Health Image Generation Technology Of Oilfield Distribution Network Considering Equipment Health Index And Operation And Maintenance Strategy

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Research Article

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Abstract

A comprehensive grasp of the health status of existing distribution equipment and networks is the need of daily operation and maintenance management of distribution network and improvement of efficiency, the starting point of intelligent distribution network construction, and the cornerstone of all modern distribution technology research and application (energy internet, big data, cloud computing, Internet of Things). In order to solve the problems of state detection, power system efficient planning, operation and maintenance, etc. This paper selects the evaluation indexes suitable for smart grid from the aspects of safety, economy, reliability and environmental protection, and establishes a comprehensive evaluation index system of smart distribution network health, which divides the health state of oilfield distribution network into health, sub-health, general defects and serious defects. At the same time, this paper puts forward a generation technology of distribution network health degree portrait based on analytic hierarchy process and entropy weight method. In this paper, the health index is obtained by weighting the characteristic key quantity through the health degree evaluation method. In the selection of the key characteristic quantity, the line loss rate, power factor and line voltage are selected as the key characteristic quantity, and three indexes of safety, economy and reliability are taken as the standard. First, the entropy weight method was used to calculate the weight of the key feature quantity, then the health grade G was determined according to the key feature factors, and finally the health grade H was determined by the weighting of each factor. Dividing different health levels into different colors can eventually generate a straight line of health portraits at different times and days.

1. Introduction

Distribution network bears the important responsibility of distributing electric energy to users, and its reliability level determines whether the power system can meet the demand of users. Smart grid is different from traditional distribution network in safety, reliability, quality, economy and environmental protection. Smart grid condition monitoring is not only the monitoring management, condition maintenance and life management of power grid equipment, but also further developed into risk-based maintenance, and continuously extended to many fields such as safe operation, optimal dispatch, economic operation and service. The development of smart grid is inseparable from the understanding of existing equipment and network health, and its reliability evaluation plays a very important role in power system reliability. At present, the research on reliability evaluation of distribution network can be divided into two categories: 1) reliability evaluation of distribution equipment; 2) Reliability evaluation of distribution network.

(1)Reliability evaluation of power equipment is the basis of reliability evaluation of distribution network. Western countries first put forward the method of fault prediction and health management of power equipment, and health status assessment is one of the key technologies, that is, monitoring the safe operation of power equipment through the changes of some important characteristic parameters, relying on real data and reliable methods to judge the health status of the equipment itself, and even carrying out scientific fault diagnosis and isolation, so as to take necessary measures to alleviate the performance degradation of the equipment. Health index theory was originally put forward by EA Company in Britain[1], which is used to measure and characterize a quantitative value of equipment health status. Most studies on the field of health management of power and electrical equipment have this index, and the range of values is different. Based on CBRM (Condition-based Risk Maintenance), the running status of distribution equipment is evaluated [2]. The system is based on the power operation databases of European and American countries, and has been successfully applied to many power companies in Britain, as well as countries such as the United States, Canada and Australia. Literature [3] a novel statistical kernel-based GRNN approach has been presented to calculate the health index of power transformers. Four conditional scores based on six important tests(TDCG, DBV, acidity, water, furan and dissipation factor) have been used to train the proposed model.Literature [4] presents a bayesian information fusion method for determining power probabilistic health indicators.This method synthesizes various data obtained from transformer measurement and maintenance and uses these data to establish an inference model (BBN) by using Bayesian belief network.

(2)Reliability evaluation of distribution network. China Electric Power Research Institute has carried out the special project of State Grid Corporation "Research and Demonstration Application of Modern Distribution Network Health Index Theory and Engineering Realization System". According to the characteristics of domestic distribution network, this project discusses the research of distribution network health index from four aspects: basic theory, application method, data platform and demonstration application, and puts forward the definition, classification standard, calculation method and model of distribution network health index, which is verified by actual cases. Professor Ma Zhao [3] summarizes the concept and research status of equipment health index, and puts forward the definition, classification, calculation method and model of distribution network health index. Secondly, taking the 110kV substation in a pilot area of Nanjing and Beijing as the network research object, the application scenario of distribution network health index is put forward. Finally, the development trend of distribution asset management in the future and the significance of deepening research on distribution network health index theory and engineering realization system for distribution asset management in the future are summarized.Literature [5] characterizes the main key features affecting distribution equipment and distribution network by consulting data, analyzing actual situation and calculating data. Document [6] introduces the key features that have an impact on the line operation, and establishes a line risk assessment model based on PCA dimension reduction for line risk assessment. In the literature [7], the complex distribution network was diagnosed based on analytic hierarchy process (AHP), and the 10KV power network was taken as an example for verification. Literature [8] studies and analyzes the health and importance of distribution network operation, and gives a specific formula for calculating distribution network health index. Literature [9] will summarize the evaluation process of distribution network health index, and put forward the evaluation method based on group equipment and network. Literature [10] discusses the key characteristics of different distribution equipment in 10kv distribution network, and establishes a health model by using Logistic regression method for verification through 30 transformers as an example.

