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Introduction on Advances in Diagnosis for Power Electronics Devices in wind energy, based on a doubly-fed asynchronous generator

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***Abstract*— In this paper a survey on some of the recent researches in fast fault detection and localization in AC-DC-AC converters for wind energy conversion systems are presented. The faulty switching devices are detected and localized in both converter rotor side and converter grid side in the doubly-fed asynchronous generator. Those approaches are based on parametric estimation, pattern recognition neural network and fuzzy logic. Those methods are able to diagnose an open and short fault switch in the converter. Their reliability was proved by simulations and experiments using a 10 kW simulator.**

***Keywords*— converter, neural network, fuzzy logic, pattern recognition, fault detection, switch**

I. Introduction

AC / DC / AC static converters are used today in many power electronics applications; among these applications include renewable energy. Continuity of service of these systems and their security, reliability and performance are now a major concern. Indeed, Power systems are mostly feeding safety critical loads requiring nonstop and fault tolerant operation. Therefore continuity of service is of a high importance in power generation units. Modern wind energy conversion systems are sensitive to failure in power switches. A sudden failure in one of the power switches decreases system performances and leads to disconnecting the system. Moreover, if the fault is not quickly detected and compensated, it can lead to hard failure [1-2]. Hence, to reduce the failure rate and to prevent unscheduled shutdown, real-time fault detection, isolation and compensation scheme must be adopted [3]. The focus of this paper is to explore on some of the recent researches on fast fault detection and reconfiguration in AC-DC-AC converters for wind energy conversion systems in a doubly-fed asynchronous generator based on parametric estimation, pattern recognition, fuzzy logic and neural network.

II. System Description

The doubly fed induction generator allows variable speed operation that can extract maximum power.The stator pulsation (imposed by the GRID) is assumed to be constant; therefore it is possible to control the speed of the DFIG acting on the rotor apparent power via the parameter g. The converters in the grid side and the rotor side are controlled by the Pulse Width Modulation. Some of the researches are based on a classical back-to-back converter and uses a common redundant leg for both three-phase power converters, illustrated in fig 1. The redundant leg composed of the switches S7 and S8 and will replace the faulty one of the other legs under any power switch failure in the Grid Side Converter (GSC) or the Rotor Side converter (RSC).

III. The Fault Detection Methods

A. *Parametric estimation*

The approach is based on a “time criterion” and a “voltage criterion”, to attain short detection time, an FPGA is used. Power switch fault detection is based on the comparison between measured and estimated pole voltages, vko (k = 1, 2, 3), respectively noted vkom and vkoes. The FPGA-based fault detection and compensation block directly applies the switching patterns, determined by the RSC and GSC controllers, to the power converters. In faulty case, the fault detection scheme detects the fault (in the RSC or the GSC) and the control orders of the two drivers of the faulty leg are removed. Moreover, the fault signal triggers the suited bidirectional switch and the control orders of the faulty leg are applied to the redundant one. Finally, the fault detection scheme is disabled by the same fault signal. However, in real case, because of turn-off and turn-on propagation time and interlock dead time generated by the switches drivers, the voltage error is not null and constituted of peak during switching time. To avoid false fault detections due to power semi-conductors switching, a ‘time’ criterion is used. The output of the comparator is connected to an up-counter as shown in Fig 2. Therefore the output of the up-counter is equal to the number of clock pulses while vkom and vkoes are

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different. Finally, the up-counter output is applied to a second comparator with a threshold value, Nt, several times larger than the switching time. The resulting signal fk from the fault detection scheme is used to isolate the faulty leg, to trigger the suited switch tk and to stop the fault detection scheme. [3]

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B. Neural network based on pattern recognition

