Hindawi
Security and Communication Networks
Volume 2023, Article ID 9834743, 1 page
https://doi.org/10.1155/2023/9834743

Retraction

Retracted: Aging Law and Life Evaluation Model of Cable Insulation Based on WOA-SVR

Security and Communication Networks

Received 20 June 2023; Accepted 20 June 2023; Published 21 June 2023

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] L. Li, X. Ma, and W. Guo, "Aging Law and Life Evaluation Model of Cable Insulation Based on WOA-SVR," *Security and Communication Networks*, vol. 2022, Article ID 7610380, 12 pages, 2022.

Hindawi
Security and Communication Networks
Volume 2022, Article ID 7610380, 12 pages
https://doi.org/10.1155/2022/7610380

Research Article

Aging Law and Life Evaluation Model of Cable Insulation Based on WOA-SVR

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Received 12 April 2022; Revised 18 May 2022; Accepted 25 May 2022; Published 7 June 2022

Academic Editor: Mohammad Ayoub Khan

Cables are mainly composed of wires and are used to transmit signals or electrical energy. It can be seen everywhere in real life. However, due to the changeable environment in which it is located, it often leads to the problem of insulation aging. Therefore, it is particularly important to study the law of cable insulation aging and to evaluate its life. Humpback whale hunting behavior is simulated by WOA, a swarming intelligence algorithm. It can intelligently identify the relationship between various data. SVR is a linear regression model with a special computational loss. The aim of this paper is to investigate a WOA-SVR model to evaluate the aging law and life of cable insulation. This paper analyzes a variety of detection models. Finally, the partial discharge detection model and the depolarization detection model are selected for comparative testing with the WOA-SVR model studied in this paper. The test method is to count the aging of cable insulation under different temperature, humidity, and electric field strength environments. The test results show that the evaluation accuracy of the WOA-SVR model in this paper is 92%, 97%, and 98%, respectively, under different temperatures, humidity, and electric field strengths. The average accuracy of its evaluation is higher than the other two models. Therefore, the WOA-SVR model is more accurate and reliable for the cable insulation aging law and life evaluation.

1. Introduction

Analysis and treatment of cable insulation aging is a technology for developing and implementing condition monitoring and equipment management for safety-related instrumentation and control cables in power plants. As the application of power system is more and more extensive, the distribution of cables is more and more extensive and complex. The aging issue of cable insulation systems is also becoming more and more important. One of the main problems with its insulation reliability is the occurrence of partial discharge (PD). During power generation, planned shutdowns, and design basis events, cables are an integral part of nuclear power plant operation and control. The polymer insulation and sheathing used in cable construction deteriorate over time. Mechanical degradation of the polymer can lead to cracking of the insulation and result in electrical short circuits.

The use of cables is diverse, and the actual life of cables working in different environments is also different. Blind replacement is bound to result in a waste of resources. Replacing cables is also a cumbersome and time-consuming project. Not only does it consume a lot of time, but also the economic loss caused by the missed work is unacceptable. Therefore, in practical work, it is necessary to effectively evaluate the working status of the cable and scientifically maintain and replace the cable.

The current method for judging the aging of cable insulation can only draw a general conclusion but cannot make a quantitative analysis of the remaining working life of the cable to obtain an accurate conclusion. In addition, most of the current detection methods are destructive methods, which not only take a long time to detect, but also cause secondary damage to the cable itself, reducing the subsequent service life of the cable. Therefore, it is still a difficult problem to test the insulation state and evaluate the life of the cable.

The WOA algorithm is based on the behavior of humpback whales. Since the position of the optimal design in the search space is not known a priori, the WOA algorithm assumes that the current best candidate solution is the target prey or close to the optimal solution. After the best search agent is defined, other search agents will therefore try to update their positions to the best search agent.

With the development and application of science and technology, the previous evaluation methods have problems such as insufficient accuracy. The innovation of this paper is that the partial discharge detection model, the depolarization current detection model, and the WOA-SVR model are compared and tested according to different temperatures, humidity, and electric field strengths. The test results can more intuitively see the advantages of the WOA-SVR model in this paper for cable insulation aging law and life evaluation.

2. Related Work

Regarding the problem of cable insulation aging, many scholars have carried out related research on it. Among them, He et al. studied the aging characteristics of space charges formed under alternating current stress. The mechanical properties and the degree of crosslinking are characterized as complementary methods. Unlike the degree of crosslinking, space charge accumulation under alternating current stress has an opposite trend. This means that space charge under alternating current stress is closely related to the defect concentration in the cable insulation. The study of He et al. helps to understand the space charge characteristics under alternating current conditions and to understand the alternating current aging principle of cable insulation [1]. Borisova et al. measured the absorption-controlled charge and discharge currents of cross-linked polyethylene (XPE) cable insulation before and after heat aging. Experimental dependencies were analyzed according to the equivalent Voigt protocol. The known parameters of the Voigt scheme are used to calculate the frequency dependence of the relative permittivity, loss factor, and loss tangent of the XPE film in the low-frequency region at high temperature. And the analysis results of XPE absorption characteristics are applied to the modeling of the thermal aging process of cable insulation [2]. Fifield et al. used the installed cable condition monitoring program to correlate nondestructively measured aging key indicators with corresponding EAB values. A snapshot of the cable health is placed on the cable life curve to obtain predicted values. It can safely retain cables well into their remaining useful life. Cable conditions that change further along its life curve may need to be scheduled to be evaluated more frequently or even scheduled to be replaced immediately before functional failure [3]. Gian et al. studied how partial discharges behave under multilevel inverter waveforms and their effect on insulation life. It shows that PD phenomenology is very different. Its effect on insulation life depends on the number of stages and voltage pulse rise time. This applies to Type I and Type II insulation [4].