Based on the research and application of the existing distribution network health index theory, in order to evaluate the reliability of distribution system reasonably and effectively, this paper puts forward the generation technology of distribution network health image which comprehensively considers equipment health index and operation and maintenance strategy. The main work is as follows:

(1) Analyze the distribution network health index theory and classification standard, and analyze the optimal operation and maintenance strategy of the power network.

(2) According to Q/GDW645—2011 Guidelines for Condition Evaluation of Distribution Network Equipment, the health level of distribution network is divided from [0,5] into health (4,5), sub-health (3,4), general defects (2,3), serious defects (1,2) and critical defects (0,1] .

(3) The key features of distribution network are classified from three aspects: safety, economy and reliability. Power factor, line voltage deviation and line loss rate are selected as three key feature quantities, and the key feature quantities are weighted by entropy method to calculate their respective weights.

(4) Taking the data of 7 lines in a 110kv substation in the oilfield as samples for example analysis, the calculation of health index, the classification of health degree and the generation of health degree images are completed.

(5) The optimal operation and maintenance strategy of distribution network based on health index theory is put forward, which provides a reliable basis for the planning, construction, operation and maintenance of distribution network.

2. Determination Of Evaluation Index Of Intelligent Distribution Network

2.1 Definition of Health Index

Professor Ma Zhao put forward in "Research on the Theory and Application of Modern Distribution Network Health Index" [11] that the health index is to concretize the abstract power grid operation state through quantitative methods, and to measure and display the power grid operation state clearly and intuitively through specific numerical values. The health index can be obtained through logical analysis and mathematical operation based on the key characteristic quantities affecting the power grid operation. For the distribution network, the health index can comprehensively show the current running state of the network. The health status evaluation index of smart grid has a wide range of design and many factors to consider, so it is necessary to select the appropriate evaluation index according to the characteristics of smart grid.Oil field distribution network is a complex network system with real-time balance, discreteness and continuity, so it is difficult to describe the health of complete oil field distribution network from a single dimension. How to extract scientific and effective health evaluation indicators of smart grid from various key factors affecting distribution network and equipment is one of the research focuses of this paper. In this paper, the distribution network health index is comprehensively characterized from four dimensions: safety, reliability, economy and green on the basis of consulting domestic and foreign literature [12], combining with the statistical analysis of fault causes in actual operation of power system distribution network, and referring to the following regulations and standards: Guidelines for State-owned Distribution Network Maintenance and Operation Regulations of State Grid Corporation of China.

2.2 Smart grid health grade classification

In order to establish the distribution network health index, the value range of oilfield distribution network health is determined as (0,5], and the greater the score, the better the health state. Combined with the current research and field application, the distribution network health status of Shengli Oilfield is divided into five grades: health, sub-health, general defect, serious defect and critical defect. As shown in Fig. 1, the five colors represent the health status of five oilfield distribution networks, for example, green represents the health status at [4, 5], which means health status, and red represents the health status at [0,1], which means critical defect status.

The meanings represented by the five health portraits of oilfield distribution network are:

1) Health portrait: The oilfield distribution network can continue to perform the specified functions without barriers within the specified time and under the specified conditions, and the performance in three dimensions, such as safe, reliable and economical power supply, is up to standard, with sufficient margin for corresponding key features, and strong ability to resist risks and adapt to the environment (complete functions and excellent performance). As long as the daily operation and maintenance strategy is executed normally, the defects and risks can be found and solved in time.

2) Sub-health portrait: The oilfield distribution network can normally perform the specified functions within the specified time and under the specified conditions, and the performance of three dimensions, such as safe, reliable and economical power supply, has yet reached the standard, but some key features are close to the standard limits, and the ability to resist risks and adapt to the environment has declined (complete functions, decreased performance). It is necessary to pay attention to the existing defects and risks, but as long as the daily operation and maintenance strategy is executed normally, it is necessary to ensure that the defects and risks are found and solved in time.

