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Retraction

Retracted: Online Fault Detection of Dry Reactor Based on Improved Kalman Filter

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret 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 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. Zheng, X. Liu, Q. Kang, Y. Yang, H. Xun, and J. Zhang, "Online Fault Detection of Dry Reactor Based on Improved Kalman Filter," *Journal of Sensors*, vol. 2022, Article ID 3947025, 6 pages, 2022.

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Research Article

Online Fault Detection of Dry Reactor Based on Improved Kalman Filter

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In order to meet the requirements of online fault detection for dry reactor, an online fault detection technology based on improved Kalman filter is proposed. The main content of the technology is based on the dry reactor detection technology, through the study of improved Kalman filter, the use of fault diagnosis and other methods, and finally through the experiments and analysis to build improved Kalman filter dry reactor online fault detection research means. The experimental results show that the maximum relative error of the improved Kalman filter is 6.039%, and the average relative error is 2.388%. The improved algorithm is very effective and greatly improves the prediction accuracy. The research based on improved Kalman filter can meet the demand of online fault detection of reactor.

1. Introduction

Dry reactor (hereinafter referred to as dry reactor) is widely used in substations and plays a pivotal role in improving the reliability of power system by playing the role of current limiting and reactive power compensation in the power grid [1]. At present, there is no effective means to detect the operation status of reactors in the network, and the faults cannot be found in time, and the precontrol measures cannot be taken. In order to improve the intrinsic security of equipment, it is particularly urgent for the network to accurately grasp the operating status of equipment, accurately identify anomalies in early stage, accurately locate faults, and predict and warn fault risks.

The main cause of dry resistance operation failure is coil damp, partial discharge, partial overheating insulation loss, and other reasons resulting in insulation breakdown between turns of winding coil. According to incomplete statistics, interturn short circuit faults account for more than 70% of the total failures of reactors. When the interturn short circuit fault occurs in dry resistance, the local temperature at the short circuit position rises sharply, accelerating the insulation aging near the short circuit turn, resulting in the continuous development of the short circuit fault, expanding the multiturn short circuit fault and causing the reactor fire in a short time [2]. If the reactor is removed from the power grid after a fault occurs, the equipment will not only be severely burned and cannot be used for maintenance, but also bring safety risks to other electrical equipment around the station, which may further expand the accident and cause greater economic losses.

In recent years, accidents such as interturn short circuit and fire and burning occur frequently in the operation of the power grid. Special detection work is carried out to prevent accidents to a certain extent (Figure 1). However, regular offline maintenance is mainly adopted, which has many disadvantages: (1) regular outage maintenance is required, which inevitably leads to power interruption and economic losses; (2) the actual state of power equipment is not fully considered, if the excessive maintenance will cause waste of manpower and material resources, but insufficient maintenance may directly lead to the occurrence of failure; (3)

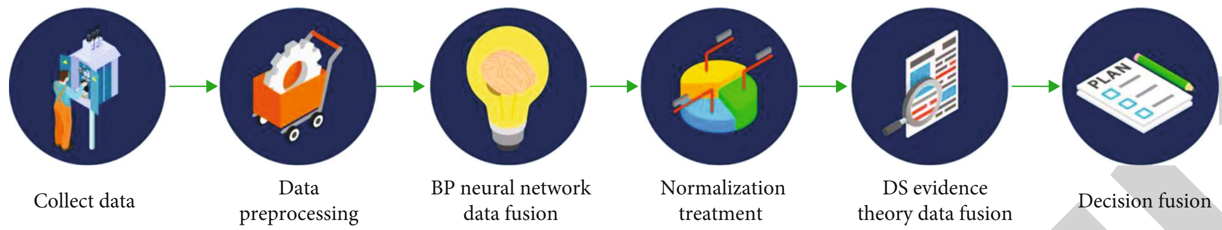

Figure 1: Online fault detection.

during operation, the operation state of dry reactor cannot be monitored and warned, and maintenance cannot be arranged reasonably in the early stage of failure, which may lead to the expansion of the fault range; (4) the actual test conditions cannot be completely consistent with the operating conditions of the equipment, so the reliability of the test results cannot be guaranteed. Compared with offline regular maintenance, the use of live line detection technology can not only timely warn the initial failure of equipment, but also master the development trend of dry resistance operation state. However, the limitations of existing live line detection technology are too great to be promoted and applied in the field [3].