Kiger et al. described the need for research and development work on the regulation and assessment of insulation aging. This makes these technologies applicable to other safety-related cables to support the sustainability of light water reactors. In particular, research should focus on adaptations of existing reflection methods to locate problems such as high resistance shunts, electrical trees, water trees, and voids in medium voltage cable insulation [5]. Gang et al. studied the characteristic parameters of the aging dielectric response phenomenon of cross-linked polyethylene (XLPE) cable insulation. Gang et al. conducted an experimental study on cable samples by accelerated aging of water trees. It conducted polarization and depolarization current (PDC) tests on samples with different aging degrees and analyzed the experimental data. The results show that the current curve is affected by the cable length and cannot directly reflect the actual state of the cable insulation. The peak time and dielectric loss factor at lower frequencies can be used to determine the age of the cable [6]. Zhu et al. performed quantum chemical calculations and isothermal relaxation current (IRC) measurements on thermally aged XLPE cables to study the effect of defects on the dielectric properties and trap energy distribution of XLPE insulation. IRC results show that both trap density and trap depth increase with aging [7]. Although the research of the above scholars can solve the related problems of insulation aging to a certain extent, or play a certain preventive role, most of these researches are based on theoretical research, the actual case application is relatively small, and the law of cable insulation aging and life expectancy assessments are not accurate enough. Therefore, it is of great significance to use the WOA-SVR method in this paper to evaluate the aging law and life of cable insulation.

3. Detection Method of Cable Insulation Aging

3.1. Cable Insulation Aging Problem. Cable insulation aging means that the insulation layer of the cable is damaged or the electrical conductivity of the cable conductor is insufficient. Cables can be divided into signal cables, control cables, power cables, etc. according to their uses. According to its photovoltaic power station system, it can be divided into alternating current cables and direct current cables. Figure 1 shows the general structure of the cable. The insulating layer also includes inner and outer sheath insulating layers and armored insulating layers. The insulation type and code of the cable are shown in Table 1. Table 2 is the insulation code of the inner and outer sheath of the cable. Table 3 shows the insulation code of the armored layer of the cable [8]. There are no strict boundaries between "wire" and "cable." Usually, products with a small number of cores, a small product diameter, and a simple structure are called wires, those without insulation are called bare wires, and the others are called cables.

Direct current cables are mostly laid outdoors. It needs to be moisture-proof, sun-proof, cold-resistant, heat-resistant, and UV-resistant. In some special environments, chemical substances such as acid and alkali are also required. Alternating current load cables are laid in indoor environments. It can be selected according to the general power cable selection requirements.

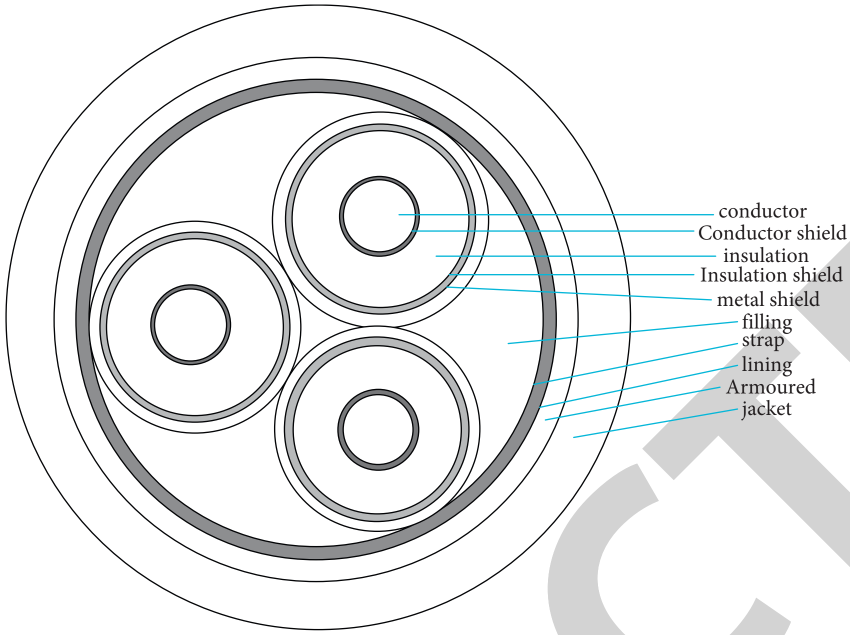

Figure 1: Cable insulation construction.

Table 1: Insulation type and code of cable.

Insulation type	Code
Ethylene propylene rubber insulation	CE
XLPE insulation	CJ
PVC insulation	CV
Silicone rubber insulation	CS
Natural butadiene styrene insulation	CX

Table 2: Insulation code of inner and outer sheath layer of cable.

Inner sheath	Code	Outer sheath	Code
PVC	V	PVC	2
Neoprene	F	Polyethylene	3
Chlorosulfonated polyethylene	H		

Table 3: Cable armor insulation code.

Armored	Code
Double steel belt	2
Fine wire	3
Braided copper wire	8
Wire braid	9

The model composition and order of cables are expressed as follows: [1: Category, use] [2: Conductor] [3: Insulation] [4: Inner sheath] [5: Structural characteristics] [6: Outer sheath or derivative] [7: Use Features].

The insulation of the cable is the insulation system composed of the cable insulation material. It is the basic condition for the normal work and operation of the cable. The service life of the cable is determined by the life of the insulating material (i.e., oil paper or resin, etc.). Practice has proved that most of the damage and failure of cables are caused by damage to the insulation system. Figure 2 shows the phenomenon of cable insulation aging. The problems caused by the aging of cable insulation have seriously affected people's daily life or office [9, 10].