3) General defect portrait: The oilfield distribution network can normally perform the specified functions within the specified time and under the specified conditions, but the performance of three dimensions, such as safe, reliable and economical power supply, has been partially degraded, and the corresponding characteristic indexes are more limited, but the comprehensive influence degree is small, and the ability to resist risks and adapt to the environment has slight defects (complete functions and slight performance defects). It is necessary to pay attention to the existing defects and risks, avoid risks by strictly implementing inspection, overhaul and test procedures, and improve the health level by taking corresponding measures to improve the safety, reliability and economy of oilfield distribution network.

4) Serious defect portrait: The oilfield distribution network can still normally perform the specified functions within the specified time and under the specified conditions, but the performance of safe and reliable power supply has been partially seriously degraded, and the corresponding characteristic indicators are over-limited, resulting in a large comprehensive impact, and obvious defects in risk resistance and environmental adaptability (complete functions and obvious defects in performance). Warn the oilfield distribution network staff to take corresponding measures to improve the safety, reliability and economy of the distribution network to improve the health level, otherwise, the oilfield distribution network will easily be in a critical defect state.

5) Portrait of critical defects: the oilfield distribution network has been unable to perform the specified functions normally, and the performance in the dimensions of safe and reliable power supply has been seriously degraded, with serious consequences. It is necessary to arouse the attention of oilfield distribution network staff and increase measures in a targeted manner, otherwise, the oilfield distribution network will face paralysis and cause great losses to oilfield production.

2.3 Key feature selection

In this paper, after consulting domestic and literature [13–14], combining with the statistical analysis of fault causes in actual operation of power system distribution network, and referring to the following rules and standards: "Guidelines for Condition-based Maintenance of Distribution Network" and "Operation Rules of State Grid Corporation Distribution Network", it is decided to classify the key characteristics of distribution network health from four dimensions: safety, reliability, economy and environmental protection.Classification criteria and calculation formula are shown in Table 1.

1. Safety means that the distribution network should have the ability to resist certain risks and disturbances, and have the ability to deal with emergencies. Even if the distribution network is disturbed during operation, it can continue to maintain the power supply of the distribution network and keep the normal operation of the distribution network. Generally, load change rate, power factor and PV curve slope are the indexes to measure the safety of distribution network.
2. Reliability refers to the ability of distribution network to continuously supply power to oilfield loads according to specified quality standards and required power, that is, the ability of "guaranteeing quality and quantity"-ensuring the quality and continuity of power supply of distribution network. Usually, line voltage deviation, fault recovery time and load margin are used.
3. Economy refers to the operation economy of distribution network under typical load conditions, which reflects the loss situation, operation and maintenance cost and overall system operation efficiency of distribution network in oilfield. The measurement indicators are line loss rate, network loss and operation and maintenance cost ratio.
4. Environmental protection index refers to the access of clean energy and the popularization of electric vehicles, which not only alleviates the dependence on fossil energy, but also greatly reduces the emission of greenhouse gases.

In this paper, the permeability of distributed energy is selected as the environmental protection index. The higher the permeability, the higher the proportion of clean energy in the whole system, the better the environmental protection.

Table 1 The classification table of key characteristic quantities of smart grid:

Evaluation dimension	Key feature quantity	Meaning	Computing formula
Security	Load qualification rateT_s	The ratio of successfully transferred load to the total load affected	$T_s = \frac{P_s}{P}$
	Power factor$\cos\varphi$	Ratio of active power to apparent power in power grid	$\cos\varphi = \frac{P_{有功}}{P_{视在}}$
	Slope of PV curve	The greater the slope of PV node curve, the lower the voltage stability and the closer the system is to the critical operating point。	$CS = \max\left\|\frac{\Delta P}{\Delta V}\right\|$
Reliability	Voltage deviationΔU	Difference between actual voltage and system standard voltage	$\Delta U = \frac{U - U_N}{U_N}$
	Voltage qualification rate	Node number ratio of system node voltage in allowable deviation rangeγ	$\gamma = (1\text{-}n/N)$
	Failure recovery timeΔT	Time from failure to recovery to pre-failure state of system state	$\Delta T = \Delta t_1 + \Delta t_2 + \Delta t_3$
Economy	Ratio of line loss$(\Delta T)\%$	The percentage of the power lost in the process of line transmission to the total power provided by the power plant	$(\Delta T)\% = \frac{\Delta T}{T_s}$
	Proportion of operation and maintenance expensesC_{s2}	The proportion of network operation and maintenance expenses to total electricity sales	$C_{s2} = \frac{C_M}{W_s P}$
Environmental protection	Penetration rate of distributed energyλ_{DG}	The ratio of Pi distributed generation to the maximum load power of power gridPLmax	$\lambda_{DG} = \sum \frac{Pi}{PLmax}$

