International Journal for Applied Information Management
Vol. 3, No. 4, December 2023, pp. 154-161

Soft Sensing Image Analysis and Processing Method of Substation Equipment Defects

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(Received: September 15, 2023; Revised: October 14, 2023; Accepted: November 18, 2023; Available online: December 10, 2023)

Abstract

In the context of incentivizing regulation for distribution companies, the utilization of a reference network model proves to be a valuable tool for evaluating their effective cost. These models play a crucial role in planning expansive distribution areas that encompass various voltage levels. This paper introduces a green space planning algorithm designed to optimize the location, size, and power supply areas of medium and low voltage substations within the Reference Network Model (RNM). The algorithm aims to enhance the efficiency and environmental impact of these substations. The focus of this study extends to two key aspects: the creation of "environment-friendly" substations and the significance of implementing "resource-saving" substations in China. The evaluation of "environment-friendly" and "resource-saving" characteristics is conducted through comprehensive analysis, with results indicating notable features. Feature 1, associated with environmental friendliness, is measured at 0.363, while Feature 2, emphasizing resource-saving attributes, achieves a high score of 0.835. Furthermore, Feature 3, addressing the importance of implementing these eco-friendly substations in the Chinese context, attains a commendable score of 0.824. The findings underscore the potential of the proposed green space planning algorithm in enhancing the sustainability and efficiency of medium and low voltage substations within the incentive regulation framework for distribution companies.

Keywords: Substation, Equipment, Commissioning Management, Measurement

1. Introduction

With the continuous development of science and technology, computer technology has become an indispensable part of our life. In the distribution network, pole transformer is not only the most common equipment related to power supply safety and environmental beautification, but also has a large number and heavy maintenance workload. Standardization is difficult to achieve. In view of the problems existing in the original substation, such as poor resistance to natural disasters, unreliable operation, low intelligence, non insulation, easy corrosion, backward technology and uncoordinated with the environment, etc.

With the continuous progress of information technology, many experts have studied the intelligent substation. For example, some domestic teams have studied the equipment commissioning management method of 110kV intelligent substation project. Based on the analysis of 110kV intelligent substation project and its characteristics, the intelligent substation is compared with the conventional substation. This paper briefly introduces the grounding corrosion of substation power grid, analyzes the causes of corrosion, and introduces the application of sacrificial anode in power grid grounding. This paper discusses the establishment method of 3D visualization digital model and the establishment of corresponding standard database, and establishes the 3D visualization digital model library on this basis. The economic power supply radius of the substation is optimized. According to engineering practice, the two main contents of equipment commissioning management are quality management and safety management. Through consulting a large number of domestic and foreign literature, the quality and safety problems in equipment commissioning management

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DOI: https:// doi.org/10.47738/ijaim.v3i4.64

are analyzed and studied, which provides a scientific basis for putting forward more effective management methods in the future. Aiming at some problems existing in substation lightning protection system, a new design and implementation method of intelligent grounding system is proposed. The evaluation model of equipment operation state based on characteristic parameter tracking method is introduced. By inputting initial data such as key eigenvalues and test period, the observed data are fitted linearly. Through the analysis of the fitting curve, the characteristic parameter value and detection time of the equipment are predicted, and the quantitative relationship between the state of the electrical equipment and the detection period is obtained [1]. A hierarchical clustering wireless sensor network (WSN) based on mufti-agent system (MAS) is proposed. The sustainable power supply node is designated as the cluster head node, and the node temperature measurement node is a common node belonging to the cluster, and there is interaction between them. Through the analysis of the status quo of the security management and control of an intelligent substation, the construction goal of the security management and control system is defined. Through the linkage of positioning alarm and video monitoring in the system, the effective identification of regional personnel is ensured, the safety of personnel operation is improved, the occurrence of electric shock accidents is reduced, and the overall operation and maintenance management efficiency of intelligent substation is improved. Combined with Floyd shortest path algorithm, the dynamic adjustment of the inspection cycle of intelligent substation is realized, which saves the inspection time and effectively shortens the inspection path. Compared with the traditional detection strategy, the effectiveness and Scientology of the optimization scheme are verified. The method can also be applied to the operation and maintenance inspection of intelligent robot in substation [2]. Some experts have studied the feature extraction and classification methods of power equipment images. Based on the measurement of noise level of substations and surrounding equipment in China Southern Power Grid, the characteristics and propagation law of substation noise are understood, and the comprehensive treatment scheme of substation noise pollution is proposed. This paper introduces the common quality problems in substation civil engineering, combined with the geographical characteristics and climatic conditions of the region. Although the research results of intelligent substation are quite fruitful, there are still some deficiencies in the soft sensing image analysis and processing methods of substation equipment defects.