The most challenging aspect in an electric circuit diagnostic system is to detect a fault immediately after it occurs and pinpoint to the cause of the faults. As soon as a fault is detected and isolated where it is, it is possible to either isolate or shut down the faulty part of the circuit to minimize the damage [4]. During the last two decades, Artificial Neural Networks (ANN) had been successful to detect different types of fault, reliable and providing a greater efficiency in fault detection, neural network are also able to learn from examples and generalizing them. Faulty switches are detected by analysing the obtained pattern and pattern recognition is achieved by a neural network that has a learning capability. The Neural Network is configured for data classification, through a learning process. The measured three-phase currents used in order to control power conversion system, can be transformed into the stationary reference frame currents (ids, iqs)

$$ids = \frac{2}{3}ias - \frac{1}{3}ibs - \frac{1}{3}ics \quad (1)$$

$$iqs = \frac{1}{\sqrt{3}}(ibs - ics) \quad (2)$$

The currents expressed in (1) and (2) can be observed in the d–q frame on which the horizontal-axis is signified by isd and he vertical-axis is signified by isq. The current vectors shown on the plane possess specific shapes that depend on the conditions of the switch devices. The current vector in circle form illustrates that all switch devices can operate without incurring the open faults. Conversely, if a switch device fault occurs, the current vector will assume an individual form different from its original state. This shape depends on the switch device in which the fault occurred. Three parameters can be extracted from the form given by the current vectors; surface, vector angle and distributed angle. Therefore a neural network is used to classify and identify the faulty switch device. The network is trained with data obtained from the simulation results. [5]

C. Fuzzy pattern recognition system

The method can not only detect both open and short faults but can also identify faulty switching devices without additional voltage sensors. The location of a faulty switch can be indicated by six-patterns of a stator current vector and the fault switching device detection is achieved by analysing the current vector. The proposed fault diagnosis technique is based on the analytic and the heuristic characters of a PWM converter. A conventional tool, binary logic, is not suited for processing uncertain and doubtful data. On the other hand, a fuzzy system can properly deal with linguistic expression and reasoning processes by employing if-then rules [6]. In fact, fuzzy pattern recognition could also be helpful for the localization of the faulty switch , a pattern may have a partial membership in different classes, fuzzy sets are appropriate for pattern classification.

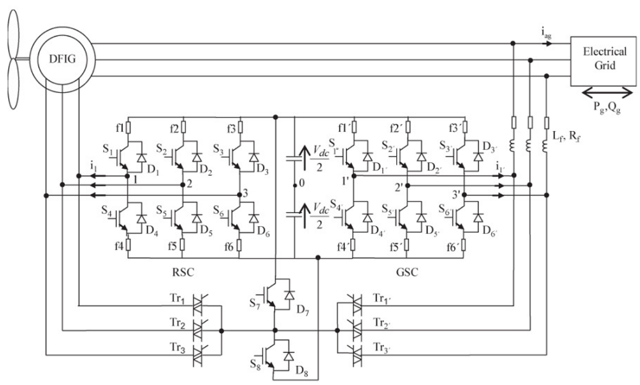

Fig. 1 Fault tolerant topology with DFIG

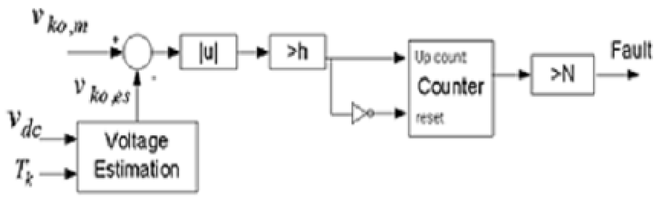

Fig. 2 The Proposed fault detection

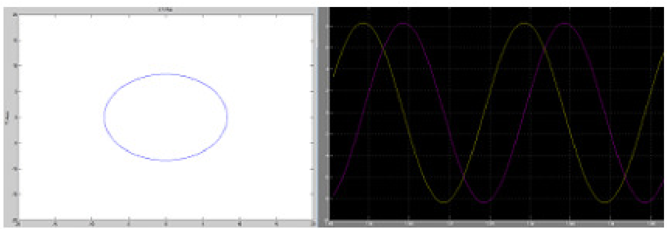

Fig. 2 Healthy mode simulation in one period

IV. CONCLUSIONS

This paper discusses different approach for diagnosis and identification of a faulty switch device with or without sensors with or without a redundant leg, based on pattern recognition or parametric estimation the methodology and the steps of each approach had been exposed.

Nowadays, many papers proposing neural network for fault detection can be found, therefore, there is still much to do in terms of algorithms adaptation, implementation, and minimal realization for fault detection in power electrical engineering. Using Simulink for three-phase power conversion system, simulation of the current vector in d-q frame in the healthy mode was obtained, a circle form as shown in fig.3, diagnosis in the faulty mode and detection of the faulty switch will be in a future publication.

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