3. Smart Grid Hi Calculation And Maintenance Strategy

3.1 Selection of key feature quantities

In the process of power system operation, the power factor of distribution network can effectively reflect the power grid operation. Generally speaking, when the distribution network is in normal operation, the power factor is in a dynamic equilibrium state. When the power factor drops to a certain value, it will lead to excessive reactive power, which will lead to a decrease in the power factor of the whole power system and affect the operation of the whole power system.Therefore, entropy weight method can be used to calculate the weight of each index, which provides a basis for multi-index comprehensive evaluation. In this paper, the five-day health index of oilfield distribution network is evaluated. There are three indexes in the system, so the steps of comprehensive evaluation by entropy method are as follows:

The power factor and line voltage are positive indicators (i.e. the greater the value, the smaller the impact on the health of distribution network), so the calculation method is shown in Formula (1):

$$y_{ij} = \frac{x_{ij} - x_{max}}{x_{max} - x_{min}}$$

1

The line loss rate is an inverse index (that is, the greater the value, the greater the influence on the health of distribution network), so the calculation method should adopt formula (2):

$$y_{ij} = \frac{x_{max} - x_{ij}}{x_{max} - x_{min}}$$

2

Where: $y_{ij}$is the normalized value; $x_{ij}$is the value without normalization; $x_{max}$is the maximum value in the current range; $x_{min}$is the minimum value in the current range.

Through the above calculation, all the key feature quantities are transformed into unitless relative values, and the values are within [0, 1]. So as to facilitate the subsequent calculation of weights.

Calculate entropy and redundancy:

The entropy value is calculated by formula (3):

$$E_j = -\frac{1}{\ln n}\sum_{i=1}^{n} p_{ij}\ln p_{ij}$$

3

Where: $E_j$represents the entropy value of the key characteristic quantity; p_{ij} represents the proportion of normalized key features in the whole range.

Entropy is a measure with uncertainty. The greater the amount of information, the smaller the uncertainty and entropy. The smaller the amount of information, the greater the uncertainty and entropy. According to the characteristics of entropy, entropy is used to judge the discrete degree of an index. The greater the discrete degree of an index, the greater the impact of the index on comprehensive evaluation. Therefore, according to the variation degree of each index, the weight of each index can be calculated by using the tool of information entropy, which provides a basis for multi-index comprehensive evaluation.

(3)Calculate the difference coefficient and weight of key feature quantities:

The difference coefficient and weight of key feature quantities can be calculated by formulas (4) and (5):

$$d_j = 1 - e_j$$

4

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j}$$

5

Where: $d_j$is the difference coefficient o; w_j is the weight of the first index.The health degree of distribution network is calculated from three dimensions: safety, reliability and economy, in which the safety dimension is measured by power factor; The reliability dimension is measured by line voltage. Economic dimension is measured by line loss rate.

3.2 Calculation of Health Index

The real-time health index of oilfield distribution network can be obtained by normalizing, grading and multiplying the data of three key feature quantities at any time by the index weight value and then adding them together, so as to obtain the final evaluated health degree of oilfield distribution network. In this paper, the calculation formula used to describe the health index of power system distribution network running state at any time is as shown in Formula (6):

$$H(t) = \frac{\sqrt{\sum_{j=1}^{M} \left(w_j(t) G_j(t) \right)^2}}{\sqrt{\sum_{j=1}^{M} w_j^2(t)}}$$

6

Where: it is the weight value determined by different key feature quantities, and the influence degree of each key feature quantity on health degree can be seen by setting the weight; The health grades determined for different key feature quantities are obtained by dividing the key feature quantities into health grades;

3.3 Maintenance strategy

According to the three key characteristic quantities of power factor, line voltage deviation and line loss rate selected in this paper, there are two main methods to improve the power factor of distribution network:

(1)improve the natural power factor:1)Try to make the distribution network run at full load; 2)Reasonably distribute the distribution network layout and improve the actual operation of the distribution network; 3)Adopt electromagnetic switch with no pressure operation.

(2)Reactive power compensation:

1) adopt synchronous compensator to make distribution network work in overexcitation state; 2) Capacitors are connected in parallel to generate capacitive current to compensate inductive current generated by distribution network for reactive power compensation.

(3)Reducing line voltage deviation can be solved by reducing line impedance and boosting voltage:

(4)Reduce the line impedance: 1) replace overhead lines with cables; 2) In areas not suitable for overhead lines, the line reactance is compensated by series capacitors to reduce the line impedance.

