Fault diagnosis for wind power generation system based on association rule mining

Wenju Ji*, Jianwen Wang

Inner Mongolia University of Technology, Hohhot, 010051

*Corresponding author's e-mail: 15184703240@163.com

Received 1 March 2013, www.cmnt.lv

Abstract

This paper concentrates on the problem of fault diagnosis for wind power generation system, which is a crucial problem for wind power industry. Firstly, framework of the fault diagnosis system for wind power generation is presented. This framework is made up of two main parts, that is, “local device module” and “remote diagnosis center”. In the local device module, wind turbines are connected to other servers through lower computers, and then data is transmitted to the remote diagnosis center. Furthermore, the remote diagnosis center can receive the data transmitted by the local devices and then discover faults by the proposed association rule mining algorithm. Secondly, in the proposed association rule mining algorithm, the opportunity and effectiveness of a specific rule is represented as the number of chances to utilize this rule and the average utilization ratio of this rule, and then the rules with higher probability are preserved to conduct the Fault Diagnosis. Finally, specific wind power generation equipment is used to test the effectiveness, and experimental results show that the proposed method can discover different kinds of faults in the power generation system with high accuracy.

Keywords: wind power generation system, fault diagnosis, association rule mining, support, confidence

1 Introduction

Wind power is an important way to use the wind energy, striving to develop clean energy (e.g. wind power) is a strategic method of the government. Wind electric technical equipment construction is belonged to wind power industry [1]. As far as we know that countries around the world have taken many effective measures to enhance the development of domestic wind power technology and equipment industry [2]. In recent years, China’s wind power technology and wind power generation equipment has developed fast. Particularly, a great deal of high quality wind electrical equipment constructing enterprises have appeared in China. Moreover, according to statistics yearbook of China (2010), China's installed capacity of wind power positions at the first location in the world [3-6].

However, areas with rich wind energy resources are generally more far from cities and locate in rugged environment [7, 8]. Particularly, wind turbines distribution is more dispersed with more monitoring parameters, which may greatly influence the control of the wind power system. To fully utilize wind power generation, we should take effective measures to detect faults in wind power generation system [9]. If the faults in wind power generation can be discovered, we can effectively improve the reliability of wind farm operation [10].

The main creative ideas of this paper lie in that we introduce the association rule mining technology in wind power generation system fault diagnosis. Association rule mining is belonged one of the typical data mining technologies, and data mining is a very hot research field in the field of computer science [11-12]. The objective of data mining aims to discover comprehensible, useful, and non-trivial knowledge from large-scale datasets. Association rule mining denotes the searching attribute - value conditions which may happen with high frequency together in a same dataset. Association rule mining can extract the close relationships between data elements in transactional data, and it has been successfully utilized in many applications such as Smoking cessation treatment, Privacy Preserving, Composite Granules, Regional Pharmacovigilance Center, Determine promising secondary phenotyping hypotheses, Software defect prediction, semantic image classification.

2 Framework of the fault diagnosis system for wind power generation

In this section, we will show the architecture of our fault diagnosis system (shown in Figure 1). As the wind turbines almost locate in remote areas, we install the diagnosis center using the remote control mode. As is shown in Figure 1, in the local device module, several wind turbines are connect to other servers via lower computer, and then data is output to the remote diagnosis center after being processed by some local servers. On the other hand, remote diagnosis center can receive the data transmitted by the local devices. Furthermore, our proposed algorithm is implemented in the overall diagnosis server, which works with the support of “Diagnosis center workstation”, “Remote database servers” and “Remote Web server”.

3 Association rule mining based fault diagnosis for wind power generation system

Association rule mining uses two frequency based measures, that is, support and confidence. Support is represented as sup \( \{A \rightarrow C\} \), which denotes the ration of particular transactions including both \( A \) and \( C \). On the other hand, confidence is represented as conf \( \{A \rightarrow C\} \), which refers to the strength of a rule. Then, an association rule can be represented by the following equation:

\[ \text{Conf} (\{A \rightarrow C\}) = \frac{\text{Sup}(A \rightarrow C)}{\text{Sup}(A)} \]
\[ \{a_1, a_2, \ldots, a_n\} \rightarrow \{c_1, c_2, \ldots, c_m\} \{s\%, c\%\}, \]  

(1) where \(s\%\) and \(c\%\) mean the support and confidence respectively.

Supposing that \( R = \{r_1, r_2, \ldots, r_r\} \) refers to a set of records, in which each one is characterized by a set of attributes \( \{a_1, a_2, \ldots, a_n\} \). In there are \( N(R_i) \) chances to utilize the \( k^{th} \) rule \( R_k \), the expected utilization rate is \( E(R_k) \). Then for the \( l^{th} \) application, its expected utilization rate can be represented as follows.

\[ E(R_k) = \sum_{i=1}^{N(R_i)} E_i(R_k) = \sum_{i=1}^{N(R_i)} (U_i(R_k) \cdot P_i(R_k)), \]  

(2)

where \( U_i(R_k) \) and \( P_i(R_k) \) are the utility and the probability of the rule \( R_k \) in the \( l^{th} \) application. To make the problem be easier, we assume that each application has the same probability, and then \( E(R_k) \) can be represented as follows.

