Hindawi
Advances in Multimedia
Volume 2023, Article ID 9763067, 1 page
https://doi.org/10.1155/2023/9763067

Retraction

Retracted: Application Design of AI Image Recognition in Power System

Advances in Multimedia

Received 15 August 2023; Accepted 15 August 2023; Published 16 August 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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1].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.

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[1] B. Jia, Z. Zhang, J. Jia, H. Shen, and L. Ding, "Application Design of AI Image Recognition in Power System," *Advances in Multimedia*, vol. 2021, Article ID 3998933, 8 pages, 2021.

Hindawi
Advances in Multimedia
Volume 2021, Article ID 3998933, 8 pages
https://doi.org/10.1155/2021/3998933

Research Article

Application Design of AI Image Recognition in Power System

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Received 9 August 2021; Accepted 12 October 2021; Published 8 December 2021

Academic Editor: Zhendong Mu

With the continuous development of social economy, more and more attention is paid to the safety of power systems. However, since the power system involves a wide range of areas, how to effectively maintain power safety is extremely important. The AI image recognition technology is introduced to effectively identify the relevant signal lamps, digital instrument panels, switch positions, etc., of power equipment and sort out the specific identification process. Simulation experiments prove that AI image recognition is effective and can support the application of power systems.

1. Introduction

The oscillation problems of traditional power systems mainly include negative damping oscillations caused by heavy load lines, modern fast excitation and high-ceiling factor excitation systems, as well as subsynchronous resonance/oscillation (SSR/SSO) caused by induction generator effects, torsional vibration of the shaft system, and transient torque amplification. [1, 2]. In the modern "double-high" power system, the interaction between a large number of renewable energy units with low inertia, weak stability, weak immunity, and randomness of output with existing power generation equipment, transmission networks, electrical loads, and their own has brought a variety of new types of oscillation problems [3]. This type of oscillation is dominated by the converter, the excitation mechanism is complex, and the frequency range is wide (10-1-103 Hz order of magnitude) [4]. Therefore, in modern power systems, traditional low-frequency oscillations, SSR/SSO, and new-type oscillations dominated by converters coexist, threatening the safe and stable operation of the power system [5].

The existing broadband oscillation analysis methods are mainly methods based on mathematical models, and commonly used methods include eigenvalue analysis method, impedance method, open loop resonance method, etc. These methods can better analyze the state space model and impedance model for specific problems under the premise of linearization and reveal the internal mechanism of oscillation [6, 7]. However, because the broadband oscillation of the power system is a complex system problem caused by multiple types of equipment and multiple time-scale control interactions, its precise parameters are difficult to obtain, and the electromagnetic transient equivalent model is difficult to construct, and it has significant randomness and strong nonlinearity. Therefore, the existing methods are difficult to comprehensively analyze the broadband oscillation problem in the actual system [8, 9]. In this context, artificial intelligence has excellent performance such as low dependence on system models, strong learning capabilities for nonlinear and complex relationships between large amounts of data, and rapid adaptability to random time-varying environments, providing new solutions for a broadband oscillation problem for power systems. Throughout the development history of artificial intelligence, it can be found that it has continuously enriched its own methods in the development process and has gradually formed a system suitable for solving broadband oscillation problems. For a long time, as an important part of data science, artificial intelligence can efficiently extract useful information from massive data through data analysis and excavation and reveal the inherent laws of complex systems, thereby avoiding the accurate modeling problem of actual high-dimensional power systems [10, 11].

The image recognition of equipment alarms is realized in combination with AI image recognition, by means of remote digital video monitoring and digital image recognition system in this paper, to determine the cause of accident alarms on the scene more accurately, to provide new means for accident detection, and to provide reliable analysis for accidents.

2. Discussion on the Application of Artificial Intelligence to Broadband Oscillation

2.1. Basic Principles and Application Characteristics of Artificial Intelligence. Artificial intelligence methods often used in broadband oscillation research mainly include intelligent optimization algorithms inspired by the laws of nature and biology, imitating its principle and structure design, machine learning that makes computers intelligent, and deep learning that simulates the deep thinking of the human brain [12].

As the core of artificial intelligence, machine learning can make computers have the ability to simulate humans to learn new things and continuously improve their own performance through accumulated experience [11, 13].

