Research on standardized evaluation model of status detection data on power equipment based on AHP

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Abstract. The power equipment produces a large number of status detection data during daily operation and maintenance, and most of the data is unstructured. So it makes against to the efficient processing and the deep mining of data. This article illustrates an empirical evaluation model for the status detection data of power equipment, and the model is modified by entropy method, then sorts schemes by index weights. A new evaluation model is provided to the standardization and efficient utilization of data for status detection data of power equipment, which provides strong support and guarantee for status assessment and diagnosis analysis of power equipment.

1. Introduction

With the construction of the smart grid and the in-depth development of the state maintenance, it has become a normalization work that real-time and dynamic analysis carried out on the equipment by the power company. So the data of power during operation and maintenance is increased in exponential speed. However, most of those data comes from manufacturer or experience record, which causes a lot of sources of information and poor normalization. Therefore, the redundant data is not conducive to high-efficiency utilization and secondary analysis. [1,2]

In order to improve the grid's control ability, strengthen the specialization and lean management of the power equipment professional, and reduce security risks, it is necessary to standardize the status detection data of power equipment, and improve the level of automatic analysis of the data, which is beneficial to find the abnormal in the massive status detection data and give the corresponding preventive measures.

2. The sources and sort of status detection data

There are a variety of sources in the status detection data of power equipment. Now the production management system(PMS) built by National Electric Net Ltd established a uniformly standard on data's process, access and control. PMS also provides information such as display, early warning, analysis, diagnosis, evaluation and prediction. [3] Because lower rate of PMS access, there are a lot of data which comes from production management system and condition monitoring system, such as

SCADA, outgoing inspection report , spreadsheets or text documents of routine text and so on. Therefore, in order to realize the integration of the status data of the power equipment, it is necessary to solve the problem that the semi-structured data of the status detection data of the power equipment is transferred to the structure.

2.1. Classification by the period of data generation

According to the general regulations and requirements of the power industry, the information sources of power equipment's status data usually include information before operating, operation information, maintenance information, and other information. Some information sources are shown in the table.

Table 1. Classification by the Period of Data Generation

Classification	Interpretation
before operating	Equipment technology ledger/Installation and acceptance record/Test report and drawings, etc
operation information	Daily inspection/Operation and maintenance/ On-line monitoring/Live detection and adverse condition information
Maintenance information	Routine test report/Diagnostic test report/Professional inspection record
Other information	Asset information.

2.2. Classification by the frequency of data generation

According to the frequency of data update, we can divide those information into three categories: static data, dynamic data and quasi dynamic data.

Table 2. Classification by the Period of Data Generation

Classification	interpretation	Remark
static data(SD)	Equipment account parameters/Test parameters before operation	No changes have been made after recorded.
dynamic data(DD)	Operation record data/Inspection record parameter/Charged detection parameter/Online monitoring parameters/Environmental parameters	Update regularly.
quasi dynamic data(QDD)	Test parameters for maintenance / Defect / fault / hidden information / Repair and repair information	Update periodically or ad hoc.

2.3. Classification by data characteristics

According to the characteristics, it can be divided into structured data, semi-structured data, unstructured data and other types. Structured Data is what can be divided into fixed elements and can be represented by one or more two-dimensional tables. Unstructured data is the data outside of the structured data, which structure is not fixed, and can be hold in a variety of forms. such as pictures, images, audio and video.

In addition, semi-structured dada is between structured data completely and totally unstructured data. They are not filled with the same specification and require intermediate transformation process, such as HTML and XML.

All the information is generated in Table 3.

Table 3. Summary of the Overall Condition

topic	Exchanged data entities	Source system	Frequency	structured data	unstructured data	semi-structured data
before operating	logbook of equipment	PMS2.0	SD	●		
	Factory test data	PMS2.0	SD			●
	Test report and drawings	PMS2.0	SD			●
operation information	Operating condition info	STSS	DD	●		
	Environmental info	MDWS	DD			●
	Online monitoring info	PMS2.0	DD	●		
	Charged detection info	PMS2.0	DD		●	
Maintenance information	Routine test report	PMS2.0	QDD			●
	Diagnostic test	PMS2.0	QDD			●
Other information	Asset information	ERP	SD	●		

3. Establishing the standardized evaluation model

In this paper, four typical indicators, top oil temperature, signals of dissolved gas-in-oil, partial discharge signals and casing loss data, are selected to be the data quality assessment objects. Combined the AHP and entropy weight, then we will get the standardized evaluation model.

