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The Life Cycle Reliability Evaluation of Optical Cable

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Abstract

Along with the optical fiber communication technology is widely used in power system, optical cable fault which will lead to failure has become an important factor influencing power grid reliability, but the existing optical cable evaluation index is single, only statistical cable fault conditions operation index, can not fully reflect the actual reliability of cable. This paper tries to construct a whole life cycle based on optical cable statistical reliability evaluation index system, uses the entropy method to evaluate the reliability of the optical cable is more objective, true, to carry out cable reliability research has certain reference significance.

Key words: *power system, optical cable, reliability evaluation, entropy method*

1. Introduction

Along with the optical fiber communication technology is widely used in power system, cable fault which will lead to failure has become an important factor influencing reliability of grid. According to the 2011 Annual, an area of main equipment backbone communication network operation analysis of statistics, cable failure number for all equipment interruption times of 30%, cable outage time for all device interrupt time 67.78% [1-2].

Electric power system reliability research started earlier, but the main focus in the power transmission equipment and user power supply network [3]. Grid secondary systems (including communication systems) in the dispatching department of safety evaluation to be involved, and the cable relevant assessment indices rarely, with statistical cable fault conditions operation index, can not fully reflect the actual reliability of cable [4]. Therefore, to establish a scientific and effective optical cable reliability evaluation system, improve the reliability of optical fiber network, has become power supply enterprise urgently technical and management issues.

2. Research Method

2.1. Life Cycle Reliability Model

There are many methods and models on reliability evaluation index system [5]. These models in the stratification is mainly in the ISO seven layer network model based on the network, from the longitudinal relations on a hierarchy, not from a network of horizontal division. Based on the above analysis, construction of cable of whole life cycle of the reliability evaluation model, from the life cycle perspective of optical cable develop reliability research is more comprehensive. We designed the new reliability evaluation model from the planning and design, construction and operation maintenance of three aspects, as shown in Figure 1.

2.2. The Selection of Evaluation Index

Index system for evaluation is the important basis, directly affecting the objectivity of evaluation results and maneuverability. In order to ensure that the evaluation results are scientific and reasonable, index system should follow the scientific, systematic, feasible, briefly and the principles of independence. According to the cable life cycle reliability evaluation model, combined with the network safety evaluation index and index of communication operation and maintenance, identified as follows based on statistical data cable reliability evaluation index system [4-10].

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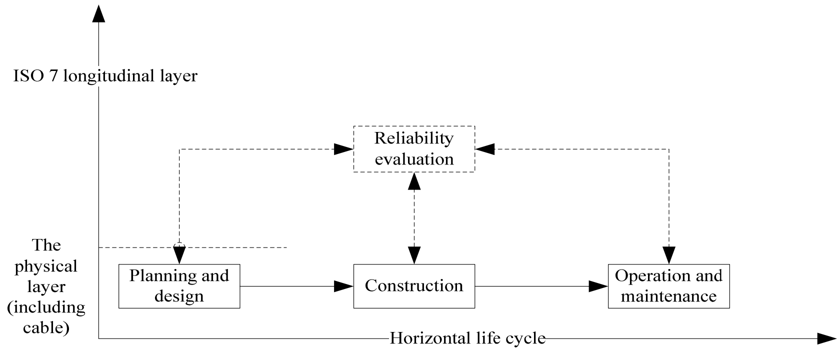

Figure 1. Cable Life Cycle Assessment Model

Table 1. Optical Cable Evaluation Index System

Category	**Leval indicator**	**Leval two index**
Planning and design	X1：Special power optical fiber cable coverage	
Construction	X2：Cable works fine rate	
	X3：Hundreds of kilometers of fiber optic cable maintenance resource allocation rate	X31:maintenance number allocation rate X32: instrumentation distribution rate X33: spare parts allocation rate X34: vehicle allocation rate
Operation and maintenance	X4：The standby optical fiber test normal rate	
	X5：Cable run rate	
	X6：Cable inspection plan completion rate	
	X7：Fiber optic cable defect repair in time	

2.3. Determining The Index Weight

The earliest application of entropy is in thermodynamics. Shannon will be the first of the concept of entropy in information theory is introduced to, used to measure the uncertainty of the system. The entropy method is the biggest characteristic can improve the difference of the index distribution weights, can better land in different areas (unit) cable reliability level for comparative evaluation.