The supervised learning algorithm uses sample data sets with known labels to establish a good mapping relationship between input and output, with high computational efficiency and recognition accuracy; unsupervised learning algorithms do not need labeled data, thus saving time and labor costs; reinforcement learning has powerful online self-learning capabilities, as shown in Figure 1.

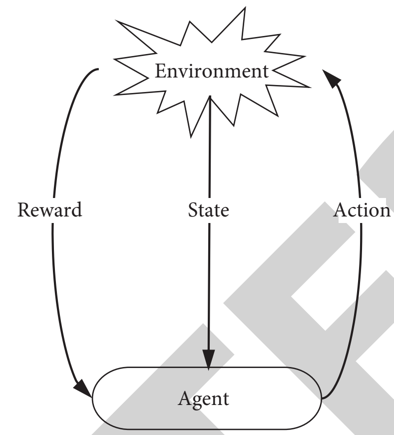


Figure 1: Reinforcement learning explanatory diagram.

Because the shallow structure of traditional machine learning has insufficient generalization ability for actual complex problems, deep learning with several hidden layer structures has become a research hotspot [14]. Deep learning has strong data dimensionality reduction and analysis capabilities and can use unsupervised learning to realize the automatic extraction of feature, which can effectively deal with large and complex nonlinear problems. Typical deep learning algorithms include convolutional neural networks (CNNs) and deep belief networks (DBNs). In recent years, deep reinforcement learning and deep transfer learning algorithms obtained by combining deep learning, reinforcement learning, and transfer learning have also become a research direction in the field of artificial intelligence.

2.2. Classification and Mechanism of Broadband Oscillation. The oscillations in the traditional power system mainly include low-frequency oscillations and SSR/SSO. However, in the modern "double-high" power system, due to the interaction between power electronic equipment and various components of the power grid, it has caused a new type of oscillation with wide-frequency time-varying characteristics and strong nonlinearities. Different from the oscillation mechanism of the traditional power system, the new type of oscillation is mainly an electromagnetic oscillation caused by power electronic control, and the frequency range is 10-1-103 Hz, so it is called "broadband oscillation" (Figure 2). According to the difference in the frequency interval, the traditional oscillation and the new broadband oscillation are divided into low-frequency oscillation (0.1–2.5 Hz), sub/supersynchronous oscillation (several Hz 2 times the power frequency), and medium- and high-frequency oscillation (100 Hz to over 1000 Hz).

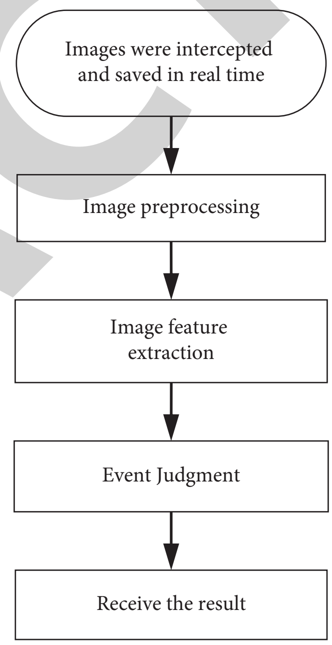


Figure 2: Power system image processing flowchart.

In addition, the multipower electronic converter will also be coupled and interact with its power grid in a higher frequency range, causing the problem of medium- and high-frequency oscillations from 100 Hz to over 1000 Hz. For example, the interaction of the voltage source converters-high voltage direct current (VSC-HVDC) system and the AC grid and negative damping characteristics when modular multilevel converters (MMC) are integrated into the weak grid in the middle- and high-frequency bands may cause the medium- and high-frequency oscillation of the system.

Considering that the parameter identification, positioning and suppression methods of SSR/SSO and the traditional low-frequency oscillation based on artificial intelligence can be transferred to a certain extent to the "electromechanical" oscillation with a frequency range similar to the low-frequency oscillation, and its thinking also plays an important reference significance for the sub/supersynchronous and the mid-to-high-frequency broadband oscillation, so these methods are also summarized for reference in this paper.