The reasons for the aging of cable insulation mainly include environmental factors, chemical corrosion, and overload aging, as shown in Figure 3. Environmental factors include humid environment, high temperature environment, high pressure environment, and so on. Chemical corrosion also includes electrochemical corrosion, high temperature gas corrosion, etc. Chemical corrosion is because the cable is directly buried in an area with acid and alkali effects, which often causes the armor, lead, or outer sheath of the cable to be corroded. The protective layer has been subjected to chemical corrosion or electrolytic corrosion for a long time, resulting in the failure of the protective layer, the reduction of insulation, and the failure of the cable. Overload aging is overload operation. Due to the heating effect of the current, the conductors will inevitably heat up when the load current passes through the cable. At the same time, the skin effect of the charge, the eddy current loss of the steel armor, and the loss of the insulating medium will also generate additional heat, which will increase the temperature of the cable. During the aging process of electrical insulation, its degree of polymerization and tensile strength will gradually decrease, and water, CO, and COZ will be generated, followed by furfural (furan formaldehyde). This aging product is mostly harmful to electrical equipment. They will reduce the breakdown voltage and volume resistivity of the cable insulation, increase the dielectric loss, reduce the tensile strength, and even corrode the metal

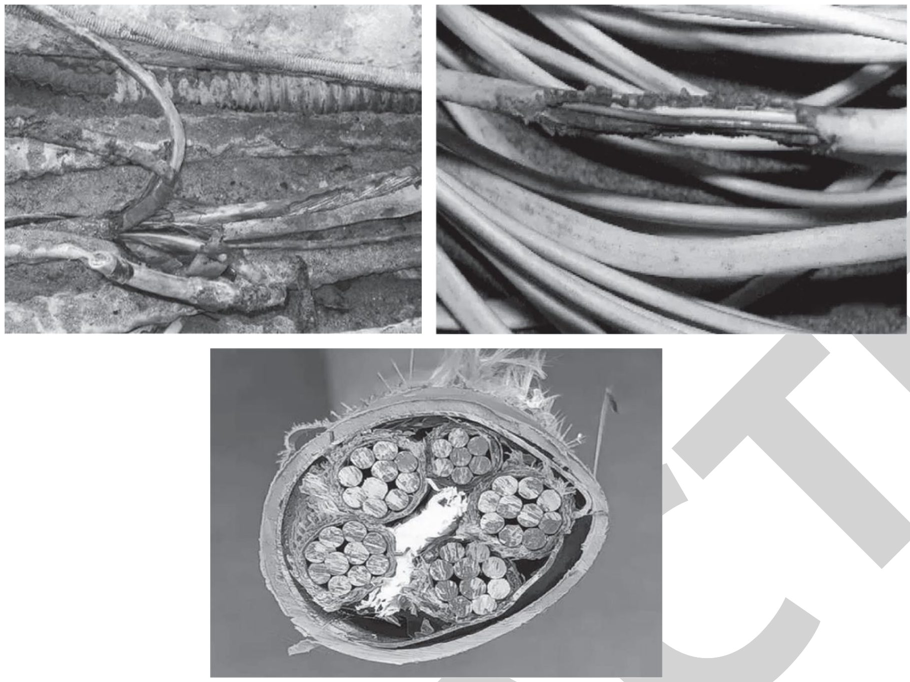

Figure 2: The phenomenon of cable insulation aging.

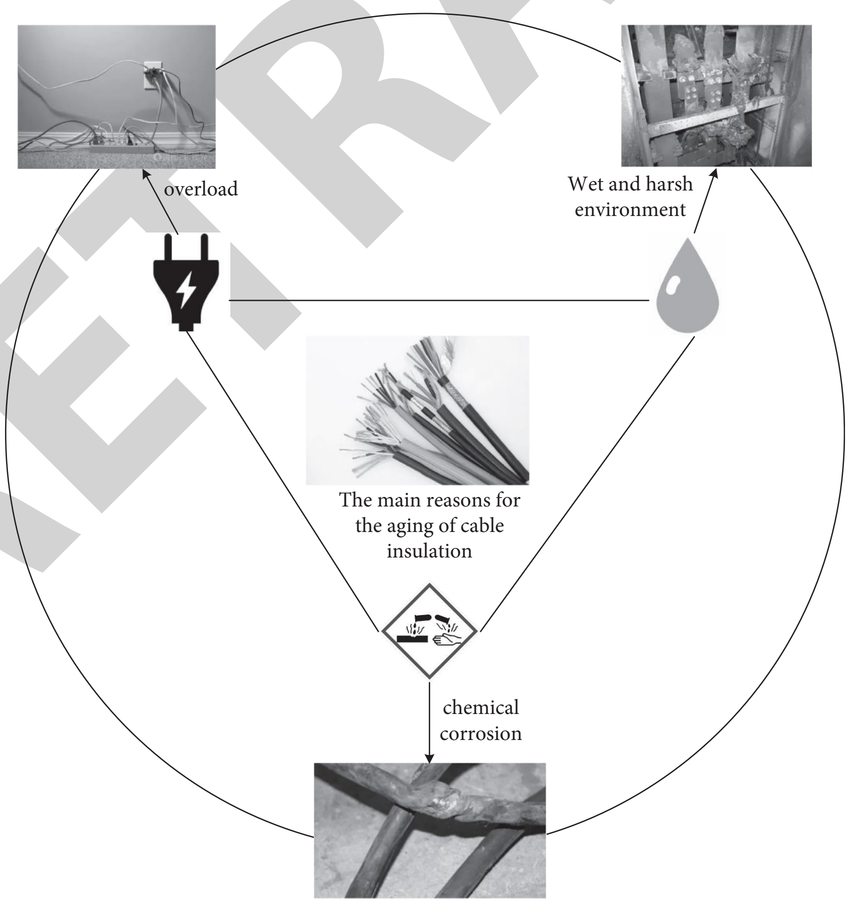

Figure 3: Main causes of cable insulation aging.

materials in the equipment. Therefore, the cable insulation material should not only have good electrical insulation properties and mechanical properties, but also have a slow decline in performance after years of operation, that is, good aging properties [11, 12].

Testing methods for cable insulation currently include dynamic mechanical analysis, ultrasonic sound velocity and attenuation characteristics, elongation during fracture measurement, time-frequency reflection method, insulation resistance method, local amplification method, depolarization current method, and dielectric spectrum analysis and detection methods, etc. [13]. Figure 4 shows a flowchart of one of the depolarized cable insulation testing methods. Table 4 shows the comparison of these methods.