According to the definition of entropy and the theory, when the system may be in a different state, each state probability Pi (i=1,2, ... n), then the entropy of the system is E.

$$E = -\sum_{i=1}^{n} Pi \log Pi \quad (1)$$

When the system state is probability (Pi=1/n), entropy is maximum.

$$E(P1, P2, P3 \cdots Pn) \le E(\frac{1}{n}, \frac{1}{n}, \frac{1}{n} \cdots \frac{1}{n}) = \log n \quad (2)$$

According to the entropy formula, when the system is only a state of n=1, the entropy of the system was 0, i.e. the system without uncertainty. With the increase of n, the entropy of the system increases, but much smaller than the growth rate of n.

Using entropy method for reliability assessment procedure is as follows:

Determine the evaluation object set A= (A1, A2, A3 ... An);

Determine the evaluation index set X= (X1, X2, X3 ... Xm), X31-X34 through the weighted average method to form X3;

Build the index matrix, each appraisal object corresponding to the index data, are arranged in a n*m matrix A:

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nm} \end{bmatrix}$$

Normalization matrix A

$$B=\begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1m} \\ b_{21} & b_{22} & \cdots & b_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ b_{n1} & b_{n2} & \cdots & b_{nm} \end{bmatrix}, \quad b_{ij}=\frac{a_{ij}}{\max a_{ij}} \tag{3}$$

Calculate each index entropy

$$e_j=-\sum_{i=1}^{n}(b_{ij}/\sum_{i=1}^{m}b_{ij})\bullet\log(b_{ij}/\sum_{i=1}^{m}b_{ij}),\quad \mathrm{j}=1,2,3\cdots\mathrm{n}. \tag{4}$$

Normalization e_j

$$E_j=\log(\frac{e_j}{\log n-e_j}), j=1,2,\cdots n \tag{5}$$

Index weight:

$$W_j=\frac{1/E_j}{\sum_{j=1}^{m}1/E_j}, j=1,2,\cdots n \tag{6}$$

2.4. Reliability Calculation

According to the calculated weight of index, the matrix A are weighted calculation to obtain the object of study, the integrated reliability quantitative is R.

$$R_i=A_i\bullet W,(i=1,2,3\cdots n) \tag{7}$$

$$A_i=\begin{pmatrix} a_{i1} \\ a_{i2} \\ \vdots \\ a_{im} \end{pmatrix},\quad W=\begin{pmatrix} W_1 & W_2 & \cdots & W_m \end{pmatrix}$$

3. Results and Analysis

Using the above method, we evaluated 6 power supply enterprises of the optical cable reliability. Using statistical data of Table 2 and the formula (1) to (7), we calculate the reliability of results in Table 3. For verified the results, we used average method to calculate the reliability data of 6 enterprises, the results in Table 4.

Table 2. 6 Power Supply Enterprises 2011 Annual Statistical Data

Category	Leval indicator	A1	A2	A3	A4	A5	A6
Planning and design	X1:	0.8688	0.8672	0.8882	0.8437	0.7678	0.7874
Construction	X2:	0.9104	0.9669	0.9739	0.9674	0.9815	0.915
	X3:	0.5946	0.7798	0.9241	0.6924	0.8294	0.8811
	X4:	0.9629	0.9564	0.9783	0.9294	0.9752	0.9272
Operation and maintenance	X5:	0.995	0.9926	0.9977	0.9997	0.9948	0.9914
	X6:	0.8356	0.8336	0.9761	0.8352	0.8453	0.9605
	X7:	0.995	0.9801	0.9475	0.9676	0.9014	0.9128

Using entropy method and average weight method calculate the 6 power supply unit reliability data are as follows:

Table 3. Using Entropy Method to Calculate the Reliability of Numerical

Leval indicator	A1	A2	A3	A4	A5	A6	Entropy weight
X1:	0.13254	0.13229	0.13549	0.12871	0.11713	0.12012	0.15255
X2:	0.11968	0.12711	0.12803	0.12718	0.12903	0.12029	0.13146
X3:	0.1262	0.16551	0.19613	0.14696	0.17603	0.18701	0.21224
X4:	0.11659	0.1158	0.11846	0.11253	0.11808	0.11227	0.12108
X5:	0.07988	0.07968	0.08009	0.08025	0.07986	0.07959	0.08028
X6:	0.13789	0.13756	0.16108	0.13783	0.1395	0.15851	0.16502
X7:	0.13667	0.13463	0.13015	0.13291	0.12382	0.12538	0.13736
Integrated reliability	0.84945	0.89259	0.94944	0.86637	0.88344	0.90316	
Reliability rank	6	3	1	5	4	2	

Table 4. Using Average Method to Calculate the Reliability of Numerical

Leval indicator	A1	A2	A3	A4	A5	A6	Average weight
X1:	0.12424	0.12401	0.12701	0.12065	0.1098	0.1126	0.14286
X2:	0.13019	0.13827	0.13927	0.13834	0.14035	0.13085	0.14286
X3:	0.08503	0.11151	0.13215	0.09901	0.1186	0.126	0.14286
X4:	0.13769	0.13677	0.1399	0.1329	0.13945	0.13259	0.14286
X5:	0.14229	0.14194	0.14267	0.14296	0.14226	0.14177	0.14286
X6:	0.11949	0.1192	0.13958	0.11943	0.12088	0.13735	0.14286
X7:	0.14229	0.14015	0.13549	0.13837	0.1289	0.13053	0.14286
Integrated reliability	0.88121	0.91185	0.95607	0.89166	0.90024	0.91168	
Reliability rank	6	2	1	5	4	3	

Through the comparison of tables 3 and 4 of the data, we found that the entropy weight method to index differences are more sensitive, such as the 6 power supply units of X1 index, X3 index and X6 index difference is bigger, with entropy weight method to calculate the index weights were 0.15255, 0.21224 and 0.16502, are all above average weight 0.14286, where X3 the greatest difference between weight index, than the average weight is 0.06983. The 6 units of the cable operation index index difference is smaller, weight of index is automatically adjusted to 0.08028, weakening the indices in the index group weight. By increasing the diversity index weight, reduce the homogeneity index weight, make the management more clearly see the reliability management.

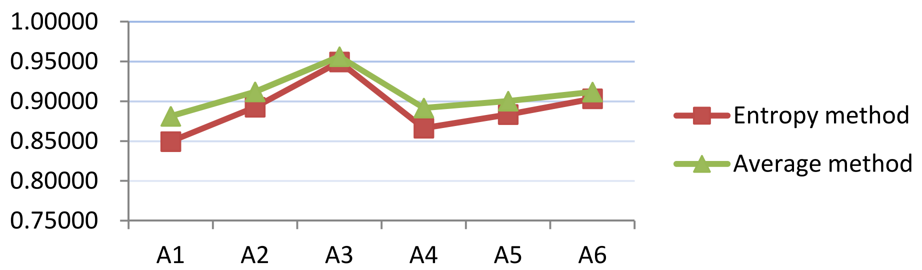

Figure 3. Entropy and Average Weight Method Reliability Calculation Results

Using entropy method to calculate the reliability of the enterprises ranking is A3, A6, A2, A5, A4, A1. Used average method to calculate the reliability ranking is A3, A2, A6, A5, A4, A1. We see a two algorithm obtains reliability ranking in second and third are not consistent, because the average weight method ignores the key index difference, leading to the final business reliability ranking and authenticity of error. A6 compared with A2, on two key indicators of X3 optical cable maintenance resource allocation rate and X6 cable inspection plan completion rate to do better, from the actual reliability evaluation, cable in A6 can get better maintenance, high reliability.

4. Conclusion

Reliability evaluation of many uncertain factors, how to eliminate or reduce the uncertainty has been a key indicator of reliability management, this article through the cable life cycle analysis, extracted based on statistical data cable reliability evaluation index system, the optical cable reliability evaluation more objective. Using the principle of entropy, this paper gives a increased differentiation index weight weight distribution, with the actual statistical data on the entropy method and average weight method were compared, the results show that the entropy weight method to calculate the reliability performance reflect the relative reliability level between each enterprise, more conducive to the development of enterprise management department fiber optic cable reliability benchmarking work.

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