2. Literature Review

In current social development, dry reactor is difficult to be popularized and applied mainly for the following reasons: (1) When dry resistance is charged with electricity, it is necessary to have enough safe distance, so that the detection accuracy will be reduced. At the same time, the infrared temperature measurement, whether artificial or conventional robot, can only detect the outer envelope, not the inner envelope temperature measurement. Several resistant outer layers are equipped with metal protective layer, so the live detection cannot be carried out. (2) In high altitude, high cold, high temperature, high wind, and other harsh or steep terrain areas, it is difficult to rely on personnel to conduct equipment inspection for a long time in the room, and the monitoring results are prone to error. (3) Manual inspection has problems such as high labor intensity, low work efficiency, scattered detection quality, and high management cost. Human factors are easy to lead to missed and false inspection, which will lay hidden dangers for major power accidents [4]. This research is based on multistate intelligent sensing technology of dry reactor operation state. It comprehensively uses infrared, ultraviolet, electromagnetic field dynamic imaging, acoustic positioning, local radiation, and other means to monitor the dry resistance in multiple states; to find the optimal intelligent algorithm; to realize the identification of the early warning signs of dry resistance latent fault; to judge the fault location, fault severity, and development trend; then to accurately evaluate the operating state of the equipment; and to establish the operating state sensing system. This article provides accurate decision-making basis for dry reactance equipment operation and maintenance. This article guides the maintenance team to carry out maintenance quickly, reduces the labor intensity of maintenance staff, improves the efficiency of dry resistance maintenance, effectively extends the service life of dry resistance, ensures the reliability of power supply, improves the operation, maintenance and maintenance capacity of substation equipment, and promotes the development of nonpower failure detection technology and intelligent operation and inspection of power grid equipment.

In view of the above problems, in order to meet the requirements of online fault detection of dry reactor, a technology based on improved Kalman filter is proposed [5]. The main content of the technology is based on the dry reactor detection technology, through the study of improved Kalman filter, the use of fault diagnosis and other methods, and finally through the experiments and analysis to build improved Kalman filter dry reactor online fault detection research means. The prediction result of the improved Kalman filter algorithm is much smaller than that of the traditional Kalman filter algorithm, both the maximum relative error percentage and the average relative error percentage. The improved algorithm is very effective, and it greatly improves the prediction accuracy. In addition, the modified algorithm only calculates the correction factor at the end, so the improved algorithm also has a good convergence speed like the traditional algorithm.

3. Research Methods

3.1. Dry Reactor Detection Technology

3.1.1. Research on Encapsulation Temperature Detection Technology of Dry Air Core Reactor. In normal operation, the reactor will generate a certain amount of heat. However, with the increase of equipment operation time, the imbalance of load, and the increase of contact resistance and excessive current caused by the rust corrosion and poor contact of some contacts, the abnormal thermal state and overheating failure of the system, equipment, and line are caused [6]. These anomalies and fault spots emit more and more infrared energy than normal.

The principle of temperature measurement of infrared thermal imager is that the objective lens of infrared thermal imager receives the infrared radiation from the surface of power equipment, converging through the optical system, and the infrared energy received just falls on the focus of the system, that is, the focal plane of the infrared detector; after photoelectric conversion of the detector, the infrared energy of the power equipment is converted into electrical energy, and then a series of electrical signals are processed to obtain a thermal image of the power equipment measured on the viewfinder of the thermal imager. The temperature anomaly in the image is found by the visual thermal image, and its temperature value is measured. Infrared thermal imager makes use of this characteristic of the power system to measure the temperature distribution field and its changes on the surface of the power equipment, to achieve contact-free temperature measurement, to carry out imaging detection, and to find out the possible thermal abnormalities and potential fault points of the power equipment, so as to realize the fault diagnosis of the equipment and the line [7].

The overheating failure of the box body, cooler, oil circuit casing, inner ring, encapsulation, and other components of the reactor due to eddy current, non-eddy current, or magnetic leakage will be detected by infrared thermal imager, which will achieve very good results [8].