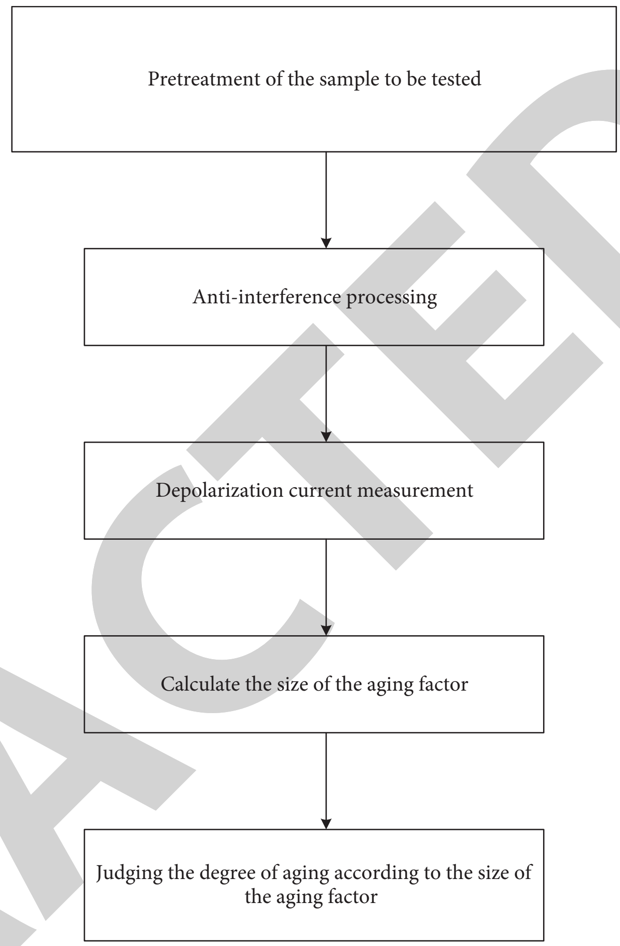

Figure 4: Depolarized cable insulation test flow.

3.2. WOA-SVR

3.2.1. Relevant Calculation of WOA. The WOA algorithm is an intelligent algorithm for simulating the feeding behavior of humpback whale bubble nets [14], as shown in Figure 5.

Related formula:

$$D = \left|CX^{*}(t) - X(t)\right|, \tag{1}$$

$$X(t+1) = X^{*}(t) - AD. \tag{2}$$

Among them: $X(t)$ is the actual position of the current whale, $X^{*}(t)$ is the best prey position, A and C are coefficients, and t is the current number of iterations.

And A and C are

$$\begin{aligned} A &= 2ar_1 - a, \\ C &= 2r_2, \\ a &= 2 - \frac{2t}{T_{\max}}. \end{aligned} \tag{3}$$

Among them, $T_{\max}$ is the maximum number of iterations, r_1 and r_2 are random numbers in (0, 1). A is a linearly decreasing number from 2 to 0.

The hunting behavior of humpback whales is

$$X(t+1) = X^{*}(t) + D_p e^{bl}\cos(2\pi l). \tag{4}$$

Among them:

$$D_p = \left|X^{*}(t) - X(t)\right|. \tag{5}$$

The location update method is

$$X(t+1) = \begin{cases} X^{*}(t) - AD, p < P_i, \\ X(t) = X^{*}(t) + D_p e^{bl}\cos(2\pi l). \end{cases} \tag{6}$$

The prey search method is

$$\begin{aligned} D &= \left|CX_{\text{rand}} - Xt\right|, \\ X(t+1) &= X_{\text{rand}} - AD. \end{aligned} \tag{7}$$

Among them, X_{rand} represents the randomly selected whale position.

3.2.2. SVR Model. The SVR model is a linear regression model with a special computational loss. SVR is proposed as a branch of SVM. SVM is to maximize the distance to the nearest sample point to the hyperplane. SVR is to minimize the "distance" of the sample points farthest from the hyperplane. The principle is shown in Figure 6.

The linear function model is

$$f(x) = \omega x + b. \tag{8}$$

It introduces slack variables ξ_i and ξ_i^{*}. The constraints of the slack variables in the linear programming model under study are all less than types. Then multiple nonnegative slack variables can be introduced through the normalization process. Slack variables are often introduced to facilitate solving in a larger feasible region. And

$$\begin{aligned} &\begin{cases} \xi_i = y_i - ((f(x_i) + \varepsilon), & \text{if } y_i > f(x_i) + \varepsilon, \\ \xi_i = 0, & \text{otherwise}, \end{cases} \\ &\begin{cases} \xi_i^{*} = (f(x_i) - \varepsilon) - y_i, & \text{if } y_i < f(x_i) - \varepsilon, \\ \xi_i^{*} = 0, & \text{otherwise}. \end{cases} \end{aligned} \tag{9}$$

The main problem is described as

Table 4: Comparison of diagnostic methods.

Testing method	Sensitivity	Scope of test	Spend
Dynamic mechanical analysis	High	Local	High
Ultrasonic sound velocity and attenuation	High	Local	Low
Elongation at break measurement	High	Local	Low
Time city-frequency city reflection method	High	Overall	High
Insulation resistance method	Low	Overall	Low

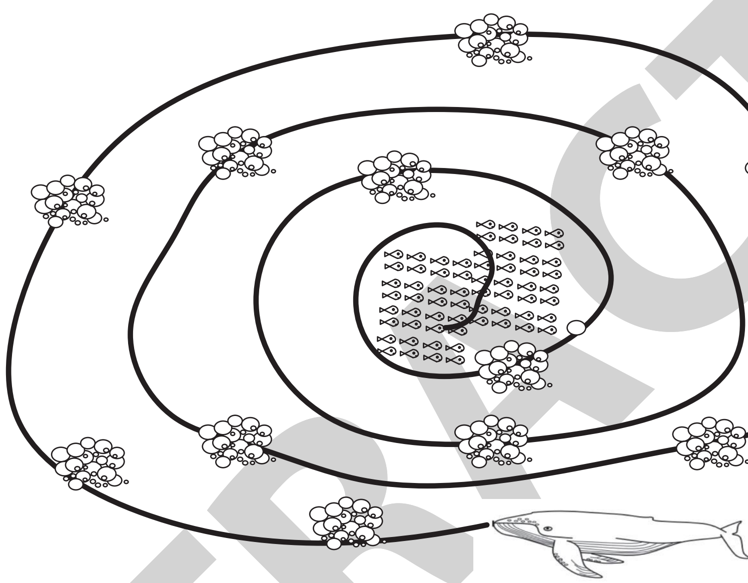

Figure 5: Schematic diagram of the feeding behavior of humpback whales.