2.3. The Necessity and Rationality of the Application of Artificial Intelligence to Broadband Oscillation

(1) In terms of mathematical models, it is difficult to establish an electromagnetic transient mathematical model of an appropriate scale that takes into account the multiscale interaction of components, and it is difficult to obtain model parameters accurately. Broadband oscillation involves a wide range of components, and each component in the "double-high" system contains multiscale control strategies. Therefore, if electromagnetic transient modeling is performed, the order of the system model is extremely high. In addition, the control strategy and parameters of the equipment in the actual system are difficult to be obtained accurately due to the confidentiality of the manufacturer's technology and the uncertain operating status.

Artificial intelligence is a powerful tool for data analysis and mining. It can efficiently extract useful information from massive amounts of data, avoiding the accurate modeling problem of high-dimensional models of actual power systems. For example, feature engineering can realize the mining of useful information and the reduction of data dimensions through feature construction and extraction and selection of data. In addition, the end-to-end learning method can also automatically obtain features from the data and directly learn the mapping from the original data to the desired output.

(2) In terms of analysis methods, the existing methods are difficult to accurately and comprehensively analyze broadband oscillations. The existing oscillation analysis methods are mainly linear methods such as eigenvalue analysis method and impedance analysis method, and the broadband oscillation problem with strong nonlinear characteristics is difficult to be accurately analyzed; although the nonlinear analysis method is convenient to study the nonlinear-related information of broadband oscillation, it has a large amount of calculation, is limited by the scale of the system and the order of equations, and is prone to dimensionality problems. How to use it reasonably to realize accurate and comprehensive analysis of the broadband oscillation of the actual system remains to be further explored.

(3) In terms of manifestations, the oscillation modes are diverse and have time-varying and temporal-spatial distribution characteristics, which put forward higher requirements for the rapidness and adaptability of monitoring and suppression methods. Traditional oscillation monitoring and suppression methods are generally designed for oscillations in a specific frequency range or units in a specific range. It is difficult to track the system operating status in real time to deal with the wide-frequency oscillation problem of random time-varying systems and is also difficult to coordinate the multipower electronic equipment multifrequency oscillations for dealing with the time-space distribution characteristics of broadband oscillations in the wide-area system.

The artificial intelligence method can adjust the strategy online through real-time interaction with the environment, so it has a strong ability to quickly adapt to the random time-varying environment. For example, artificial neural networks can adaptively adjust the network structure or weights according to changes in the input information of the external environment; reinforcement learning can continuously improve its own behavior strategies to adapt to the changing external environment through interactive learning between the agent and the environment.

To sum up, the research of broadband oscillation is still facing many difficulties, and artificial intelligence methods have low dependence on system models and can learn complex nonlinear problems and adapt to random time-varying environments. Therefore, the artificial intelligence technology can be introduced into the research of broadband oscillations to complement the existing oscillation analysis methods and provide new and feasible research ideas for system broadband oscillations.

2.4. Application Status of Artificial Intelligence in Broadband Oscillation Identification. Broadband oscillation identification mainly includes parameter identification and oscillation detection. The existing method is used to perform signal analysis on the acquired data through time domain, frequency domain, or time-frequency domain methods; compare the obtained parameters with the set threshold; determine whether the system is oscillating; and provide information on the frequency and amplitude of the oscillation. However, for the parameter identification part, on the one hand, common signal analysis methods such as Prony's algorithm, fast Fourier transformation, and ESPRIT algorithm are all linear analysis methods, which are difficult to adapt to the feature extraction and analysis of multimodal coupling nonlinear oscillation signals. On the other hand, the limitations of the phasor algorithm, communication bandwidth, and sampling theorem of current phasor measurement unit (PMU) make the spectrum analysis method based on the phasor can only effectively identify low-frequency oscillations or achieve the parameter identification of sub/supersynchronous oscillations through algorithm improvements, and the wide-frequency oscillation frequency range involves 10-1-103 Hz, so the application of existing spectrum analysis and identification framework based on synchrophasors is limited in higher frequency oscillation identification. In addition, in the "double-high" system, the operating status is changeable and the broadband oscillation manifestations are diverse. In the oscillation detection part, the current alarm threshold needs to be set based on human experience and the adaptability under a variety of operating conditions is insufficient.