(5)Boosting:

1) Install phase-shifting capacitors to stabilize the voltage during distribution network operation; 2) Adopt automatic adjustment system to adjust the voltage in real time. To reduce the line loss rate, the following points can be considered from the aspects of power grid capacity, reasonable distribution, balance of three-phase load and equipment management: PRTV anti-pollution flashover material is sprayed on the insulator surface, which prevents the direct contact between dirt and insulator and indirectly reduces the line loss rate; Reduce the line loss rate by adjusting and increasing the climb;

(6)Regularly or irregularly inspect the distribution network equipment and replace the old equipment in time.To reduce the line loss rate, the following points can be considered from the aspects of power grid capacity, reasonable distribution, balance of three-phase load and equipment management: 1) PRTV anti-pollution flashover material[15] is sprayed on the insulator surface, which prevents the direct contact between dirt and insulator and indirectly reduces the line loss rate; 2) Reduce the line loss rate by adjusting and increasing the climb; 3) Regularly or irregularly inspect the distribution network equipment and replace the old equipment in time. Figure 2 shows the push process of operation and maintenance countermeasures. In an example, in order to better compare the changes of line loss health in one day, the line health portraits are displayed on the big data platform every day.

It is stipulated that when the average health index of a certain line on that day is lower than 3, the big data platform will issue a warning, that is, the health of a specific line shows general defects/serious defects/critical defects. Then analyze the reasons of health deterioration according to the health index, and push the line loss improvement strategy according to the deterioration factors: 1) when the average power factor is lower than 0.7, push the "reactive power compensation" strategy; 2) When the average line voltage is lower than 85%, push the "boost" strategy; 3) When the power factor is higher than 0.7 and the line voltage is higher than 85%, it means that the line itself is trouble-free, and the deterioration of the line loss may be due to the problems in the readings of the outlet power quantity and the inlet power quantity. "Data measurement is wrong, and the line is healthy".

4. Examples Of Health Division

4.1 Calculation of Health Weight Index

In this paper, the power factor, voltage deviation and line loss rate of 7 lines of 110KV distribution network in an oilfield are taken as key characteristic quantities to calculate the network health index. In an example, the health degree portraits of 7 lines including A ~ G in 4 days, 4.24 days, 4.30 days, 5.2 days, 5.27 days and 5.31 days are made respectively. In the figure, the abscissa represents time with an interval of 1 hour, and the ordinate represents the line.

Firstly, the health grade G is determined according to the key feature quantity, and then the final health grade H is obtained by weighting. The line loss rate, line voltage deviation percentage and power factor weight are 0.6, 0.15 and 0.25 respectively.

1. voltage deviation calculation process shows: Taking the data of line A at 7: 00 on April 24, 2020 as an example, it can be known from the data that the voltage level of the distribution network system is 110KV, and the actual operating voltage of the line is 105KV, which can be obtained from Formula 7:

$$\triangle \mathrm{U} = \frac{105 - 110}{110} \times 100\% = -4.5\%$$

7

That is, the voltage deviation of line a in this period is -4.5%, and the voltage deviations of other lines are also obtained by the above method. At present, when the distribution network of China's power system operates normally[16], the voltage deviation value of most lines does not exceed 10%, so the health level of voltage deviation is divided according to this standard as shown in Table 2:

Table 2
Health Classification of Line Voltage Deviation

Ratio of line loss	Health grade
[0, 10%)	5
[10%, 20%)	4
[20%, 30%)	3
[30%, 50%)	2
[50%, ∞)	1

(2) Show the calculation process of line loss rate: Taking the data of line A at 7: 00 on April 24, 2020 as an example, it can be known from the data that the power supply and sales of the distribution network in this period are 384 kW and 345.5 kW, which can be obtained by formulas 8 and 9:

$$\triangle \mathrm{T} = 384 - 345.5 = 38.5\mathrm{KV}$$

8

$$(\triangle \mathrm{T})\% = \frac{38.5}{384} = 10\%$$

That is, the line loss rate of line a in this period is 10%, and the rest line loss rates are also obtained by the above method[17–18]. When the distribution network of China's power system operates normally, the line loss rate of most lines does not exceed 10%, so the health level of line loss rate is divided according to this standard as shown in Table 3.