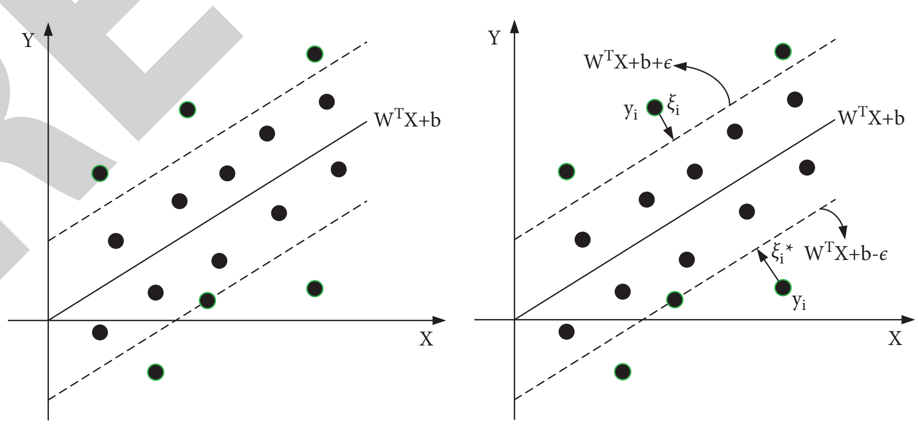

Figure 6: SVR principle.

$$\min_{\omega,b,\xi_i,\xi_i^*}\frac{1}{2}\|\omega\|^2 + C\sum_{i=1}^{m}(\xi_i+\xi_i^*),$$
$$f(x_i) - y_i \le \varepsilon + \xi_i, \tag{10}$$
$$y_i - f(x_i) \le \varepsilon + \xi_i^*.$$

For the kernel technique of the SVR model, that is, to expand the previous one-dimensional space to multiple dimensions, then the computational model can be obtained:

$$f(x) = \omega\phi(x) + b. \tag{11}$$

And

$$\omega = \sum_{i=1}^{m}(\alpha_i^* - \alpha_i)\phi(x_i). \tag{12}$$

Among them: α_i and α_i^* are Lagrangian coefficients.

From the relevant content of the support vector model, it can make

$$k(x_i, x_j) = \phi(x_i)^T\phi(x_j). \tag{13}$$

So the regression model is

$$f(x) = \sum_{i=1}^{m}(\alpha_i^* - \alpha_i)k(x, x_i) + b. \tag{14}$$

3.3. Life Evaluation Model. After decades of development, the research theories and methods of cable aging have formed a variety of regular models. Understanding these regular models helps to better understand the specific process and aging mechanism of aging. This is of great significance for the prevention of cable failures and the life assessment of cables [15, 16].

At present, insulation aging assessment models can be divided into material models and abstract models. The materialistic model is to study the specific aging mechanism inside the insulating material. It describes a series of physical and chemical changes that occur during aging through a series of tests. It combines the material molecular microscopic theory and thermodynamic motion theory to analyze the experimental data and establish its corresponding mathematical model. The materialistic model studies the specific physical and chemical characteristics of the aging process of insulating materials. This helps to better understand the principle response of the aging process of materials, which has important academic and practical significance. However, in practical applications, because the aging of cables includes not only internal physical and chemical reactions, but also the influence of aging factors in the external working environment, the evaluation results of the material model have certain limitations. Abstract model refers to the physical laws obtained by summarizing experimental facts when explaining physical phenomena in physics, without using their internal causes. This paper will use the abstract model to study the aging state of the cable. It analyzes the aging law of insulating materials by conducting thermal aging tests on cables and then obtains the conclusion of its working life [17, 18].

The commonly used aging phenomenological evaluation models are as follows.

3.3.1. Aging Evaluation Model Based on Temperature. There are many factors that lead to the aging of cable insulation materials, of which temperature is considered to be the most important reason. Cables generate a lot of heat during operation. The high temperature causes the external appearance of the insulating material to become harder. The skin is cracked and the cracks continue to deepen, and the air gap cavity gradually becomes larger and larger, resulting in a decrease in insulation. The rate of aging of cable insulation depends on the rate of internal chemical and physical reactions. The faster the reaction rate, the shorter the working life of the cable insulation.

3.3.2. Aging Evaluation Model Based on Mechanical Properties. Cables are inevitably affected by mechanical external forces during installation and operation. This will cause slight damage to the cable insulation and affect the insulation performance of the cable. The change process of cable insulation performance can be reflected by some mechanical performance indicators. At present, the most widely used mechanical performance indicators are elongation at break, hardness, tensile strength, etc. In the test, the aging process and the law of insulating materials are revealed by measuring the changes of these parameters. The index of medium elongation at break is designated by the national standard GB/11026.2-2003 as a characteristic index of the insulation state of the cable. When its value drops to half of the initial value, the life of the insulating material is considered to be over. It can not only be used to evaluate the aging degree of the cable in the experiment, but also be used as a standard for the verification of other evaluation methods.

3.3.3. Aging Evaluation Model Based on Electric Field. The faults of cables in operation are mostly caused by electrical stress, especially in the high-voltage field. Corresponding chemical and physical reactions will also occur in insulating materials under the long-term action of the electric field, resulting in the most common electrical tree in cable faults. If the cable is in a wet working environment, the electrical branches will also develop water branches. Unbalanced electric fields are easily generated in the impurities and fine pores of the cable. With the accumulation of time and the continuous impact of electric charges, the defects in these parts continue to deteriorate and eventually lead to partial discharge and even dielectric breakdown [19, 20].

