# Research on hierarchical differentiation intelligent examination method for operational health of low voltage distribution network

**Haian Han**[1]

[1] Shan Xi electric power company metering center, Number 10 of Wu Luo street, Taiyuan Shanxi province, 030032, China

**Abstract.** The operational health assessment of the Low-voltage Electricity District is the basic task of grid and refined management of low-voltage distribution network. Considering of the large number of stations and the lack of standardized management constraints, using the big data platform and multi-source heterogeneous data management technology, a kind of intelligent medical check-up method for the health of district station is proposed. Firstly, the self-organizing neural network clustering technology is used to classify the station area into 15 categories, which must take into account of geographical attributes, economic attributes and so on. Then, for each major type of area, the analytic hierarchy process is used to realize the subjective weight of the differentiated subject indicators. The entropy weight method is used to realize the objective weight of the three-level subdivision index, and the distance map method is used to realize the percentile mapping of the three-level subdivision index. Finally, the subjective and objective comprehensive weights are given to get the running health score of the station. Based on the actual platform data of a power supply unit in Shan Xi Province, the accuracy of the confusion matrix of the health classification of the station is about 92%, which verifies the effectiveness and applicability of the method.

## 1. Introduction
The low-voltage distribution network area is an important part of the power grid, and it has the closest connection with power users. With many factors such as the development of social economy, the increase of electricity load, the rapid increase of supply and sales of power in the low-voltage distribution network, the line loss and voltage qualification rate, the promotion of the assessment of the sub-area, the management requirements for the Low-voltage Electricity District increasingly urgent[1][2]

However, the number of low-voltage distribution network stations is large, and there are many decision-making problems in the management of Electricity District. At present, the data of the Low-voltage Electricity District is scattered among various departments. The type, format and content of the data are diverse and difficult to handle. On the other hand, there is no effective method and means to make a reasonable evaluation of the operating status of the Low-voltage Electricity District. As a result, it is difficult to judge the operational status of the station area, and difficult to provide a basis for the refined hierarchical management decision.

Therefore, how to standardize the data of many Low-voltage Electricity District and quickly judge the operational health of the station area is an urgent problem to be solved. In the evaluation method

research, more focus on the state estimation of the distribution network. For example, the literature [3] established an evaluation index system adapted to the characteristics of high-voltage distribution network planning, and proposed an analytic hierarchy process based on Delphi method for the weight of indicators at all levels; the   entropy weight method is used to modify the index weights determined by the analytic hierarchy process, and the meta-element extension model is studied from four aspects: economic benefit, social benefit, technical benefit and environmental benefit in literature[4]. From the node vulnerability, the objective data information and the node value coefficient are comprehensively considered to obtain the utility risk entropy weight in the literature[5].In the research of evaluation index system, some literatures at home and abroad have proposed the smart grid evaluation index system[6], but the index system proposed for the smart distribution network is still relatively small. For the evaluation of low-voltage distribution network, the literature [7], From the voltage characteristics of the low-voltage distribution network to establish an evaluation index system, based on the order relationship - open the grade weighting method to determine the index weight; literature [8-11]Based on the analytic hierarchy process, a comprehensive evaluation system for the new rural low-voltage distribution network was established. The 0-10 scale method was used to determine the comprehensive weight of the individual indicators.

## 2. Low-voltage Electricity District clustering

### 2.1 Cluster description
Low-voltage distribution network is large and widely distributed in various regions. Each geographical environment of it is different, so it is necessary to cluster all the districts in Shanxi through Self-organizing Maps (SOM) into several major categories, and each subsequent is quantified by different analytic method index importance expert judgment matrix. The most important reason for optimizing SOM clustering is that the SOM has the ability to capture nonlinearly combined representations between features.

In the data feature selection of cluster analysis in district, 101 subdivision indicators of four dimensions of station user, station area geography, station area operation and station area management are considered. On the SOM cluster output, 15 rough classification types considering the economic and geographic attributes of the Low-voltage Electricity District are designed: economic attributes include operational, living and comprehensive, and geographical attributes include mountain villages, rural areas, townships, urban and rural areas, city.