Table 3
Health Classification of Line Loss Rate

Power factor	Health grade
[0.85, 1)	5
[0.7, 0.85)	4
[0.6, 0.7)	3
[0.5, 0.6)	2
[0, 0.5)	1

The power factor is directly obtained from the system operation measurement, and is not calculated in this paper. When the distribution network is in normal operation, the power factor should not be lower than 0.9, so the health level of power factor is divided according to this standard as shown in Table 4 :

Table 4
Classification of Power Factor Health Level

Line voltage deviation	Health grade
[0, 10%)	5
[8%, 15%)	4
[15%, 20%)	3
[20%, 30%)	2
[30%, ∞)	1

The value of health degree in the above three tables is (0,5), and different values correspond to different states. The larger the value, the better the health state. They respectively correspond to five grades: health (4,5), sub-health (3,4), general defect (2,3), serious defect (1,2) and critical defect (0,1), which are also divided according to these five grades when depicting the health degree portrait of oil field distribution network. The five colors represent the health status of five oilfield distribution networks, for example, green indicates that the health level is at (4,5), that is, health status, and red indicates that the health level is at (1,2), that is, serious defect status. When the power factor is 0.781, the line voltage deviation is 4.5%, the corresponding health level is 5, the line loss rate is 10%, and after the corresponding health level is 5, calculate the comprehensive health index of line 7 by formula 10:

$$H_{(t)} = \frac{\sqrt{3^2+0.6^2+0.75^2}}{\sqrt{0.6^2+0.15^2+0.25^2}} \approx 4.72 \tag{10}$$

It can be obtained that the health index at line a 7 is about 4.72, which corresponds to the health level.

4.2 Health portrait results and Line loss picture result

(1) **Health portrait results**

1) health portrait results and operation and maintenance strategy on April 24th, 2020

It can be seen from the health portrait in Fig. 3 that Line A is in a healthy state for most of the day, and is in a general defect state and sub-health state for a small part of the day; B line is in a healthy state for most of the day, and a small part of the day is in a general defect state; C line is in a healthy state for most of the day, and it is in a general defect state and sub-health state for a few times; D line is in a healthy state and a sub-healthy state for most of the day, and a small part of the time is in a general defect state; E-line is in a healthy state for most of the day, and is in a general defect state and sub-health state for a small part of the day; F line is in general defect and sub-health state for most of the day; G-line is in a healthy and sub-healthy state in most time periods of the day, and in a few time periods it is in a state of general defects and serious defects. The health indexes of 7 lines are: Line A: 3.47475207; B: 3.47735188; C line: 4.41313853; D line: 3.25823759; E line: 4.0762806; Line f: 2.59389303; G line: 3.43516711. According to the classification of health degree, it is concluded that line f is in a general defect state on that day, and then the causes of defects are analyzed according to the program, and it is concluded that the average power factor of line f is higher than 0.7, the voltage deviation is less than 15%, and the push operation and maintenance strategy is: "data measurement is wrong, the line is healthy".

2) Health degree portrait results and operation and maintenance strategies on May 2, 2020

It can be seen from Fig. 4 health image that line a is in general defect state in most time periods of the day, and in sub-health state or general defect state or serious defect state in a very small time period; B line is in a general defect state for most of the day, and is in a sub-health state or healthy state for a very small part of the day; C-line, D-line and E-line are in a healthy or sub-healthy state in some time periods of the day, and the rest time periods are in a general defect state; F-line is in a general defect state in most time periods of the day, and a few time periods are in a healthy state, a sub-healthy state and a serious defect state; G-line is in a general defect state in most time periods of the day, while a few time periods are in a healthy and sub-healthy state. The average health index of the 7-day line is: Line A: 2.53806134; B line 2.6222447; C line: 3.52801937; D line: 3.34940636; E line: 3.23770822; Line f: 2.71030898; G line: 3.05460374. According to the classification of health degree, it is concluded that the A, B and F lines belong to general defect state on that day, and then the defect reasons are analyzed according to the program, and it is concluded that the power factor of the A, B and F lines is higher than 0.7 and the line voltage is higher than 85% on that day, so it is judged that the lines themselves are trouble-free, and the deterioration of line loss may be due to the problems of the readings of outlet power and inlet power, and "wrong data measurement, line health" is pushed.

3) Results of health degree portrait on May 27, 2020 and operation and maintenance strategy

It can be seen from Fig. 5 Health Image that Line A, Line E and Line G are in a healthy state or sub-healthy state for most of the day, and are in a general defect state for a very small time; B line has been in a healthy or sub-healthy state on the same day; C-line and F-line are in a healthy state for the most part of the day and in a general defect state for the least part of the day. D-line is in general defect state or serious defect state in most time periods of the day, and is in healthy state in a very small time period. The average health index of the 7-day line is: Line A: 3.34918725; B line 4.54276541; C line: 4.201211785; D line: 1.8757232; E line: 4.18757232; Line f: 4.33537418; G line: 4.05350089. The D-line is in a serious defect state on that day, and then the defect reason is analyzed according to the program, and it is concluded that the power factor of D-line is lower than 0.7 on that day, so the "reactive power compensation" strategy is pushed.

