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Detection and classification of faults in pitch-regulated wind turbine generators using normal behaviour models based on performance curves

Ran Bi, Chengke Zhou, Donald M. Hepburn



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1 **Detection and Classification of Faults in Pitch-regulated Wind Turbine Generators** 2 **Using Normal Behaviour Models Based on Performance Curves**

3 Ran Bi^{*}, Chengke Zhou and Donald M Hepburn

4 School of Engineering and Built Environment, Glasgow Caledonian University, Glasgow, UK G4
5 OBA

6 ^{*}Corresponding author. Tel.: +44-747-249-9306; E-mail: ran.bi@gcu.ac.uk

7 Email: C.Zhou@gcu.ac.uk; D.M.Hepburn@gcu.ac.uk

9 **Highlights**

- 10 ● Propose normal behaviour models based on performance curves to detect WTG faults;
- 11 ● Examine WTG performance under the normal conditions and with pitch faults;
- 12 ● Demonstrate the feasibility of the proposed approach based on performance curves;
- 13 ● Validate the criteria for electrical pitch system fault detection;
- 14 ● Prove the advantages of the proposed approach over the ANN/ANFIS based approaches.

15 **Abstract**

16 The fast growing wind industry requires a more sophisticated fault detection approach in pitch-
17 regulated wind turbine generators (WTG), particularly in the pitch system that has led to the highest
18 failure frequency and downtime. Improved analysis of data from Supervisory Control and Data
19 Acquisition (SCADA) systems can be used to generate alarms and signals that could provide earlier
20 indication of WTG faults and allow operators to more effectively plan Operation and Maintenance
21 (O&M) strategies prior to WTG failures. Several data-mining approaches, e.g. Artificial Neural
22 Network (ANN), and Normal Behaviour Models (NBM) have been used for that purpose. However,
23 practical applications are limited because of the SCADA data complexity and the lack of accuracy due
24 to the use of SCADA data averaged over a period of 10 minutes for ANN training. This paper aims to
25 propose a new pitch fault detection procedure using performance curve (PC) based NBMs. An
26 advantage of the proposed approach is that the system consisting of NBMs and criteria, can be
27 developed using technical specifications of studied WTGs. A second advantage is that training data is
28 unnecessary prior to application of the system. In order to construct the proposed system, details of
29 WTG operational states and PCs are studied. Power-generator speed (P-N) and pitch angle-generator
30 speed (PA-N) curves are selected to set up NBMs due to the better fit between the measured data and
31 theoretical PCs. Six case studies have been carried out to show the prognosis of WTG fault and to
32 demonstrate the feasibility of the proposed method. The results illustrate that polluted slip rings and
33 the pitch controller malfunctions could be detected by the proposed method 20 hours and 13 hours
34 earlier than by the AI approaches investigated and the existing alarm system. In addition, the proposed
35 approach is able to explain and visualize abnormal behaviour of WTGs during the fault conditions.

36 *Keywords:* condition monitoring, wind turbine generator, pitch faults, performance curves, normal
37 behaviour model

38 **Abbreviation**

39	WTG	Wind Turbine Generator
40	SCADA	Supervisory Control and Data Acquisition
41	O&M	Operation and Maintenance
42	ANN	Artificial Neural Network
43	NBM	Normal Behaviour Model
44	PC	Performance Curve
45	CM	Condition Monitoring
46	ANFIS	Adaptive Neuro-Fuzzy Interference System
47	APK	A-Priori Knowledge
48	SIMAP	Intelligent System for Predictive Maintenance
49	CMS	Condition Monitoring System

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