Different from the existing identification methods based on spectrum analysis, the parameter identification problem is modeled as a regression problem and the oscillation detection problem as a classification problem by the wideband oscillation identification method based on artificial intelligence. Artificial intelligence's powerful fitting ability for arbitrarily complex nonlinear functions, the mining ability for the relationships between massive data, and the ability to reduce dimensionality of data can be used to effectively improve the robustness and accuracy of oscillation parameter identification, as well as the rapidity and reliability of oscillation detection judgment, and is expected to solve the problem of monitoring and analyzing broadband oscillations at higher frequencies under lower data volumes. The general framework of the broadband oscillation identification method based on spectrum analysis and artificial intelligence is shown in Figure 3.

In the aspect of identification of oscillating parameter, methods often used after being modeled as a regression problem include adaptive linear neuron (Adaline), exponentially damped sinusoids neural network (EDSNN), and so on. Adaline is a commonly used neural network model in modal identification. Some literature proposes to combine Adaline with Prony's algorithm, Fourier algorithm, etc., to accurately identify all oscillation parameters.

In addition to the identification of oscillation parameters, artificial intelligence can also predict oscillation modes, which is a function that traditional methods have not been able to achieve.

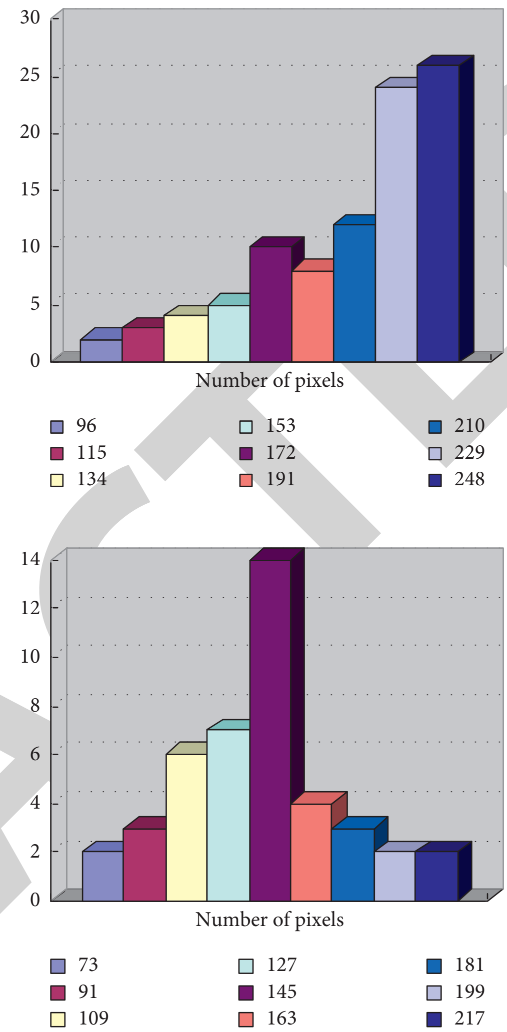


Figure 3: Red histogram with red light on and off.

2.5. Application Challenge of Artificial Intelligence in Broadband Oscillation Identification. Although the artificial intelligence methods can be used to improve the performance of oscillation identification in terms of rapidity and accuracy, and many studies have achieved satisfactory results, when artificial intelligence-based oscillation identification methods are used in actual power grids, the following quite challenging problems must still be faced:

(1) The wide-frequency oscillation has various manifestations, which pose the challenge to the wide adaptability of the artificial intelligence-based wide-frequency oscillation identification method. Most of the existing research focus on sub/supersynchronous oscillations in some specific scenarios and carry out model training. Due to the complexity of the "double-high" system, new types and manifestations of oscillations occur from time to time, and their dynamic characteristics are also different. Whether the monitoring method based on artificial intelligence still has high accuracy and precision for this kind of diversified oscillations needs to be further explored.

(2) Oscillation identification requires high accuracy, and artificial intelligence-based identification methods are extremely dependent on data. Therefore, widespread data quality problems have brought challenges to the accuracy of artificial intelligence-based identification methods. Due to the complex on-site environment of the actual power system, there will inevitably be uncertainties such as data loss, communication delay, and data errors in the process of data collection or communication. Therefore, how to design a suitable artificial intelligence algorithm structure to improve the accuracy of oscillation identification under data quality problems urgently needs in-depth research.