4) Results of health portrait on May 31, 2020 and operation and maintenance strategy

It can be seen from the health image in Fig. 6 that the A-line, C-line and F-line are in a healthy state or sub-healthy state in most time periods of the day, and are in a general defect state in a very small time period; B-line and G-line were in a healthy or sub-healthy state all the time. D-line was in a general defect state on that day. The running results show that the average health index of the 7-day line is: Line A: 3.323441330; B line 4.27915817; C line: 4.38023766; D line: 1.88674324; E line: 4.02822595; Line f: 3.2207806; G line: 4.41277291. According to the classification of health level, it is concluded that the D line is in a serious defect state on that day, and then the defect reason is analyzed according to the program, and it is concluded that the line voltage deviation of the D line on that day is more than 15%, so the "boost" strategy is pushed.

Therefore, it is necessary to improve the network security by changing the grid structure of oilfield distribution network, improving the line segmentation and connection level, and improving the network economy by increasing the reactive power compensation capacity, increasing the line voltage and optimizing the operation mode, so as to improve the healthy operation level of distribution network.

(2) Line loss picture result

In order to clearly and intuitively show the complex line loss situation, a portrait of feeder line loss is established by high-dimensional random matrix modeling, and a portrait of line loss is made for 12 feeders in an oilfield on April 20th and April 30th, 2020, as shown in Fig. 7. In the figure, the abscissa represents time, with hours as the interval unit, and the ordinate represents 12 feeders. The depth of the color block in the line loss picture represents the line loss rate, and the darker the color, the higher the line loss rate. Therefore, the line loss portrait is an intuitive description of the health change trend of each feeder line in one day, and it can also compare the health situation of each line from the spatial dimension and be used for the preliminary warning of line faults.

5. Conclusion

The health degree of oil field distribution network quantifies the health state of distribution network. According to the health degree portrait, the health degree of oil field distribution network can be visually displayed and the fault can be warned. Different health values correspond to different states.

In this paper, the health index method is used to discuss the generation of distribution network health image and the operation and maintenance countermeasures, and the main conclusions are as follows: (1) Health degree evaluation method is one of the important methods for evaluating the health degree of oilfield distribution network, and the health degree index is obtained by weighting characteristic key quantities. (2) In the selection of key feature quantities, the line loss rate, power factor and line voltage are selected as the key feature quantities with three indexes of safety, economy and reliability as the standard; (3) Entropy weight method can be used to calculate the weight of key feature quantities. (4) First, determine the health grade G according to the key characteristic factors, and then obtain the final health grade H determined by all factors by weighting. In addition, different health grades are divided into colors, and finally, a health portrait of a certain line at different times and days can be generated.

Declarations

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Conflicts of Interest: The authors declare no conflict of interest. Conflicts of Interest: The authors declare no conflict of interest.

Availability of data and material (data transparency): The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Authors' contributions: YangYang designed research, performed research, analyzed data, and wrote the paper.