### 2.2 SOM algorithm
The computational layer of the SOM clustering algorithm selects the 2-dimensional network form, because we expect to cluster the clusters into two-dimensional spatial representations, consider the economic and geographic attributes of the District region. For example, from the perspective of District's economic attributes, comprehensiveness is the intermediate transitional form of business and life; from the perspective of the geographical attributes of District, from mountain villages, rural areas, towns, towns and cities to cities, it is gradually adjacent. The essence of the SOM clustering algorithm is to find the calculation layer unit that is the shortest distance from the target unit in the learning process, that is, the winning unit, and update it. At the same time, the weights of the neighboring regions are updated so that the output node maintains the topological features of the input vector.
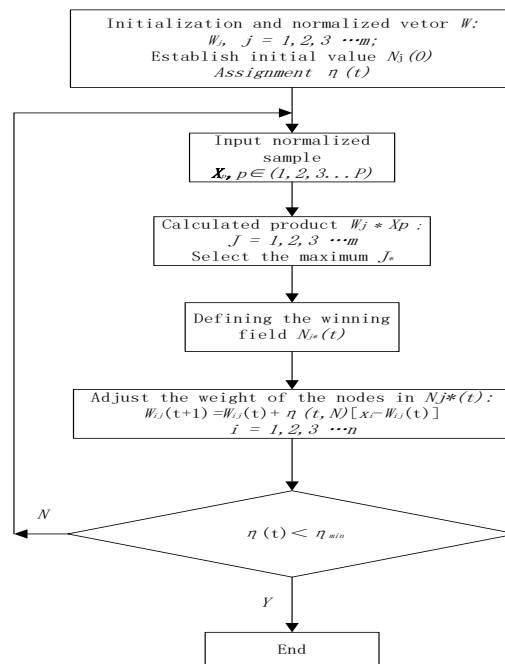
Figure 1.  Algorithm flow of SOM clustering

Table 1 shows the SOM clustering results of 107,179 stations in Shanxi Province. It can be seen that the city's comprehensive Low-voltage Electricity District accounts for a maximum of 18.91%, and the mountain village operating area accounts for at least 0.03%. For the 15 clustering clusters, the observation samples close to 1% were randomly selected, and the accuracy of the SOM clustering results was estimated to be about 92% by manual verification comparison.

Table 1.    SOM clustering results of the district community in Shanxi Province

| SOM clustering dimension | | 107,179 districts | |
|---|---|---|---|
| | | Number of stations | proportion(%) |
| city | Operational | 6154 | 5.74% |
| | Comprehensive | 20268 | 18.91% |
| | Life | 10136 | 9.46% |
| Urban and rural | Operational | 5969 | 5.57% |
| | Comprehensive | 19894 | 18.56% |
| | Life | 10002 | 9.33% |
| Township | Operational | 429 | 0.40% |
| | Comprehensive | 873 | 0.81% |
| | Life | 547 | 0.51% |
| Rural | Operational | 3066 | 2.86% |
| | Comprehensive | 16154 | 15.07% |
| | Life | 13384 | 12.49% |
| Mountain village | Operational | 33 | 0.03% |
| | Comprehensive | 182 | 0.17% |
| | Life | 89 | 0.08% |

## 3. District Health and Physical Examination Algorithm

### 3.1 Data collection

The District Health and Physical Examination is based on the Hadoop open source technology framework. Data storage and computing are based on the Hadoop Big Data platform. The system data

mainly comes from the electricity information collection system, marketing business application system, fee control system, PMS system.

### 3.2 District Health Check-up Modeling

The process of the health check score model in district is shown in Figure 2.

**Input**
Matrix Type Date, first Row is the time, Second row contains users with 0 electricity users account, synchronous line loss ;first line with the date of optimal solution ,second line was worst solution

**Mapping**
The input data is mapped to different data regions by sigmoid function as a nonlinear transformation of the solution

**Indicator ermpowerment**
1、enter the mapped data
2、data standardization
3、calculate the information entropy of each indicator
4、calculate the coefficient of variation for each indicator
5、calculate the entropy weight coefficient of each indicator
6、multiply the weights calculated by analytic hierarchy process and weights calculated by the entropy method

**Indicator score**
1、enter the mapped data
2、calculate the optimal solution and the worst solution distance for each evaluation object
3、calculate the relative closeness of each evaluation object separately
4、output the evaluation matrix