At present, there are many theoretical research results in the application of artificial intelligence in the field of oscillation suppression, but there are still many problems that need to be solved when it is used to suppress the broadband oscillation of the actual system:

(1) The extremely high requirements for safety and stability of the power system pose a great challenge to the artificial intelligence-based oscillation suppression method. Although suppression methods based on neural networks and reinforcement learning have been able to quell time-varying broadband oscillations well in simulation, control strategies obtained by neural network methods that learn from historical samples and deep reinforcement learning methods that learn from interactions with the environment are difficult to prove the stability of the system through theory. Therefore, the reliability of the control strategy is still difficult to guarantee, which is a major challenge for applying it to the actual power system that requires extremely high stability.

(2) Global multidevice coordination brings challenges to the convergence of artificial intelligence-based oscillation suppression algorithms. The wide-frequency oscillation of the power system has a wide propagation range, covering multiple areas, multiple machines, and multiple electrical equipment units, which is a global complexity problem. With the further development of the "double-high" power system, the coordinated control of source-grid-load-diversified electrical equipment is of great significance. However, when the artificial intelligence method is used to design a wide-area multidevice cooperative controller to suppress the wideband oscillation problem, due to the multielectric device of the entire network, the size of the state space increases exponentially with the increase of the number of features, which makes the artificial intelligence-based oscillation suppression method probably face the problem of dimensionality disaster, and the convergence of the algorithm will also face greater challenges.

2.6. The Process of Image Recognition Technology Based on Artificial Intelligence. In image recognition technology based on artificial intelligence, the most important way to obtain information is image preprocessing, which directly affects the recognition results, so it is a key link in the entire process. Image preprocessing can be used to assist the image recognition system, making feature of the images more accurately, which can lay some foundation for subsequent work, effectively shorten the recognition time, and reduce the complexity. In the process of preprocessing, the most important task is to improve the identification efficiency in an all-round way. The most commonly used methods are noise reduction and defogging.

The preprocessing work can be used to achieve picture restoration and restore the picture clearly and vividly. The application in the power system is to apply intelligent image recognition technology during the inspection of overhead transmission lines, which can process the collected pictures with one key and achieve the optimal solution of the picture data.

For image feature extraction, it is mainly divided into two steps: extraction and selection. In the target image, there may be many feature points, and these feature points correspond to their respective feature subsets. The selection of feature points requires science, which is the key to fully ensuring that the image can be recognized efficiently and accurately. The most common feature points of current images include the following parts: color features, image texture, image shape, spatial relationship features, etc. Among these features, color captures the feature points first, but in local feature capture, image texture features are the first feature points. It can be seen that image recognition technology based on artificial intelligence can achieve targeted feature extraction and selection in terms of application direction and recognition requirements. Generally speaking, pictures will contain a lot of information, so when applying technical means, the features of pictures should be effectively distinguished. For example, in the power system, the texture characteristics of the wires should be extracted during the inspection and repair of overhead power transmission lines, so that the problems of the lines can be discovered in time.

Therefore, first define an energy function for it, and use the energy function to introduce a series of probability distribution functions.

For a given set of states (v, h), the energy function can be defined as follows:

$$E_\theta(v,h) = -\sum_{j=1}^{n_v} a_j v_j - \sum_{i=1}^{n_h} b_i h_i - \sum_{i=1}^{n_v}\sum_{j=1}^{n_h} h_i w_{ij} v_j, \qquad (1)$$

where v_j is the binary state of the visible layer, h_i is the binary state of the hidden layer, and w_{ij} is the weight between the two. a_j is the bias vector of the visible layer, and b_i is the bias vector of the hidden layer. The adjustment parameter in RBM is $\theta = (w, a, b)$. After a given training sample, training an RBM means adjusting the parameter θ to fit the given training sample.

The joint probability distribution of state (v, h) is shown as follows:

$$P_\theta(v,h) = \frac{1}{Z_\theta} e^{-E_\theta(v,h)}. \qquad (2)$$

The normalization factor is shown as follows:

$$Z_\theta = \sum_{v,h} e^{-E_\theta(v,h)}. \qquad (3)$$

It can be seen that the probability $P(v,h)$ of a set of values (a state) of a visible node and a set of values of a hidden node (a state) is defined by the energy function.

