Wind Turbine System Health Monitoring
Based on Gaussian Mixture Model using SCADA Data

Akihisa Yasuda/Jun Ogata/Masahiro Murakawa/Hiroyuki Morikawa/Makoto Iida
The University of Tokyo/AIST/AIST/The University of Tokyo/The University of Tokyo

Abstract

Failures of internal components of wind turbines lead to prolonged downtime, and maintenance cost will increase. It is necessary to detect incipient faults and improve availability with reducing unscheduled maintenance. In this study, in order to realize system health monitoring of wind turbine by low cost, we are developing a method for evaluating the health of the wind turbines using the data of standard equipment installed for supervisory control of almost all wind turbines, called Supervisory Control And Data Acquisition (SCADA). The proposed method extracts the operating condition suitable for evaluating the health of the wind turbines by exploiting operation mode selection, instead of focusing on individual internal components. Specifically, we perform the filtering based on the domain knowledge of time series data such as rotational speed of the main shaft, nacelle direction, pitch angle, wind direction, outside temperature and gearbox temperature collected by SCADA system. We then build a classifier for determining the normal operating condition of the wind turbines. Consequently, our classifier is able to assess the deterioration of the wind turbines by utilizing SCADA data and comparing with the trained normal condition.

Objectives

To maintain the growth of wind power markets [1], the Levelized Cost of Energy should be kept as low as possible, and operation and maintenance costs should be reduced. Although an effective method for this purpose is a Condition Monitoring System (CMS), commercially available CMSs are very expensive, and implementing such systems to all existing wind farm turbines is very difficult. As an alternative to a CMS, previous studies have proposed the use of data collected by SCADA systems [2][3]. The objective of our study is improving the performance of anomaly detection and grasping the signs 3 months before failure occurrence.

Methods

In this study, a system framework based on the Gaussian Mixture Model (GMM) [4] is proposed for wind turbine health monitoring (Figure 1). The proposed framework includes off-line modeling and on-line degradation assessment. Historical normal behavior state SCADA data are collected to construct the GMM model and calculate threshold data. Then, the proposed framework uses the constructed model and threshold data to perform a performance degradation assessment of the wind turbines. In the SCADA data pre-processing process, for wind conditions, we limit the scope of the wind speed. The wind speed at wind turbines is primarily divided into three regions in the operational state [5]. Focusing on Region 2 is appropriate for health monitoring because such conditions cause moderate load on the internal components of wind turbines and induces a failure state in important components, such as the gearbox and the generator. Therefore, we only use Region 2 wind speed SCADA data (all other data are excluded).

Results

An actual failure case was examined to investigate the effectiveness of the proposed wind turbine health monitoring system. The SCADA data used in this evaluation were measured at a wind farm with eight 2 MW-class wind turbines. The data were collected at 10-minute intervals between 01/01/2014 and 08/31/2015. Note that failure/exchange events occurred twice in the same wind turbine (between 06/01/2014 and 06/15/2014 and 06/15/2015 and 06/28/2015). Therefore, we recognized a four-month period (06/15/2014-10/15/2014) as the normal behavior condition. The SCADA data for this period were used as training data.

Figure 2 shows the Negative Log Likelihood Probability (NLLP) value as an anomaly level score, which is calculated by the proposed system using only SCADA data. The number of mixture components of the GMM included in the system was 11, and the threshold value was calculated as the NLLP value using the training data and indicates a value deviating from the 95% confidence interval. Figure 2 shows that the proposed health monitoring system can discriminate between training data, i.e., the normal behavior state, and the test data, which includes anomaly states. Note that a state in which the anomaly level score exceeded the threshold was detected approximately six months before the gearbox was exchanged.

Conclusions

We have presented a GMM-based anomaly detection method for wind turbine health monitoring. In the feature extraction stage, we apply a filtering method based on domain knowledge about wind turbine operation and select nearly all SCADA data items related to internal equipment to model the entire drive train. In the anomaly detection stage, we employ a classification approach based on a GMM. An evaluation using actual SCADA data demonstrates that the proposed system has the potential to predict a failure three months in advance.

References

2. Dong, Y.; Fang, F. and Yujiro Gu 2013 Journal of Renewable and Sustainable Energy 5 033117