**Output**
The output part is the running health check score of the observation time point in a certain district
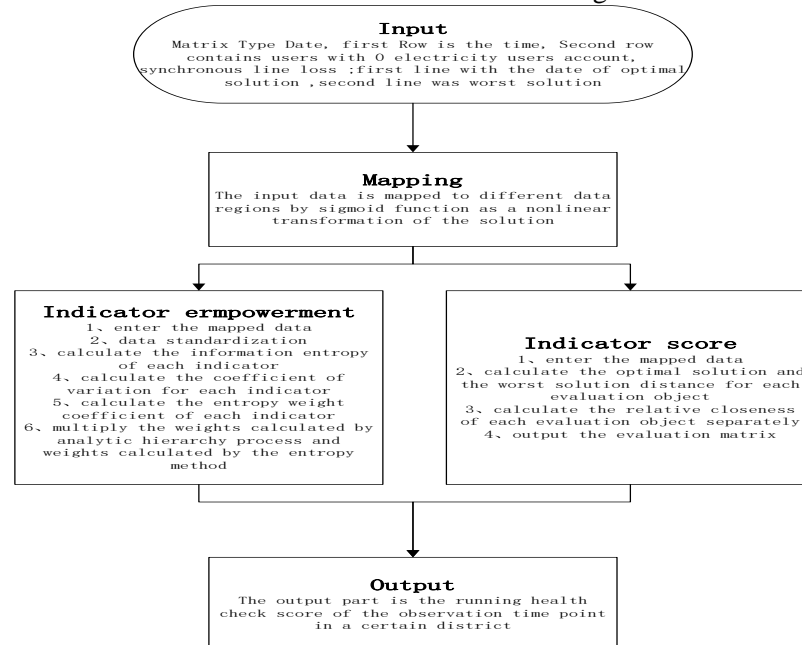
Figure 2.    The physical examination score model flow of the district

### 3.2.1 TOPSIS method index score mapping

The technique for Order Preference by Similarity to An Ideal Solution (TOPSIS) determines by determining the relative distance between the index vector of each evaluated object and the positive and negative ideal solutions. If the object being evaluated is close to the positive ideal solution and away from the negative ideal solution, the evaluation effect is better; otherwise, it is worse. Some indicator scores will take into account the expert experience to make rule corrections.

### 3.2.2 Entropy weight method index objective weighting

Based on the entropy weight method, the information contribution size of the mapped index data, such as automatic meter reading ratio, zero user share, voltage pass rate, topological relationship automatic recognition rate, and acquisition coverage rate Objective empowerment.

### 3.2.3 AHP method theme indicator subjective weight

The Analytic Hierarchy Process (AHP) was used to calculate the subjective weight of the non-underlying indicators of the health of the station. In the actual data analysis process, based on the actual data availability and expert business judgment, the evaluation index system is simplified and then hierarchically summarized into the three-layer structure shown in Figure 3.
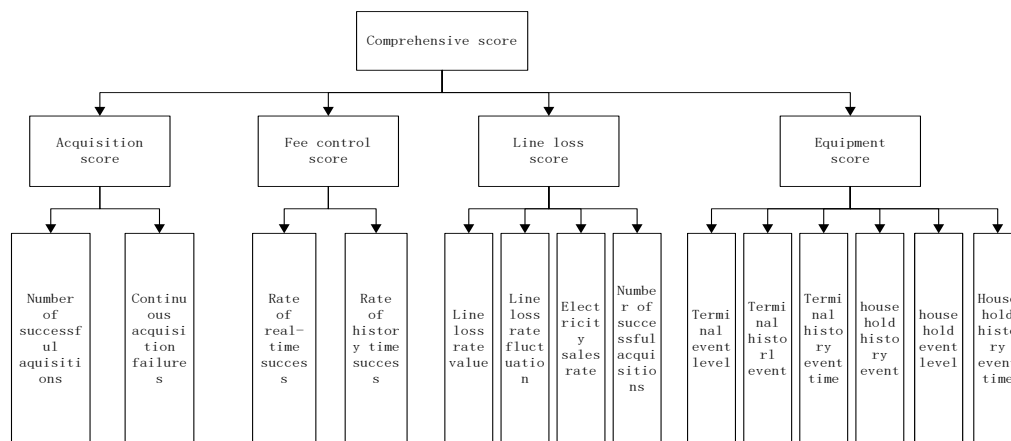
Figure 3.    Scoring architecture diagram

Table 2 shows the results of the subjective weight calculation of the AHP of the second-level indicators of the health status of the station (acquisition, fee control, line loss, and equipment dimensions).