\[ E(R_k) = P_i(R_k) \cdot \left( \sum_{i=1}^{N(R_i)} U_i(R_k) \right). \]  

(3)

Afterwards, the element \( \sum_{i=1}^{N(R_i)} U_i(R_k) \) can be converted to the product of the application chance number \( N(R_i) \), and the average utilization ratio of the rule \( R_k \) can be represented as \( \text{avg}(U_i(R_k)) \). Hence, \( E(R_k) \) can be calculated as follows.

\[ E(R_k) = N(R_k) \cdot \text{avg}(U_i(R_k)) \cdot P(R_k). \]  

(4)

Moreover, the opportunity and effectiveness of a specific rule can be illustrated as the number of chances to exploit this rule and the average utilization ration of this rule. Hence, expected utilization rate \( E(R_k) \) can also be represented as follows.

\[ E(R_k) = \text{Op}(R_k) \cdot \text{Ef}(R_k) \cdot P(R_k), \]  

(5)

where \( \text{Op}(R_k) \) and \( \text{Ef}(R_k) \) refer to the opportunity and effectiveness of the rule \( R_k \) respectively. Next, in our fault diagnosis for wind power generation system, a rule’s probability can be represented as the confidence as follows.

\[ E(R_k) = |T| \cdot \text{sup}(R_k) \cdot e \cdot \text{conf}(R_k), \]  

(6)

where \(|T|\) is the number of items in the transaction database, \( \text{sup}(R_k) \) and \( \text{conf}(R_k) \) denote the support and confidence of \( R_k \) respectively, and the rules with higher probability are preserved.

As is shown in Figure 2, we represent the above association rule mining algorithm in a flowchart. In this flowchart, the association rule mining process is made up of three steps, and then association rules for wind power generation fault diagnosis can be mined.
4 Experiment

In this section, we conduct experiments to verify the proposed algorithm using a specific wind power generation equipment, and the parameters of this equipment are listed in Table 1.

Afterwards, we extract five kinds of items from the fault transactions, that is, $I_1$: Host shutdowning by overcurrent, $I_2$: Faults in the wind turbines, $I_3$: Faults in the Governor, $I_4$: Host sudden stopping, $I_5$: Faults in host communication. In this experiment, the minimum support degree is equal to 0.22, and we choose a frequent item set $L = \{I_1, I_2, I_3\}$ with minimum confidence 0.7 as an example to demonstrate the performance of our algorithm. Thus, the association rules are generated by $L$, and the non-empty sub-set of $L$ include $\{I_1, I_2\}$, $\{I_1, I_3\}$, $\{I_2, I_3\}$, $\{I_1\}$, $\{I_2\}$, $\{I_3\}$. In Table 2, some items in the fault transaction database are provided.

### Table 1: Parameters of wind power generation equipment used in this experiment

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Mechanical power (W)</th>
<th>Rotor flux (Wb)</th>
<th>Generator power $(V/A)$</th>
<th>Friction coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>39800</td>
<td>0.195</td>
<td>39800</td>
<td>0.001875</td>
<td>0.46</td>
</tr>
<tr>
<td>Pitch angle</td>
<td>0</td>
<td>7.8</td>
<td>0.05</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Wind speed range (m/s)</td>
<td>5–12</td>
<td>32</td>
<td>Maximal wind power utilization coefficient</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Next, we integrate the experimental results together to evaluate the precision of the fault diagnosis for the wind power generation system, and the experimental result is shown in Figure 3.

### Figure 3: Fault diagnosis precision for the wind power generation system

Figure 3 demonstrates the precision of fault diagnosis for the wind power generation system, the average fault diagnosis precision is 86.9%. Hence, it can be seen that our method can detect faults in the power generation system with high accuracy.

5 Conclusions

In this paper, we study on how to discover fault diagnosis in wind power generation system. The framework to detect fault diagnosis consists of two modules: “local device module” and “remote diagnosis center”. In the local device module, wind turbines are connected to other servers through lower computers. The remote diagnosis center is designed to receive the data from the local devices and faults can be discovered by the proposed association rule mining algorithm. Particularly, in the proposed algorithm, the opportunity and effectiveness of a given rule is represented as the number of chances to utilize this rule and the average utilization ration of this rule, and then the rules with higher probability are used to implement the fault diagnosis.
References


[9] Ren B, Feng Z P 2002 Improved Genetic Algorithm and Particle Swarm Optimization as well as Comparison between Them Journal of Nanjing Normal University 2(2)14-20


Authors

Ji Wenju, 1978.4, Inner Mongolia

Current position, grades: senior engineer, doctoral student.  
University studies: Inner Mongolia University of Technology.  
Scientific interest: wind power, new energy.  
Publications: more than 5 papers.  
Experience: researching experience of 4 years, 3 scientific research projects.

Wang Jianwen, 1958.5, Jiangsu Jintan

Current position, grades: professor, doctor.  
University studies: Huazhong University of Science and Technology.  
Scientific interest: wind power, new energy.  
Publications: more than 30 papers (21 papers are indexed by SCI or EI), 2 textbooks, 3 patents, 3 utility model patents.  
Experience: researching experience more than 30 years, has hosted more than 30 scientific research projects.