3.3.4. Weibull Distribution Probability Model. Weibull distribution is used to describe the time and probability required for an object to fail or reach a certain state. That is, after the weakest link of the object is destroyed, the whole object fails. The breakdown of insulating materials is a weak link, so the Weibull distribution is suitable for the life study of insulating breakdown. The Weibull distribution analyzes the failure probability of the failure time of the cable from a statistical point of view, synthesizing the influence of the actual aging factors of the cable, and has a high reliability. The Weibull distribution can be extended from a two-parameter model to a three-parameter model. This will take into account the effects of multiple aging factors as much as possible in the setting of test conditions to simulate cable aging. It is of great significance to explore the aging process and mechanism that best suits the working environment of the cable field.

3.3.5. Other Aging Models. In the actual working environment, any type of cable is aging under the combined influence of many complex factors [21, 22]. For example, cross-linked polyethylene cables commonly used in power systems are also affected by factors such as high temperature and high pressure, humid environment, and solar radiation. Marine cables work in complex environments such as high-salt, high-humidity oil pollution for a long time. The above models are basically based on a single aging factor. When a variety of aging factors act together, the aging rate of the cable will be significantly accelerated, and the working life will be significantly shortened. Its aging mechanism is not a simple superposition of a single influencing factor. A variety of aging factors may interact with each other to induce new aging mechanisms. At present, some scholars have studied the joint aging mechanism under the influence of multiple factors, but no systematic conclusion has been formed, and there are corresponding limitations in practical application [23].

4. Life Evaluation Model Test of Cable Insulation Aging

4.1. Test Model. There are many life detection models for cable insulation aging, one of which includes the detection model of partial discharge method. Compared with the general live detection method, the partial discharge method has certain advantages. The reason is that there is a close correlation between the amount of partial discharge and the insulation performance of the cable. It can be used as one of the main basis to reflect the insulation level of the cable. Partial discharge detection is based on electric pulses, electromagnetic radiation, ultrasonic waves, light, and decomposition products formed by partial discharge and analyzes the state and characteristics of partial discharge by using the physical quantities that can describe the discharge. In recent years, the ultrasonic method and the ultrahigh frequency method among the online partial discharge detection methods have been widely used due to their insensitivity to on-site interference, no need for power failure, no need for pressurized equipment, and simple and easy operation. The ultrasonic method does not require invasive materials and is suitable for on-site testing. It has strong resistance to electromagnetic noise interference and can realize spatial positioning and defect type identification. The ultrahigh frequency method has outstanding performance in anti-interference and sensitivity, which is convenient to achieve the goal of partial discharge detection and determination of defect types. The model adopts the combined diagnosis method of ultrasonic method and ultrahigh frequency method to perform partial discharge detection and defect type identification for typical cable insulation defects. This guarantees the validity and simplicity of the measurement. The function of the ultrasonic sensor is to collect the discharge ultrasonic signal released by the power supply, which provides a basis for the analysis of the discharge characteristics and the judgment of the defect mode. The function of the ultrahigh frequency sensor is to collect the discharge time benchmark and provide the basis for defect detection. Its joint detection system is shown in Figure 7.

The second is a detection model based on conductance activation energy. Conductivity activation energy, as a dynamic property that reflects the intrinsic properties of materials, can detect latent faults in insulation. It is also related to the trap depth and electric field uniformity inside the material. For insulating materials, this method uses the aging time equivalent factor of temperature acceleration factor to calculate the equivalent aging time of different aging temperatures. It intuitively obtains the aging state information of the insulating sample through the breakdown field strength and establishes the life evaluation model of the insulating material based on the conductance activation energy.

The third is the dielectric spectrum characteristic analysis detection model for low-voltage cables. At present, the measurement method of the dielectric spectrum is mainly based on the dielectric loss tangent value at the power frequency of 50 Hz. Since this frequency is particularly susceptible to the influence of power grid quality, even if low-frequency filtering and other technologies are adopted, errors in measurement results cannot be completely avoided. And the use of this model has limitations, so this paper does not use it.

Another method is to depolarize the current. Using the polarization depolarization current method to monitor the cable winding on-site is simple and easy. It only needs to be measured when the on-site cable is out of service and has no direct electrical connection with the entire power system, which is safe and reliable. The measurement circuit of the depolarization current is shown in Figure 8.

In this paper, the partial discharge detection model and the depolarization current detection model are selected to compare and test with the WOA-SVR model. The test method is to make statistics on its aging according to different temperature, humidity, and electric field strength.

4.2. Simulation Experiment. The equipment used in this experiment includes infrared spectrometer, differential scanning calorimeter, dielectric spectrum test device, and

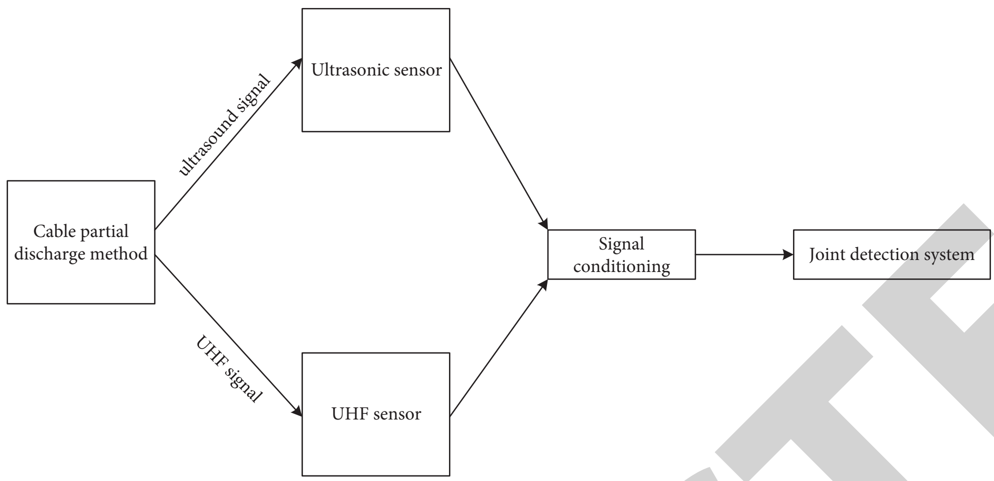

Figure 7: Combined detection system of partial discharge method.

