Wind Turbine Major Components Failure Predicting Based on SCADA Data Analysis

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Long Huan
LongYuan Power Wind Energy Overview/Portfolio

>15 GW Wind Energy  >11000 Wind Turbines  >160 Wind Farms

22 Different Turbine Manufacturers  90 Models

Investment, Design, Development, Construction, Management, O&M service.

Owner maintained more than 75% turbines in China
### What we use SCADA data for

<table>
<thead>
<tr>
<th>KPI</th>
<th>PBA</th>
<th>Benchmark analysis of Provincial company KPI</th>
<th>Group</th>
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</thead>
<tbody>
<tr>
<td>MTBT</td>
<td></td>
<td>Benchmark analysis of wind farms KPI</td>
<td>Liaoning</td>
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<tr>
<td>MTBR</td>
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<td>Turbine by turbine analysis</td>
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<td>Canada</td>
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</tbody>
</table>

**Power Curve Monitoring**
- Automatic classification
- Anomaly detection
- Anomaly data mining

**Failure Predicting and Monitoring**
- Blade
- Gearbox
- Generator
- Converter
Major Component Failures in LongYuan, 2015

Distribution of Major Component Failures

- Blade: 30%
- Gearbox: 52%
- Generator: 11%
- Main Shaft: 5%
- Yaw: 2%

The damaged Gearbox

The damaged blade
Based on the classical methods and physical rules

**Time sequence of oil temperature analysis**

**Transmission ratio analysis**

**Vibration signals analysis**

**Lubricant pressure analysis**
Root Cause analysis

**Problem**
- Gearbox failure
- Vibration
- Lubricant

**Key point**
- CMS
- SCADA

**Method**
- Correlation
- Model

**Monitor**
- Predict
- Monitoring

**Lubricant pressure**
- Viscosity
- Density
- Velocity
- Resistance coefficient

**WT Power parameters**
- Temperature
- Pump power
- Other design parameters

**Power output**
- Oil temperature
- Shaft temperature

**Data**
- CMS
- SCADA
The effect of iron scrap

1、The lubricant is used to cool down the gearbox
2、The change of the lubricant pressure follows the change of the power output. Compared with the gearbox oil temperature, the lubricant pressure is more resistant to the impact of the environmental temperature.
3、If there is the mechanical wear on the gearbox, the iron scrap will fall into the lubricant oil and the lubricant pressure will change.

Therefore, the lubricant pressure, $P_l$, is chosen as the predictive objective.
The model for Gearbox – Deep Neutral Network

Gearbox oil temperature, $T_o$
Power output, $P_o$
Shaft temperature, $T_s$.

The schematic diagram of DNN
The model for Gearbox – Deep Neutral Network

Deep Neutral Network

The trained model is

\[ \hat{P}_t = f(T_0, T_s, P_o) \]

The activation function:

\[ \tanh(t) = \frac{e^t - e^{-t}}{e^t + e^{-t}} \]

The training process of DA is to learn the parameters,

\[ \{ W_n, b_n \} = \arg \min_{W_n, b_n} \sum_{i=1}^{N} \frac{1}{2} (\hat{P}_i - P_i)^2, n = 0, 1, \ldots, L \]

EWMA Control Chart

\[ z_t = \lambda e_{rt} + (1 - \lambda)z_{t-1} \]

The upper and lower EWMA control limits depend on time

\[ UCL(t) = \mu_{e_t} + L \sigma_{e_t} \sqrt{\frac{\lambda[1-(1-\lambda)^2]}{(2-\lambda)n}} \]

\[ LCL(t) = \mu_{e_t} - L \sigma_{e_t} \sqrt{\frac{\lambda[1-(1-\lambda)^2]}{(2-\lambda)n}} \]
Cases - Gearbox

The EWMA chart of normal and abnormal turbines

<table>
<thead>
<tr>
<th>Wind Farm</th>
<th>Turbines</th>
<th>Time prior to failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liaoning</td>
<td>No 49</td>
<td>Two days</td>
</tr>
<tr>
<td>Hebei</td>
<td>No 64</td>
<td>Three days</td>
</tr>
</tbody>
</table>

CORE i5 CPU and 8GB memory
training time: 3-min,
applying time: 1-min.

Question: Can this method be used for Blade?

The EWMA chart of error
The model for Blade – deep autoencoder

Schematic diagram of Deep Autoencoder
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<tr>
<th>Wind farm</th>
<th>Turbines</th>
<th>Time prior to failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shandong</td>
<td>No. 9</td>
<td>7 hours and 20 minutes</td>
</tr>
<tr>
<td>Shandong</td>
<td>No. 2</td>
<td>6 hours and 10 minutes</td>
</tr>
<tr>
<td>Anhui</td>
<td>No. 5</td>
<td>8 hours</td>
</tr>
</tbody>
</table>

All validation are blind.

CORE I5 CPU and 8GB memory

training time: 40-min,

applying time: 10-min.
Conclusions

- The DNN model is applicable to identify impending gearbox failure based on SCADA data.
- The DA model is applicable to identify impending blade failure based on SCADA data.
- The proposed method raised alarms early enough for the replacement or repair.
- There were no false alarms for failure monitoring.
- The effectiveness of these methods needs to be further examined by more cases.
- At present, these models have been deployed for monitoring the failure in a wind farm of Longyuan.
Question?
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