3.1. AHP

3.1.1. The determination the weight based on AHP. There are four steps of applying AHP to make a decision. [4] The first step is to stratify the complex problems and form a hierarchy substructure diagram consisting of the target layer, the criterion layer, the index layer, and the scheme layer is formed. The second step is to use the "1-9 scale" to form a judgment matrix. Then we can verify the consistency of the matrix. Finally, by means of layer by layer, the weight of the scheme layer can be obtained, and the most important scheme is the optimal solution to the problem.
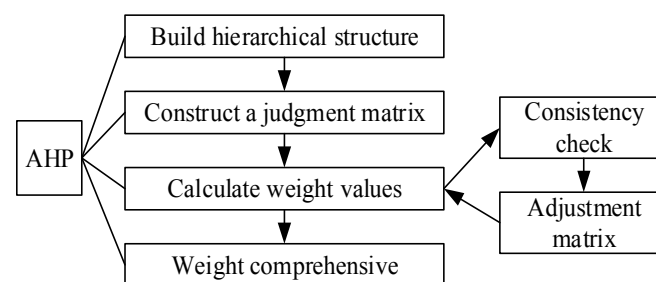

Figure 1. The determination the weight based on AHP

(1) Build hierarchical structure

Applying AHP to solve the problem, first of all, it is clear to analyze the problem of decision making, and make it rationalize and stratify. And it is generally composed of the target layer, the criterion layer and the measures layer. As is shown in Figure 2.

We hope to improve the utilization and quality through the assessment of power equipment detection data. Therefore, the goal can be set as "assess data quality scientifically and improve data quality level". And in this paper we choose completeness, correctness, timeliness, accuracy and effectiveness as five guidelines. And there are no sub-codes. Finally, based on those guidelines, we

should analyze the problem and find out the solution that can achieve the goal, as the lowest level of measures.
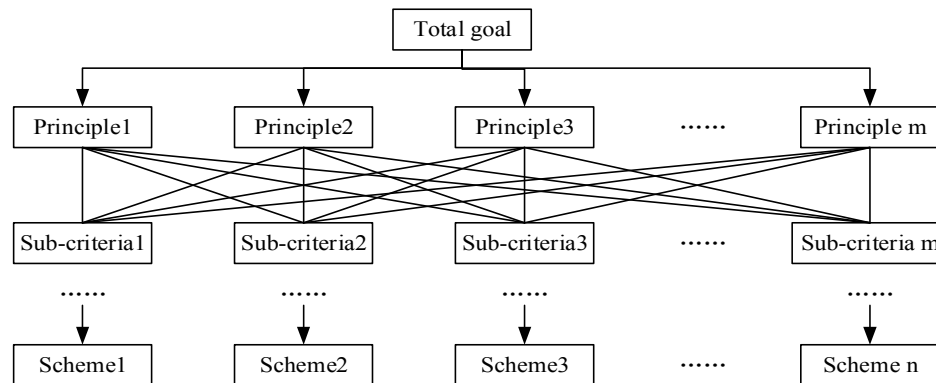
Figure 2. Hierarchical structure

(2) Construct a judgment matrix

The key step is to structure the judgment matrix in the research question by using the AHP. In this paper, we will get a judgment matrix in the beginning. Then this matrix will be compared between every two factors by experts in status detection of power equipment and get the sort order by weightiness of all factors. The degree of importance will be assigned by the Numbers 1 to 9. [5]

Table 4. Implications of the degree of importance

The degree of importance	Implications
1	It represents the two elements are of equal importance
3	It represents the former is more important than the latter
5	It represents the former is obviously more important than the latter
7	It represents the former is deeply more important than the latter
9	It represents the former is extremely more important than the latter
2/4/6/8	It represents the median of the above judgment
reciprocal	If the importance ratio of i to j is a_{ij}, then the ratio of j to i : $a_{ji}=1/a_{ij}$

Consulting the broad experts, the judgment matrix for the transformer is shown in Table 5

Table 5. Judgment matrix

Principle	completeness	correctness	timeliness	accuracy	effectiveness
completeness	1	1/3	2	4	3
correctness	3	1	4	6	5
timeliness	1/2	1/4	1	1	1
accuracy	1/4	1/6	1	1	1/2
effectiveness	1/3	1/5	1	2	1

(3) Calculate weight values

Consistency check of judgment matrix is an important research field of analytic hierarchy process. There is a comparative judgment matrix for each criterion and the factors it governs. In this paper, Let us suppose $A=(a_{ij})_{m \times m}$, $A>0$. λ are solved by $AW=\lambda W$. λ_{max} is the minimum value of λ. Then we got the eigenvector W^* of λ_{max}. And W^* is normalized to vector W. The objective has a weight of W= [w_1, w_2, …, w_m]^T. [6]