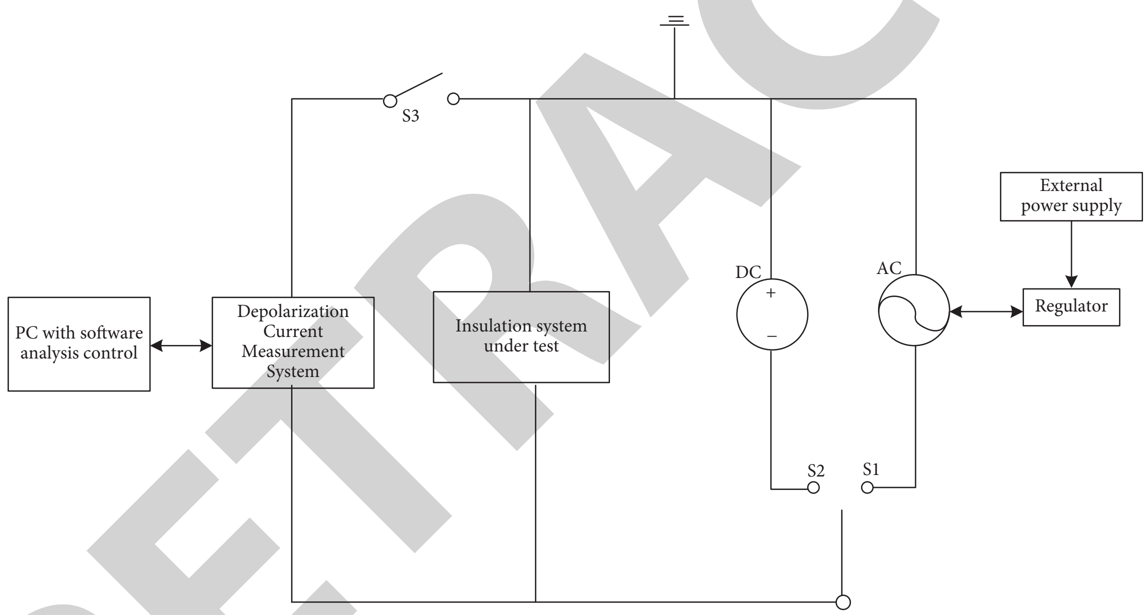

Figure 8: Measurement circuit for depolarization current.

space charge measurement system. Among them, the infrared spectrometer selected EQUINOX-55 Fourier transform infrared spectrometer. From the perspective of hardware structure, it includes a light source, a dryness meter, a sample compartment, a computer, and a recorder. The dielectric spectrum testing device is a broadband dielectric spectrum testing device. The analyzer is Alphy-A, and the frequency range is 10^2~10^7 Hz. The alternating current voltage is 10 uV~V rms, and the impedance is $10^{-2}\Omega$~$10^{14}\Omega$. The direct current bias voltage is −40 V~+40 V, and the current is 70 mA. The capacitance range is 10^{-15}F~1F, and the loss resolution can reach 10^{-5}. The principle of the electroacoustic pulse (PEA) method is that after the sample is subjected to an electric pulse, the two electrodes and the space charges inside the sample release acoustic waves. Piezoelectric sensors can pick up this signal. Using deconvolution and correlation correction techniques, the quantitative characterization of the charge information inside the sample can be completed.

The selected partial discharge detection model, depolarization current detection model, and WOA-SVR model are used for testing. Firstly, the statistical chart of the aging condition of the XLPE cable after a certain period of time at different temperatures without moisture is obtained, as shown in Figure 9.

As can be seen in Figure (a), at the temperature of 90°C to 120°C, with the increase of temperature, the aging rate of the cable obviously increases. And the aging rate evaluation values of the WOA-SVR model in this paper are 50.52%, 56.49%, and 61.59%, respectively, which are in

