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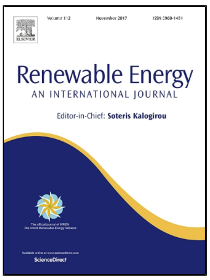

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Condition Monitoring and Fault Detection in Wind Turbines Based on Cointegration Analysis of SCADA Data

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Abstract

This paper presents a new methodology – based on cointegration analysis of Supervisory Control And Data Acquisition (SCADA) data – for condition monitoring and fault diagnosis of wind turbines. Analysis of cointegration residuals – obtained from cointegration process of wind turbine data – is used for operational condition monitoring and automated fault and/or abnormal condition detection. The proposed method is validated using the experimental data acquired from a wind turbine drivetrain with a nominal power of 2 MW under varying environmental and operational conditions. A two-stage cointegration-based procedure is performed on six process parameters of the wind turbine, where data trends have nonlinear characteristics. The method is tested using two case studies with known faults. The results demonstrate that the proposed method can effectively analyse nonlinear data trends, continuously monitor the wind turbine and reliably detect abnormal problems.

Keywords: wind turbine, condition monitoring, fault detection, cointegration, SCADA, trend analysis

1. Introduction

It is well known that unexpected failures of wind turbine components can cause costly repair and often months of machine unavailability, thereby increasing operation and maintenance costs and subsequently cost of energy. Therefore, condition monitoring and fault diagnosis of wind turbines (WTs) at the early stage of fault occurrence is important [1–3]. Condition Monitoring (CM) is often defined as the process of monitoring a parameter of condition in machinery (e.g. vibration or temperature) such that a significant change is indicative for a developing failure [4]. Various CM techniques have been developed to detect and diagnose abnormalities of WTs, as reviewed in the literature [2,5–10], such as vibration analysis, oil monitoring and analysis, acoustic emission, ultrasonic testing techniques, strain measurement, radiographic inspection, thermography. The recent review in [10] presented a comprehensive survey on the state-of-the-art condition monitoring and fault diagnostic technologies for wind turbines with the focus on the signals and signal processing methods.

Another solution – based on the use and analysis of Supervisory Control And Data Acquisition (SCADA) data – has been recently employed in [3,11–17]. This approach is cost-efficient, readily available, and is beneficial for identifying abnormal components because only key process parameters need to be tracked [2,3,15,16]. However, the previous investigations in [3,11–17] have shown that condition monitoring and fault diagnosis of WTs through processing and interpreting simultaneously a large amount of data obtained from a SCADA system is difficult and can be daunting for an experienced analyst or engineer. Moreover, monitoring of data trends and removal of undesired effects of environmental and operational variability from SCADA data are important when SCADA approaches are used. However, these issues have not been adequately investigated in the literature. Therefore, the major objective of this study is to develop a new SCADA data analysis method for effective trend removal, continuous condition monitoring, and reliable abnormal detection of WTs.

The cointegration approach – originally developed in the field of Econometrics in the late 1980s and early 1990s [18–20] – has been recently proposed as a new methodology for monitoring nonstationary

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