Using eigenvalue method to calculate:

Elements in each row of A is multiplied and opened of n root and we got $W^* = (w_1^*, w_2^*, w_m^*)^T$,

$$w_i^* = \sqrt[m]{\prod_{j=1}^{m} a_{ij}} \tag{1}$$

The W^* is normalized and the weight vector W^* is obtained. $W^* = [w_1, w_2, \ldots, w_m]T$

$$w_i = w_i^* / \sum_{i=1}^{m} w_i^* \tag{2}$$

Sum up each column in A and get the vector $S = (s_1, s_2, s_m)$,

$$S_i = \sum_{i=1}^{m} a_{ij} \tag{3}$$

Calculate the value of λ_{max}.

(4) Consistency check

In practice, it is necessary to make the consistency test to determine that the matrix satisfies the general consistency and logically reasonable. There are three indicators: consistency index (CI), the average random consistency index (RI) and the consistency ratio (CR). The calculation formula and table are as follows:

$$CI = \left| \lambda_{max} - n \right| / (n-1) \tag{4}$$

Table 6. Calculation

matrix dimension	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41

$$CR = CI / RI \tag{5}$$

If CR<0.1, it is considered that the judgment matrix satisfies the consistency test. And if CR>0.1, it is considered that the judgment matrix does not meet the requirement of consistency, which is necessary to revise. When the judgment matrix meets the requirement of consistency, the weight of each index is calculated. And the expectations of the indicators for the next calculation is determined.

3.2. Amend the weight by entropy weight method

The subjective factors of AHP have great influences on the final evaluating conclusion. The weight of evaluation index was determined by improved AHP and was modified by entropy method. The concept of entropy in information theory comes from the one in statistical thermodynamics. And statistics on the self-information of all symbols are averaged. So the entropy of information is also called the average amount of information. [7] The entropy in information is used to measure the uncertainty of random variables and to solve the measurement of information. The smaller the value of the entropy in information is, the greater the amount of information is, and the higher the weight is.

The correction step of entropy weight method is as follows. [8] The original data matrix is set up with m pending objects and n evaluation indexes.

$$X = \left(x_{ij} \right)_{m*n} \tag{6}$$

To an evaluation index:

$$E_j = -\sum_{i=1}^{m} \frac{\ln p_{ij}}{\ln m} \tag{7}$$

$$p_{ij} = x_{ij} / \sum_{i=1}^{m} x_{ij} \tag{8}$$

The value of the information utility of the evaluation index is $D_j = 1-E_j$, and the entropy weight of the evaluation index is:

$$W_j = D_j / \sum_{j=1}^{n} D_j \tag{9}$$

3.3. Calculate the evaluation rules score

$$\vec{\omega} = \left\{ \frac{W_1 w_1}{\sum_{j=1}^{n} W_j w_j}, \frac{W_2 w_2}{\sum_{j=1}^{n} W_j w_j}, ..., \frac{W_n w_n}{\sum_{j=1}^{n} W_j w_j}, \right\} = (\omega_1, \omega_2, ..., \omega_n) \tag{10}$$

$$s.t. \qquad \sum_{j=1}^{n} \omega_j = 1; \quad \omega_j > 0$$

According to those rules, the selected data objects are analyzed and calculated the percentage of data which meets the rules of assessment. Then we got comprehensive assessment values (SA), expectation (SE) and relative difference (SR) from W, E and S.

$$SA = \sum_{i=1}^{n} W_i S_i / \sum_{i=1}^{n} W_i \tag{11}$$

$$SE = \sum_{i=1}^{n} W_i \times E_i / \sum_{i=1}^{n} W_i \tag{12}$$

$$SR = \sum_{i=1}^{n} W_i S_i / \sum_{i=1}^{n} W_i - \sum_{i=1}^{n} W_i \times E_i / \sum_{i=1}^{n} W_i = SA-SE \tag{13}$$

In this paper, if $SA \in (90,100]$, the data quality level of the object is "excellent". And if $SA \in (80,90]$, its level is "good." Then if $SA \in (70,80]$, its level is " medium". The rest of the value of SA is "poor".

4. Conclusion
Based on the AHP, this paper establishes a standardized evaluation model for the status data of power equipment. The related factors were processed quantitatively through constructing hierarchical structure model, establishing judgment matrix, calculating weight, and testing consistency. Then the model was modified by entropy method, which can decrease influence of personal factors and the result of the prediction is more practical. Qualitative analysis and quantitative analysis are combined in this model. And it may lead great changes in work, thinking, and management. Accordingly, we can improve the efficiency and technical support of inspection and ensure the safe and stability operation of network.

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