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Figures

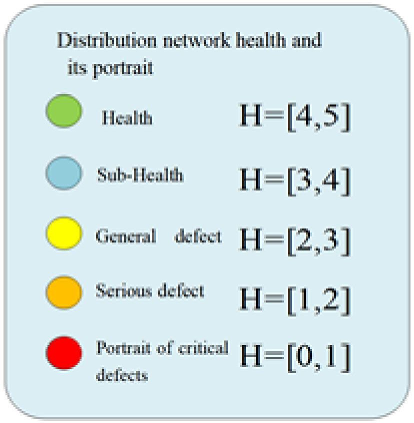


Figure 1

Distribution network health and its portrait

Figure 2

The push process of operation and maintenance countermeasures

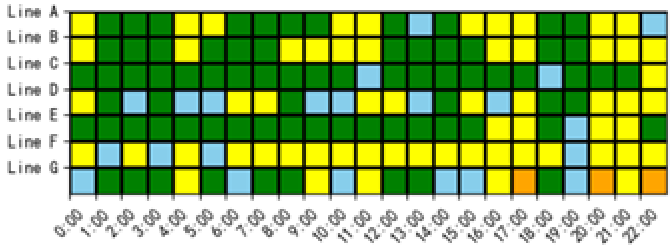


Figure 3

Image of oilfield health on April 24th

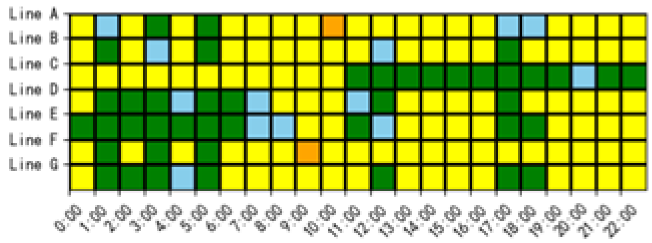


Figure 4

health degree portrait of oil field on May 2

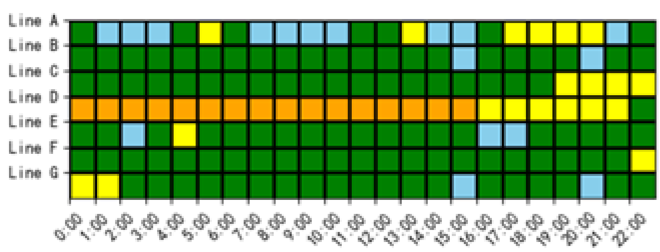


Figure 5

Health degree portrait of oil field on May 27

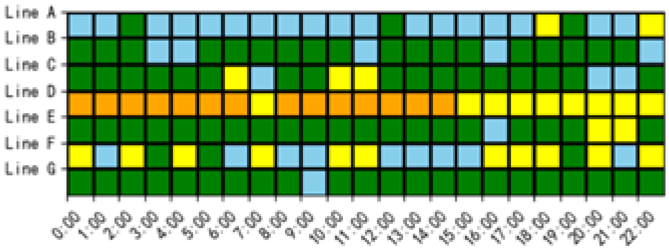
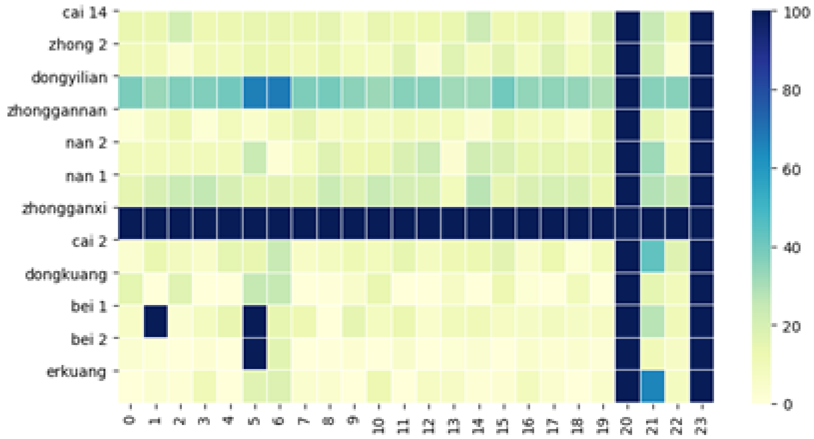
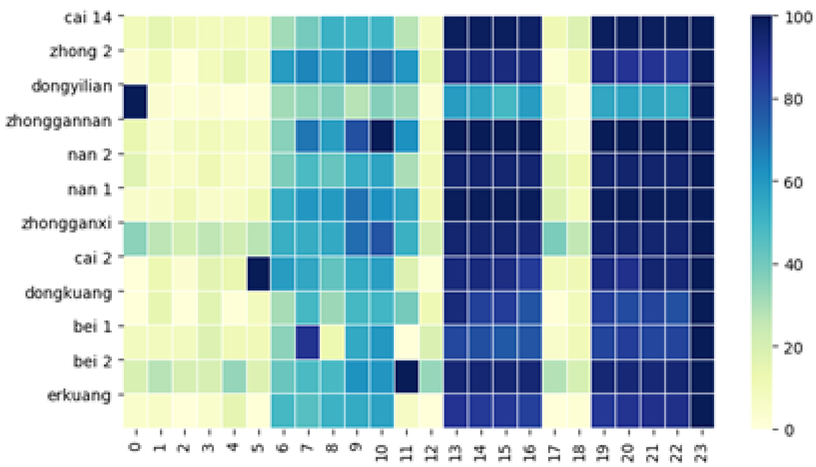


Figure 6

health degree portrait of oil field on May 31



(a)



(b)

Figure 7

(a) Portrait of line loss on April 20th, 2020

(b) Portrait of line loss on April 30, 2020