In the process of partial discharge, in addition to the transfer of charge and the loss of electric energy, there will also be luminescence. The light radiation generated is mainly generated by the process of the particle returning from the excitation state to the ground state or low energy level and the recombination process of positive, negative ions, or positive ions and electrons. In view of this characteristic, it is proposed to use the light intensity of light radiation to detect the state of UV local emission, and the light intensity generated in the process of partial discharge of typical models is studied fundamentally [9]. Ultraviolet detection method is to use photodetectors to convert optical signals into electrical signals and reflect the intensity of partial discharge through the analysis and processing of electrical signals. Because the optical signal can be completely isolated from the primary loop in the detection process, it has good anti-interference ability and is favored by researchers [10]. Optical detection method can be used to detect partial discharge outside insulation. Studies show that more than 26% of electrical faults are related to external defects of insulation materials. At the same time, as the photoelectric sensor manufacturing technology tends to mature, high sensitivity, small volume, it provides the possibility for online monitoring.

3.1.2. Multistate Fault Diagnosis Method for Dry Reactor. The fault diagnosis method needs to process different fault signals of dry reactor in order to obtain an evaluation criterion. Finally, the state of the dry reactor corresponding to the signal can be obtained by judging the characteristics of a certain field signal and the difference between it and the threshold value in the evaluation criterion [11]. There are many fault diagnosis methods, which method is suitable for the application of dry reactor and can obtain accurate criteria which will be the content of research. Evidential reasoning theory can be widely used in equipment state assessment and fault diagnosis because of its obvious advantages in redundant information processing. However, its disadvantages are also obvious; that is, it cannot be applied to events where there is conflicting evidence, as shown in Figure 2.

In view of the inherent shortcomings of D-S evidentiary reasoning theory, the D-S evidentiary reasoning theory is integrated with BP neural network to realize the comprehensive fault diagnosis of dry reactor. The diagnosis model is shown in Figure 3.

3.2. Research on Improved Kalman Filter

3.2.1. Kalman Filter Algorithm. Kalman filter algorithm can well solve the noise problem mentioned above. This algorithm describes the filter according to the state space model of the new random system composed of the state equation of the system and the observation equation [12]. Because noise and interference are inevitable in the real world, the existence of noise makes the actual value of a system have certain deviation. Thus, a system always consists of two parts; one part of the data is deterministic, and the other part of the data is noise due to interference. When these two parts are reflected in the system, the state of the system, whether past, present, or future, is not an exact value, but a statistical value. Then there is the problem of estimating the data in the future in a period of time according to the historical data of the past, which is called filtering.

3.2.2. Improve the Traditional Kalman Algorithm. Before building the model, the data will be screened to eliminate noise and interference. However, since loads will be affected by many external factors, such as temperature and date, the load changes will also be screened out, which will have a great impact on the results. After the initial prediction results are obtained, the proposed improved algorithm uses the previously screened data to perform mean calculation and divide with the mean of the screened data to obtain the correction factor [13]. Finally, the first predicted value is modified with the correction factor to obtain the final modified result and the mean value of screened data as

$$\mathrm{mve}_k = \frac{\sum_{i=1}^{l} e_i}{l}. \quad (1)$$

l is the number of screened data; e_i is the screened data; mve_k represents the mean value of screened error data at the kth moment. The mean of the correct data is shown as

$$\mathrm{mvr}_k = \frac{\sum_{i=1}^{n-l} d_i}{n-l}. \quad (2)$$

n represents the length of the total data; d_i indicates the data left after filtering. mvr_k represents the mean of the correct data at time k. Correction factor such as

$$h_k = \frac{\mathrm{mvr}_k}{\mathrm{mve}_k}. \quad (3)$$

In the formula, h_k represents the correction factor at moment k. The final result is expressed as

$$\vec{X}'_{ki} = h_i \vec{X}_{ki}. \quad (4)$$

3.2.3. Algorithm Analysis. The prediction results obtained by the Kalman filter load model are compared with the actual verified sample output, and the relative errors of the prediction data at each time are obtained, as shown in Figure 4 [14]. It can be seen that the prediction results of the traditional Kalman model have relatively high accuracy during 01:00~06:00, but the prediction accuracy is very poor