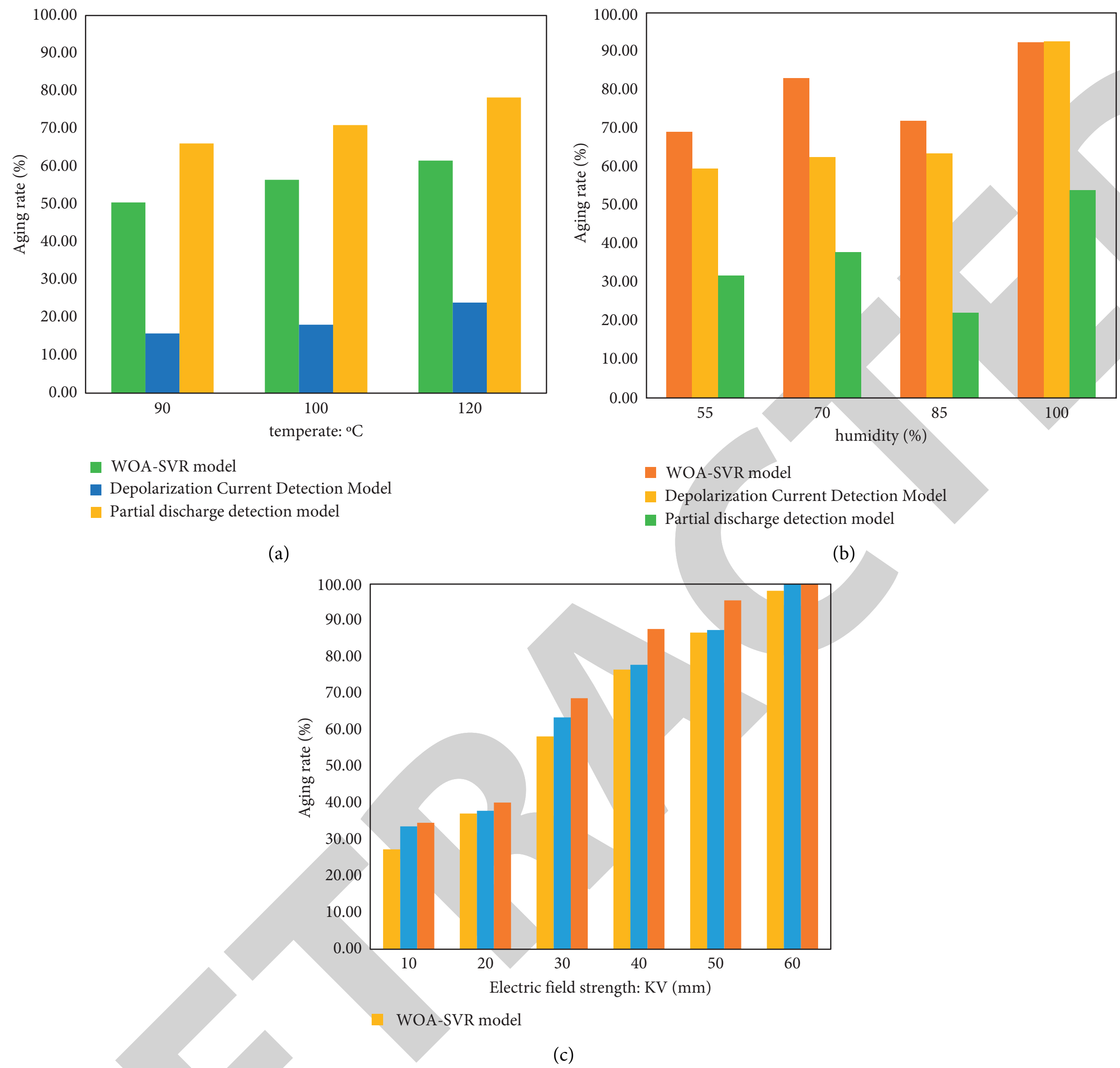

Figure 9: Comparison of aging conditions in different environments. (a) Aging rate after 480 hours at different temperatures. (b) Aging rate after 120 hours under different humidity. (c) Aging rate after 48 hours under different electric field strengths.

the middle of the evaluation values of the other two models. As can be seen from Figure (b), in the case of 55% to 100% relative humidity, with the increase of humidity, the aging rate of the cable also has an obvious upward trend. And the evaluation value of the aging rate of the WOA-SVR model in this paper is, respectively, 70% to 90%, which is larger than the evaluation value of the other two models. As can be seen from Figure (c), in the case of 10 KV/mm to 60 KV/mm, with the increase of the electric field strength, the aging rate of the cable is also obviously increasing. And the evaluation value of aging rate of WOA-SVR model in this paper increases from 27.36% to 98.17%, which is slightly smaller than the evaluation value of the other two models.

Finally, this paper compares the calculated value of the actual aging rate with the evaluation value obtained by the partial discharge detection model, the depolarization current detection model, and the WOA-SVR model. The evaluation accuracy of the three models is obtained for comparison, as shown in Figure 10.

It can be seen from Figure 10 that the evaluation accuracy of the WOA-SVR model in this paper is 92%, 97%, and 98% under different temperatures, different humidity, and different electric field strengths, respectively. The average accuracy of its evaluation is higher than the other two models. The average accuracy of the partial discharge detection model is 82%, 83%, and 76%, which are relatively low. Therefore, it can be concluded that the WOA-SVR model in this paper has a significantly higher accuracy in assessing insulation aging. It is more accurate and reliable for the aging law and life evaluation of cable insulation.

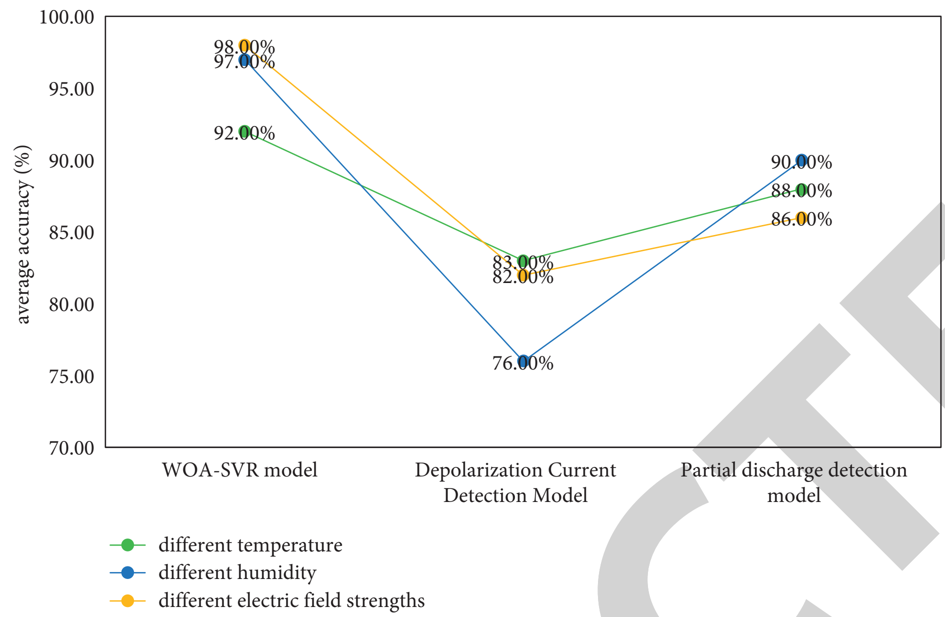

Figure 10: Comparison of the evaluation average accuracy of the three models.

5. Conclusions

This paper firstly gives an overview of the overall content of the full text in the abstract and secondly introduces the importance of cables in the introduction. It introduces the concept of WOA-SVR and summarizes the innovations of this paper. The related work part exemplifies some related researches, so as to understand the current situation of the related content studied in this paper. Then in the theoretical research part, it first introduces the relevant content of cable insulation aging, including its concept, aging phenomenon, causes, and diagnosis methods, and then introduces the specific algorithm of WOA-SVR. Finally, the relevant calculation methods and life evaluation model are explained in the experimental part, and the model is compared with the other two models. The results show that the WOA-SVR model has a significantly higher accuracy in assessing insulation aging. It has a better effect on the aging law and life evaluation of cable insulation.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Disclosure

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

Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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