Table 2 AHP subjective weight calculation results of the second-level indicators of the health status

| SOM clustering dimension | | AHP subjective weight calculation results | | | |
|---|---|---|---|---|---|
| | | acquisition | fee control | line loss | equipment |
| city | Operational | 0.19 | 0.32 | 0.38 | 0.11 |
| | Comprehensive | 0.20 | 0.31 | 0.36 | 0.13 |
| | Life | 0.22 | 0.29 | 0.35 | 0.14 |
| Urban and rural | Operational | 0.22 | 0.29 | 0.35 | 0.14 |
| | Comprehensive | 0.23 | 0.28 | 0.33 | 0.16 |
| | Life | 0.25 | 0.26 | 0.32 | 0.17 |
| Township | Operational | 0.25 | 0.26 | 0.32 | 0.17 |
| | Comprehensive | 0.26 | 0.25 | 0.30 | 0.19 |
| | Life | 0.28 | 0.23 | 0.29 | 0.20 |
| Rural | Operational | 0,28 | 0.23 | 0.28 | 0.20 |
| | Comprehensive | 0.29 | 0.22 | 0.27 | 0.22 |
| | Life | 0.31 | 0.20 | 0.26 | 0.23 |
| Mountain village | Operational | 0.31 | 0.20 | 0.26 | 0.23 |
| | Comprehensive | 0.32 | 0.19 | 0.24 | 0.25 |
| | Life | 0.34 | 0.17 | 0.23 | 0.26 |

## 4. Conclusion

Considering that there are nearly 107,200 Electricity District areas in Shanxi Province, and the factors such as the structure and personnel composition of the District network are complicated, this paper proposes a set of methods to quantitatively evaluate the operational health of the Low-voltage Electricity District. Firstly, through the SOM clustering technology, the station area is roughly divided into 15 categories considering geographical location and economic attributes. Then, for each type of station area, the customized analytic hierarchy process, entropy weight method and superior and inferior solution distance method are used to complete the evaluation index. The weightiness of the operating fitness is a percentage score.

The innovation of this research is also to comprehensively utilize the multi-dimensional perspectives around the management of the Low-voltage Electricity District to design two sets of indicator systems. One set includes 4 items and 101 items of indicators for the SOM clustering data characteristics, and the other set includes 6 large class of 15 subjects and 40 third-level indicators are

used for health evaluation.

This method has been successfully applied to the lean management of low-voltage distribution network in Shanxi Province. It provides accurate technical means for establishing efficient managerial service in Low-voltage Electricity District, and provides big-dimensional three-dimensional support for the construction of lean service management centered on customer service.

### References

[1]    Zhang Meirong. Analysis of power marketing mode in sub-station area [J]. Power Demand Side Management, 2003, 5(3): 56-57.

[2]    Huang Wenjuan, Zhang Jisheng, Shen Zhufu, et al. Research on meter reading and line loss management schemes in low-voltage stations [J]. East China Electric Power, 2009, 37(1): 34-37.

[3]    Ding Jianjian, Shou Ting, Zhu Tieming, et al. High-voltage distribution network planning evaluation index system and comprehensive evaluation model [J]. Power System Protection and Control, 2013, 41(21): 52-57.

[4]    Deng Jian, Wang Zhuangzhuang, Yuan Zai, et al. Research on comprehensive benefit evaluation of photovoltaic power generation based on matter-element extension model[J]. Power System and Clean Energy, 2015,31(11): 117-125.

[5]    Ding Ming, Guo Wei, Zhang Jingjing, et al. Vulnerability assessment of complex power grid nodes based on fuzzy comprehensive evaluation of utility risk entropy weight[J]. Transactions of China Electrotechnical Society, 2015, 30(3): 214-223.

[6]    Wang Bin, He Guangyu, Mei Shengwei, et al. Construction method of smart grid assessment index system [J]. Power System Automation, 2011, 35(23): 1-5.

[7]    IBM Corporation．Smart grid method and model[R]．Beijing：IBM Corporation，2010．

[8]    Wang Zhidong，Li Hui，Li Jun，et al．Construction method of smart grid assessment[J]．Power System Technology，2009，33(17)：14-18．

[9]    Zhang Xinjie，Ge Shaoyun，Liu Hong，et al．Intelligent distribution network comprehensive evaluation system and method[J]．Power System Technology，2014，38(1)：40-46．

[10]   Ouyang Sen, Chen Xinhui, Yan Hongjie. Evaluation of Voltage Characteristics of Low Voltage Distribution Network Based on Efficacy Coefficient Method[J]. Journal of South China University of Technology(Natural Science Edition), 2015, 43(8): 35-40.

[11]   Cao Yang, Meng Yuhui, Zhao Li, et al. Comprehensive Evaluation Method of New Rural Low Voltage Distribution Network Based on Analytic Hierarchy Process[J]. Power System Technology, 2007, 31(8): 68-72.