In order to study the soft sensing image analysis and processing method of substation equipment defects, through the study of substation, the color histogram is found. The results show that data mining technology can be applied to the analysis and processing of substation equipment defect soft sensing image.

2. Literature Review

2.1. Evolution of Intelligent Substations

The integration of computer technology into our daily lives has led to the continuous development of intelligent substations. Traditional pole transformers, although crucial for power supply safety and environmental aesthetics, have faced challenges such as susceptibility to natural disasters, unreliable operation, and low intelligence. In response to these issues, the research community has witnessed a growing interest in the development of intelligent substations as a more advanced and efficient alternative[3][4].

Researchers, both domestically and internationally, have delved into the study of intelligent substations, with specific attention given to projects like the 110kV intelligent substation. Comparative analyses between intelligent and conventional substations have been conducted to identify key differences and areas of improvement.

2.2. Addressing Grounding Corrosion and Maintenance Challenges

The literature reveals a considerable focus on addressing maintenance challenges associated with traditional substations, such as grounding corrosion. Previous studies have explored the causes of corrosion and introduced innovative solutions, including the application of sacrificial anodes in power grid grounding. Furthermore, the establishment of 3D visualization digital models has been proposed as a means to address issues related to poor resistance to natural disasters and backward technology in traditional substations. Researchers have worked on creating standard databases and model libraries to optimize the economic power supply radius and enhance the overall efficiency of substations[5][6].

2.3. Quality and Safety Management in Equipment Commissioning

ISSN 2776-8007

Quality and safety management in equipment commissioning have been identified as critical aspects of intelligent substations. Extensive literature consultations, both from domestic and foreign sources, have been conducted to analyze and study the existing problems in equipment commissioning management. These studies provide a scientific basis for proposing more effective management methods in the future, encompassing both quality control and safety protocols[7][8].

2.4. Advancements in Lightning Protection and Operation State Evaluation

In response to challenges in the lightning protection system of substations, researchers have proposed new design and implementation methods for intelligent grounding systems. Evaluation models based on characteristic parameter tracking methods have been introduced to predict equipment operation states. This involves fitting observed data linearly to obtain characteristic parameter values, thus establishing a quantitative relationship between equipment states and detection periods[9][10].

2.5. Wireless Sensor Networks and Security Measures

In the realm of wireless sensor networks (WSN) and security measures, a hierarchical clustering approach based on a multi-agent system (MAS) has been proposed. This approach designates sustainable power supply nodes as cluster heads, enhancing communication and interaction within the network. Linking positioning alarms and video monitoring in intelligent substations has been emphasized as a means to improve personnel safety, reduce electric shock accidents, and enhance overall operation and maintenance efficiency[11][12].