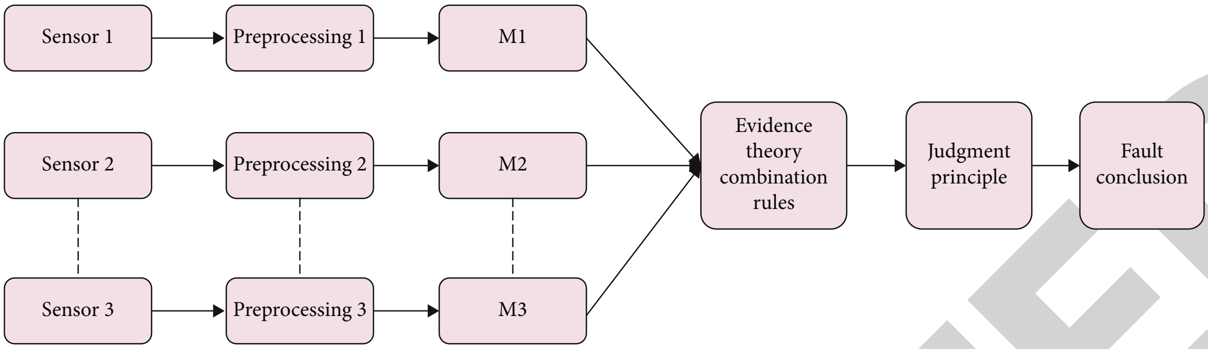

Figure 2: Fault diagnosis based on evidential reasoning.

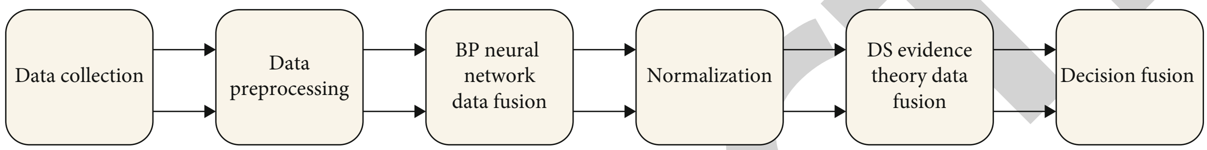

Figure 3: Diagnosis model of fusion of D-S evidential reasoning theory and BP neural network.

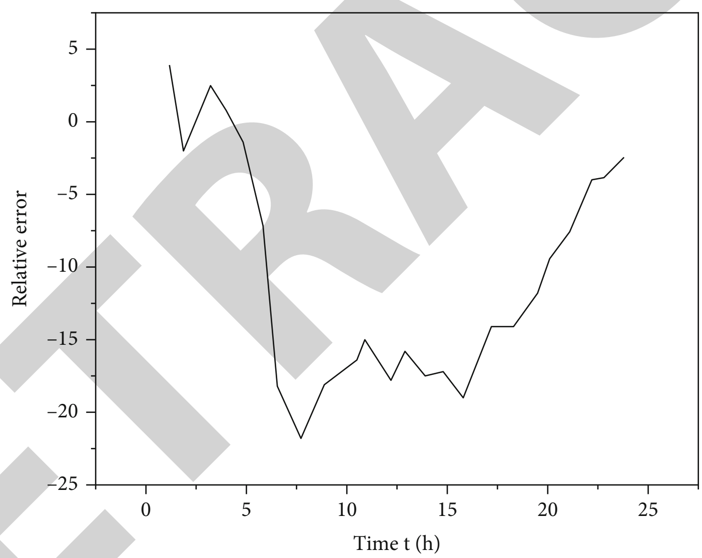

Figure 4: Prediction results of traditional Kalman algorithm.

during 07 : 00~17 : 00, and the maximum error can reach 21.5215%, which is unacceptable.

The screened data are used to work out the correction factor at each moment, and the correction factor is used to correct the previous results. The final prediction result is shown in Figure 5. It can be seen that the prediction result after adding the correction factor is greatly improved compared with the previous prediction result of the traditional model, and the prediction result at each moment is closer to the actual result [15].

Some popular algorithms are compared here, and the superiority of the algorithm is seen through comparison. A method of fuzzy neural network is proposed, which combines fuzzy logic with neural network to construct a prediction model. BP algorithm is used to adjust the threshold and connection weight of neural network, so that the network can achieve the approximation of any function [16]. In this article, THE RBF neural network is used, weather conditions, temperature, wind speed, meteorological conditions and other factors are considered, and the RBF neural network model is established to realize load prediction. The superiority and feasibility of RBF network are verified by an example.

