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Condition Monitoring and Fault Detection in Wind Turbine Based on DFIG by the Fuzzy Logic

Hichem. Merabet [a, b*], Tahar. Bahi [a], Noura Halem [c]

[a] *Electrical Department, LASA Laboratory, Faculty of Science Engineering, University of Annaba, Algeria*
[b] *Welding and NDT research center (CSC) BP 64 Cheraga, Algeria*
[c] *LMSE Laboratory , University of Biskra, Algeria*

Abstract

Doubly-fed induction generator is widely used in wind turbine conversion systems. Several research works are being made to efficiently approve existing condition monitoring and fault detection techniques for these systems. The condition monitoring of these systems becomes more and more important, the main obstacle in this task is the lack of an accurate analytical model to describe a faulty DFIG in the majority of the research tasks. In this paper, we present the monitoring strategy of short-circuit fault between turns of the stator windings and open stator phases in doubly-fed induction generator by fuzzy logic technique. The stator condition monitoring is diagnosed based on the root mean square values of current magnitude in addition to the knowledge expressed in rules and membership function. The proposed strategy is verified using simulations performed via the model of Doubly-fed induction generator built in MatLab ® SIMULINK.

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1. Introduction

Wind energy installations based on doubly-fed induction generators (DFIG) take an important place in the world of production of electric energy, because of the robustness of this machine in such installations types, the increase interest of wind energy has been accompanied by efforts to improve reliability, effective condition monitoring and better efficiency [1, 2].

* Corresponding author. Tel: +213-0698-81-02-34.
E-mail address: h.merabet.@csc.dz

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The condition monitoring and fault detection are important in energy conversion systems to avoid serious consequences because any fault is potentially able to impact the total system behavior with higher operation costs and shutdown of electrical energy production [3-5].

Generally, the DFIG can be external or internal fault. For the external faults, they are caused by the feeding source (the rotor feeding), the mechanical load, and the machine use environment. The intern faults are caused in the magnetic circuits, stator and/or rotor windings, the air-gap, and the machine cage rotor. Within this framework, the statistics reveal that the electrical faults on the level of the stator are the most recurrent [6-8].

Nevertheless, through this work, electrical faults will be well interested, particularly in the short-circuit faults between stator turns and the open stator phases faults of the (DFIG).

The short circuit inter-turn fault of stator windings usually starts as an undetected insulation failure between two adjacent turns. As a result, it slowly develops to a short circuit isolating a number of turns. In some cases, the fault occurs due to an electric arc connecting two points of the winding [9, 10].

The open stator phases are caused by several origins. This fault causes are the cancellation of the current in the phase failing, the unbalanced of the currents in other phases and the significant undulation of torque. These consequences are less serious than a short-circuit fault since it does not have of problem of heating which can deteriorate the remainder of the machine, but it remains a fault which disturbs the generator function in the supply mode of electrical power energy [11, 12].

The novel diagnosis techniques of energy conversion system have widely used the condition-based maintenance strategies to reduce unexpected failures and downtimes. These techniques have progressed from traditional methods to artificial intelligence based on fuzzy logic system, artificial neural network or combined structure techniques. These techniques have many advantages compared to conventional fault diagnostic approaches [13-15].

Therefore, the proposed approach in this paper is based on the artificial intelligence (fuzzy logic), in the aim to increase the efficiency and the reliability of the diagnosis in the supervision field and diagnosis of the DFIG [16-18]. The model based on artificial intelligence approach as well as the global model are implemented by using software MatLab ® SIMULINK and the obtained results by simulations at healthy function case, short-circuit and open stator phases faults will be mainly represented and interpreted.

2. Modeling of the healthy DFIG

A. Mechanical system modeling

A.1. Turbine modeling

The relation (1) presents the specific speed (λ) to characterize the aerodynamic performance of a wind turbine [19]:

$$\lambda = \frac{R\Omega_t}{V} \quad (1)$$

With;

Ω_t: angular velocity of turbine rotation;

R: radius of the turbine;

V: wind speed.

The output power (P_g) is given by the following equation:

$$P_g = \frac{1}{2} C_p(\lambda, \beta).\rho.\pi.R^2.V^3 \quad (2)$$

Where, the power coefficient (C_p) is given by the following relationship [20]:

$$C_p(\lambda, \beta) = C_1[(C_2.a - b) - C_3.\beta - C_4)]e^{-c_6(a-b)} + C_6\lambda \quad (3)$$

With;

$$a = \frac{1}{\lambda + 0.08\beta} \quad \text{and} \quad b = \frac{0.035}{\beta^3 + 1}$$

C_1= 0.5109, C_2 = 116, C_3= 0.4, C_4 = 5, C_5 = 21, C_6=0.0068.