3. Methodology

3.1. Substation

3.1.1. Development of substation inspection

Nearly half of substation operation and maintenance work is focused on equipment status detection. In the past, the maintenance work of substation was mainly done by operation and maintenance personnel. Its disadvantages are obvious: a large number of long-term and repeated recording and state observation work are easy to make mistakes and neglect, and many equipment fault causes are difficult to find out in time; the data recording process is completed by hand writing or manual computer input, which is difficult to ensure the accuracy of data, and it is inefficient and inconvenient to carry [5]. With the gradual completion of UHV power grid, more and more large power grid systems will bring more inspection work. Since the advent of intelligent inspection robot technology in substation, it has been vigorously promoted and popularized [7]. At present, it is a very common phenomenon to use robots as auxiliary production tools in all kinds of substations, which can alleviate the heavy problem of substation inspection work to a certain extent. Safety is the core requirement of substation, which is dangerous under high voltage [9]. In order to ensure the safety of pedestrians and equipment, it is necessary to effectively detect pedestrians according to the monitoring video near the substation. The research direction of substation inspection robot mainly focuses on motion control, positioning and navigation, forming a mature integrated application system. Each generation of robot inspection platforms with the main functions of data acquisition and equipment status observation have emerged one after another, realizing the daily operation and maintenance tasks of substation equipment automatic replacement inspection, data acquisition, infrared temperature measurement, etc. In recent years, Lung intelligent and other domestic robot manufacturing enterprises have focused on the research and development of trackless guided robot [10]. The laser vision integrated guidance technology based on the laser fixed-point guidance technology basically realizes the intelligent inspection path function of the substation inspection robot. At present, the inspection robot has reached an unprecedented height in path planning, acquisition point accuracy, inspection freedom and other aspects, and has realized the obstacle avoidance function to a large extent [11]. However, in special cases, the ability of intelligent path planning needs further research. For example, sudden obstacles lead to the robot falling from the main road, mission interruption and so on. Whether the path can be completely autonomous planning by optimizing the background path algorithm is an important factor for the substation Inspection Robot Oriented to technological progress [12].

3.1.2. Data mining technology

Data mining technology is a kind of data analysis technology, which can search and extract key, effective and available information from massive data, which belongs to the category of knowledge discovery [13]. In the process of substation equipment condition evaluation, many variables need to be monitored. In the practice of data acquisition, there are some non noise reduction and fuzzy data types hidden in a large number of data. In order to realize the accurate extraction and judgment of data, it is necessary to eliminate the interference data from the massive data to ensure the accuracy and efficiency of data extraction. The large-scale acquisition and storage of power equipment status data provides basic support for the application of data mining technology in power equipment condition assessment, and provides the possibility for efficient and accurate monitoring and analysis of equipment status [14][15]. Equipment condition assessment based on data mining technology needs to be established on the basis of continuous monitoring. With the help of data modeling technology, massive data are repeatedly modeled, analyzed and modified to ensure the reliability and accuracy of the information obtained, so as to ensure the accuracy of the state assessment results.

3.2. Color Histogram

Color histogram is one of the most commonly used methods of color feature, which is used to describe the distribution of each color in the color space. For an image, it is first converted to a specific color space, and then the number of pixels in the corresponding space is calculated to obtain the histogram without smoothing and normalization. Histogram can describe the statistical distribution of image color, but does not consider the spatial distribution of image[16]. If the color of the target and background is obviously different, the histogram will show bi modal feature, otherwise there is no bi-modal feature. Define histogram according to formula (1):

$$H(k) = \frac{n_k}{N}, K = 0,1, \dots, L-1 \quad (1)$$

Among them, is the color value, is the number of eigenvalues that can be taken, is the total number of pixels occupied by the eigenvalues, is the total number of pixels. We will find that there will be some zero values. In order to solve this problem, we can choose cumulative color histogram, formula (2) will be changed into:

$$I(k) = \sum_N^{n_k} \frac{n_i}{N}, K = 0,1, \dots., L-1 \quad (2)$$

Color histogram can simply describe the distribution of different colors in the image, and can reflect the global characteristics of the image. It is more suitable for describing some images which are difficult to segment without considering the relative position of the object in the image. Each image has a unique color histogram, but due to the neglect of spatial distribution factors, different images may have similar or even the same histogram.