The training samples and test samples were determined by improved wheel method using data samples. The BP neural network with 56 nodes is built, and the load prediction model of BP neural network is established to predict the load. Gaussian kernel function was used as the basis function, and penalty function was used to deal with constraints, and RBF neural network was constructed as the prediction model [17]. The input and output nodes of the network are used as input and output signals of the fuzzy system,

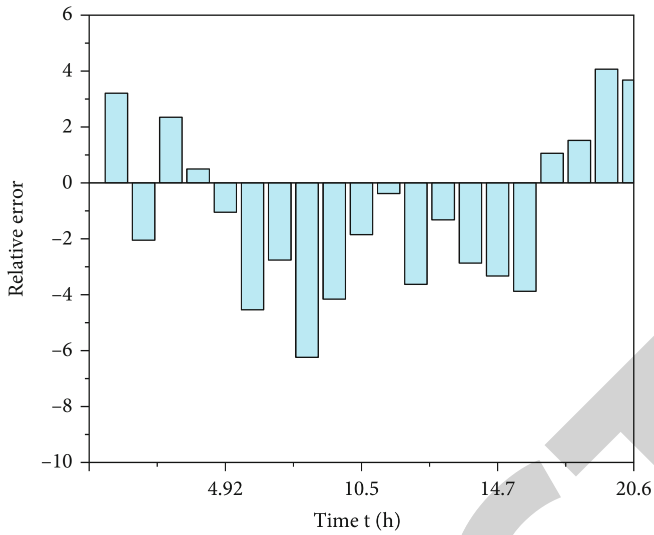

Figure 5: Prediction results of improved Kalman algorithm.

and the hidden nodes of the neural network are used to represent membership functions and fuzzy rules. The least square method is used to learn, and the fuzzy neural network is constructed to predict. The prediction results of various intelligent algorithms are compared with those of the algorithm proposed in this article.

Neural network algorithm needs to build neural network and needs to go through a lot of iterative process to get the optimal solution. There are also many improved algorithms for neural networks. They use other intelligent algorithms to improve the construction process of neural network model to find the optimal solution of network connection weight and threshold. However, it still cannot make up for the shortcoming of long time to build neural network. The methods of single-objective particle swarm optimization BP neural network (PSOBP) and multiobjective particle swarm optimization BP neural network (MPOS_BP) were proposed [18]. It uses the adopted data to establish the BP neural network model, the single-objective particle swarm optimization BP neural network model, and the multiobjective particle swarm optimization BP neural network model. The network hidden layer nodes of the three algorithms are all 56, and the training time of each network is analyzed.

The training time of the neural network algorithm will also increase with the increase of the number of nodes in the hidden layer, and the iteration will take a long time, and the problem of local optimization will also occur in the iterative solution process [19]. Because the improved algorithm does not need to spend a long time to solve the weights and thresholds of the neural network, the whole process of building the prediction model and solving the prediction results only takes 10s to 20s.

In conclusion, the proposed algorithm has certain advantages over today's intelligent algorithms in terms of prediction accuracy. In addition, it takes a long time to build the neural network, and the convergence may reach the local optimum. However, Kalman algorithm does not need to spend a lot of time to build the network, and there is no convergence problem [20].

Table 1: Maximum and average relative errors of the two methods.

	Traditional Kalman filtering algorithm	Improved Kalman filtering algorithm
Maximum relative error/%	21.521	6.039
Mean relative error/%	10.669	2.388

4. Result Analysis

As can be seen from Table 1, the prediction results of the improved Kalman filter algorithm are much smaller than those of the traditional Kalman filter algorithm, both in terms of maximum and average relative error percentage, which has greatly improved the prediction results. It can be seen that the maximum relative error of the improved Kalman filter algorithm is 6.039% and the average relative error is 2.388%. The improved algorithm is very effective and greatly improves the prediction accuracy. In addition, the modified algorithm only calculates the correction factor at the end, so the improved algorithm also has a good convergence speed like the traditional algorithm [21, 22].

5. Conclusion

In order to meet the requirements of online fault detection of dry reactor, a new technique based on improved Kalman filter is proposed. The main content of the technology is based on the dry reactor detection technology, through the study of improved Kalman filter, the use of fault diagnosis and other methods, and finally through the experiments and analysis to build improved Kalman filter dry reactor online fault detection research means. The prediction result of the improved Kalman filter algorithm is much smaller than that of the traditional Kalman filter algorithm, both the maximum relative error percentage and the average relative error percentage. The improved algorithm is very effective, and it greatly improves the prediction accuracy.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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