even bigger than in simulation. The 8th approximation signal obtained from the experimental results show the sensitivity and the effectiveness of this particular approximation signal to reproduce the contribution of the frequency component - *sf* under rotor unbalance.

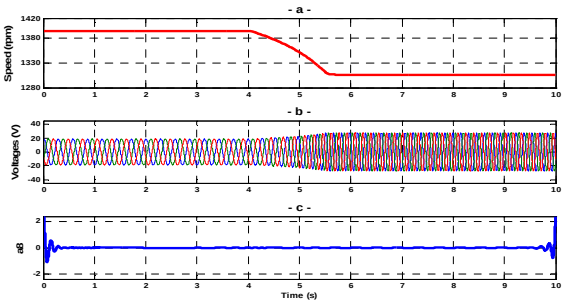

Fig. 3. DWT of the rotor voltage V_{sl} in healthy condition (Radd=0) under speed transient. Simulation results

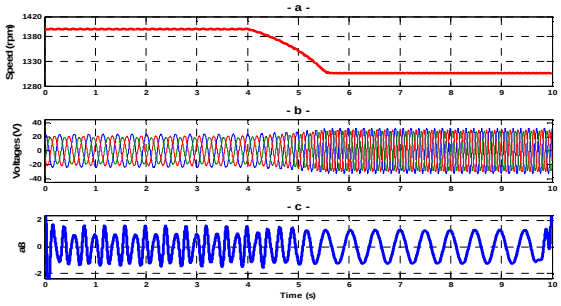

Fig. 4. DWT of the rotor voltage V_{sl} in faulty condition (Radd=Rr) under speed transient. Simulation results

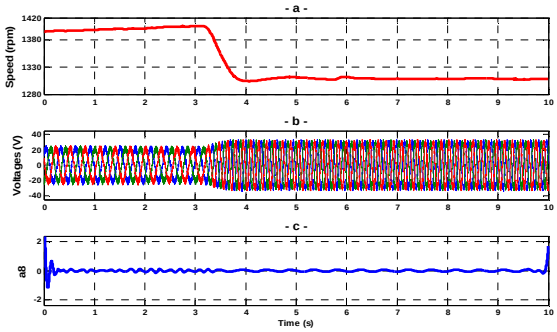

Fig. 5. DWT of the rotor voltage V_{sl} in healthy condition (Radd=0) under speed transient. Experimental results

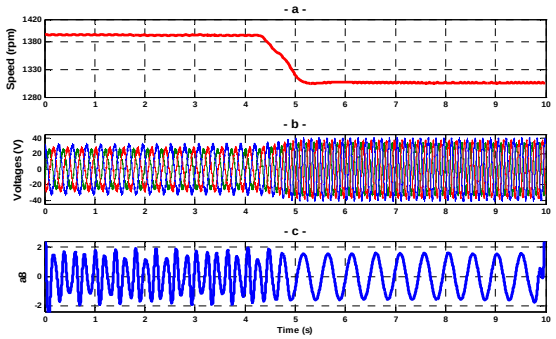

Fig. 6. DWT of the rotor voltage V_{sl} in faulty condition (Radd=Rr) under speed transient. Experimental results

4. Conclusion

The aim of this paper was to validate the effectiveness of a new and reliable approach for the characterization of rotor fault in time varying condition.The proposed approach is based on an optimized use of the DWT by a simple pre-processing of the variables to be analyzed. Results prove that for closed loop condition and under a rotor unbalance, rotor voltages are more sensitive than rotor currents. These results show the limits of the current signature analysis under time-varying conditions. A dynamic time-frequency fault indicator is presented to quantify the fault extent. Simulation and experimental results carried out, demonstrate the effectiveness of this new approach that can be applied to any type of machine and extended for diagnosing other types of faults under time–varying conditions.

References

[1] A. Stefani, F. Filippetti, A. Bellini, "Diagnosis of Induction Machines in Time-varying Conditions", IEEE Trans. on Ind. Appl., Vol. 56, N° 11, Nov. 2009.

[2] A. Stefani, A. Yazidi, C. Rossi, F. Filippetti, D. Casadei and G.A. Capolino, "Doubly Fed Induction Machines Diagnosis Based on Signature Analysis of Rotor Modulating Signals", IEEE Trans. on Indus. Appl., Vol. 44, N° 6, Nov/Dec 2008.

[3] Y. Gritli, A. Stefani, F. Filippetti and A. Chatti, "Stator fault analysis based on Wavelet technique for wind turbines equipped with DFIG", ICCEP'09, pp 485-491. Italy, June 2009.

[4] Y. Gritli, A. Stefani, C. Rossi, F. Filippetti and A. Chatti, "Doubly Fed Induction Machine Stator fault Diagnosis Under Time-Varying Conditions Based on Frequency Sliding and Wavelet Analysis", IEEE-SDEMPED'09. Cargese-France, Aug./Sep. 2009.

[5] Y. Gritli, A. Stefani, A. Chatti, C. Rossi and F. Filippetti, " The Combined use of the Instantaneous Fault Frequency Evolution and Frequency Sliding for Advanced Rotor Fault Diagnosis in DFIM Under Time-Varying Condition", IECON'09. Porto-Portugal, Nov. 2009.