Color moment makes the color distribution of an image expressed by moments, which is a very good and very simple color feature. Color moments usually select the first, second and third order moments to describe the color information in the image. Formula (3-5) is as follows:

$$\mu_i = \frac{1}{N} \sum_{j=1}^{N} P_{ij} \quad (3)$$

$$\sigma_j = (\frac{1}{N} \sum_{i=1}^{N} (P_{ij} - \mu_i)^2)^{\frac{1}{2}} \quad (4)$$

$$S_i = (\frac{1}{N} \sum_{i=1}^{N} (P_{ij} - \mu_i)^3)^{\frac{1}{3}} \quad (5)$$

4. Experience

4.1. Experimental Object Extraction

RFID reader is the most important part of RFID positioning system. The control module is responsible for cooperating with each processing module of RFID reader to ensure the normal reading and writing of the reader[17]. The communication between external interface circuit and background management system is complex, such as querying database, saving label data, etc. it is usually connected with background management system through standard network port, RS232 serial port or USB interface.

4.2. Experimental Analysis

 ISSN 2776-8007

The electronic code of each RFID tag is unique, which is embedded in the object to identify the target object. Once in the scanning range of the RFID reader, the RFID tag will send the electronic code stored in the chip to the RFID reader through the micro antenna. Compared with the traditional bar code, RFID tag has the advantages of re usability, durability, penetrability, data security and reliability, small size and various shapes. Background data management system is mainly used to manage and store tag data information, such as personnel information and cargo information stored on RFID tags. It can communicate with RFID reader through network or bus, so that the system can obtain tag information in real time. The basic function of system management is to query, delete and modify label information. The working principle of RFID system is as follows: (1) the reader broadcasts radio frequency signal to the surrounding environment to ask if there is a tag; (2) when the tag is within the valid scanning range of the reader, the tag is activated and sends the electronic code or other data in the tag chip to the reader through its own antenna; (3) the RFID system can be used to detect the RFID tag When the RFID reader receives the electronic code (ID) signal sent by the tag through the antenna, the RFID reader can send the tag to the reader, and after decoding, the tag is sent to the background data management system through rs2-232 serial port or network port; (4) the background data management system queries the database to verify the validity of the tag, and then carries out corresponding processing according to the specific application requirements.

5. Discussion

5.1. Extraction of Color Features of Power Equipment Image

Due to the influence of illumination and insufficient exposure of image acquisition equipment, the image contrast of power equipment is often low, which affects the image recognition rate[18]. Therefore, it is necessary to enhance the collected power equipment image to highlight the target features in the image. The widely used color moment method is used to study the surface color characteristics of power equipment images. Any color distribution in an image can be represented by moments. Most of the information of an image is usually concentrated on the low order moments of color distribution. Therefore, only the first, second and third moments of color can be used to approximate the color distribution characteristics of an image. The characteristic values of color moment are shown in Table 1.

Table 1. Color moment of transformer

Color distance	Feature 1	Feature 2	Feature 3
F	0.363	0.835	0.824
E	0.653	0.647	0.735
D	0.732	0.681	0.823

It can be seen from the above that the value of characteristic 1 of F is 0.363, that of feature 2 is 0.835, that of feature 3 is 0.824; that of E is 0.653, that of feature 2 is 0.647, that of feature 3 is 0.735; that of D is 0.732, that of feature 2 is 0.681, and that of feature 3 is 0.823. The results are shown in Figure 1.

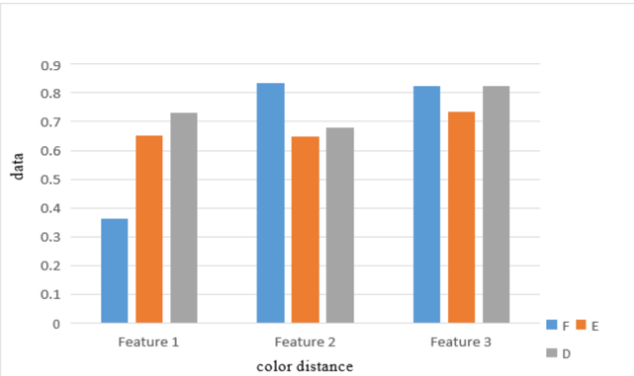

Figure 1. Color moment of transformer

It can be seen from the above that the value of characteristic 1 of D is the highest and that of feature 2 of F is the highest. Characteristic 3 of E is the smallest.

5.2. Description of Equipment Operation Characteristic Parameters

There are four types of transformer faults, the most important of which is mechanical damage[19][20]. According to the defect statistics of main transformer in an intelligent substation from 18 to 19 years, the mechanical damage and abnormal oil level defects account for 37% of the total defects of the main transformer. Therefore, the oil level status of main transformer is marked as its characteristic parameter, and its change is continuously monitored to realize the early warning of main transformer operation status, as shown in Table 2.

Table 2. Main transformer defect data classification can be found through inspection

type	Mechanical damage	Abnormal data indication	Abnormal oil level	short circuit
data	21%	30%	16%	33%

It can be seen from the above that the proportion of mechanical damage is 21%, the proportion of abnormal data is 30%, the proportion of abnormal oil level is 16%, and the proportion of short circuit is 33%. The results are shown in Figure 2.

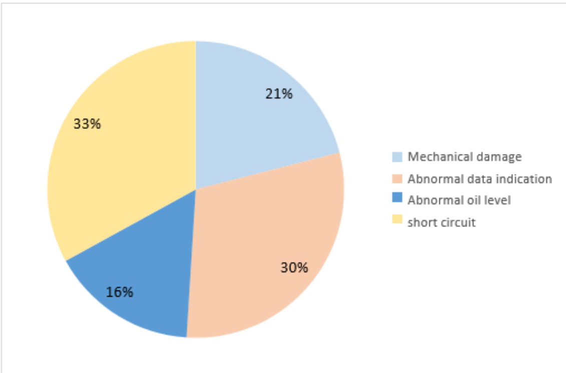

Figure 2. Main transformer defect data classification can be found through inspection

It can be seen from the above that the proportion of transformer fault caused by abnormal data display is the largest, and the proportion of transformer fault caused by abnormal oil level is the smallest.

6. Conclusion

Power plant simulation is a complex and practical simulation method. It is an inevitable trend to combine it with virtual reality technology. This paper analyzes the necessity of establishing TSS based on virtual reality technology. Aiming at the low efficiency of traditional substation virtual simulation (TSVs) development mode, a component-based and flexible substation virtual simulation development mode based on TSVs engine is proposed. At the same time, the frame structure of TSVs engine is designed and explained. A geometric programming model with fuzzy coefficients is established. The selection of power supply radius and number of substations is a complex problem, so it is necessary to establish a model with more information to determine the optimal scheme with minimum investment and loss. Using the fuzzy geometric programming model, the satisfactory results of the optimal selection radius are obtained. This paper introduces the damage types and causes of substation power facilities under destructive earthquake action at home and abroad, summarizes the damage situation of power system, and puts forward two anti-seismic measures. First of all, the strength of the traditional seismic design method is measured, and the stiffness of the building, the important electrical equipment and other facilities in the building are reinforced, which makes it play a great role in the earthquake.

7. Declarations

7.1. Author Contributions

Conceptualization: S. B. and J. Z.; Methodology: J. Z.; Software: S. B.; Validation: S. B. and J. Z.; Formal Analysis: S. B. and J. Z.; Investigation: S. B.; Resources: J. Z.; Data Curation: J. Z.; Writing Original Draft Preparation: S. B.

ISSN 2776-8007

and S. B.; Writing Review and Editing: J. Z. and S. B.; Visualization: S. B.; All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

7.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

7.4. Institutional Review Board Statement

Not applicable.

7.5. Informed Consent Statement

Not applicable.

7.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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