For the image recognition technology based on artificial intelligence, image matching classification is the last link. Through strict implementation of each process, the information in the same picture is retrieved from the database according to the process results, so that the analysis of the characteristics can be completed. As for the power system, when the artificial intelligence-based image recognition technology is used for inspection and maintenance of overhead transmission lines, the image matching classification should be carried out according to the specific conditions of the pictures, and the corresponding information should be retrieved from the database to realize the corresponding processing.

2.7. Application Analysis of the Online Monitoring System for Collecting Data Information. During the specific operation of the power system, there will be many accidents that will cause great harm to the safety of the power system, such as theft and fire. Therefore, it is necessary to do a good job in information collection in a timely manner in order to effectively avoid the adverse effects caused by unexpected situations. The information that can be conveniently provided to abnormal alarm data through online monitoring of the power system can enable technicians to understand the specific abnormal situation in a timely manner and deal with the abnormal situation in a timely manner. The monitoring system can realize real-time monitoring of people entering and exiting and can use image recognition technology to make accurate identification. The online monitoring system can use infrared cameras to grasp the infrared contours of people entering and exiting, so that the contours can be used for data preprocessing. What's more, the temperature can be sensed with the infrared camera, even if it is thermal power generation, you can recognize it according to the flame state and determine the flame temperature to fully protect the safety of the power system.

2.8. Application Analysis of Video-Condensed Snapshot and Abnormal Alarm. The amount of data storage is large, and you can choose the way of video condensing to reduce it scientifically. In order to meet the data retrieval needs of different constraints, including retrieval by time points, retrieval method by data change, etc., the data and corresponding images can be stored synchronously, and the data snapshot through the time point formed can be provided to the technicians for analysis. First, the video sorting is based on time series and the data synchronization snapshot system: it is necessary to study the storage method of images and data, eliminate redundant data, and streamline the database to fully meet the needs of users for customized queries; second, abnormal alarm, when the system recognizes a certain abnormal data, it will alarm and make synchronous abnormal display. The secondary screen cabinet intelligently monitors it, the system is used to supervise by building a set of intelligent inspection system for substation secondary equipment based on artificial intelligence image recognition technology; and finally, the data are summarized and submitted to the data warehouse, the monitoring efficiency is comprehensively improved through the data system formed by the combination of big data and power model to reduce the labor of the staff on duty and provide the solid guarantee for the operation of the power grid.

In the AI image recognition system, the first step is to intercept and save the real-time image of the video stream, and then image recognition tasks are performed such as image preprocessing, image feature extraction, and event judgment, as shown in Figure 2.

2.9. Simulation Experiment Analysis. The current video image recognition content includes monitoring and identifying alarms on the on and off of equipment signal lamps, pointer positions, 7-segment numbers, switch positions, and oil level positions of transformers.

2.9.1. Identification of Signal Lamps. The signal lights of the equipment mainly include red light, green light, and yellow light. The identification of the signal light is to identify the on and off of these three color signal lights. The color characteristic value of the signal light can be calculated by the histogram method, including the mean, variance, difference square, mean difference, etc. Figure 3 shows the red histogram of a certain red light on and off. It can be seen from the figure that when the red light is on, the pixel values are mostly distributed between 225 and 255, and the maximum number of pixels is about 135; when the red light is off, the pixel values are mostly distributed between 72 and 184. The maximum number of pixels is approximately 19. According to this feature, the square of the difference between the pixel value and the number of pixel points in the two cases can easily identify the on or off of the signal light.

2.9.2. Recognition of 7-Segment Numbers. There are a large number of 7-segment digital lights or liquid crystal numbers in power system automation equipment to display values such as voltage, current, and temperature. Figure 4 shows the structure of 7-segment numbers.

It can be seen that the 7-segment number is very clear after image preprocessing. After character segmentation, the value of the 7-segment number can be recognized by judging whether there are black pixels in the corresponding segment.

2.9.3. Recognition of Pointer Position. There are a large number of pointer-type voltmeters, ammeters, barometers, and thermometers in the power system equipment. The processing process of the pointer gauges and pointer images is shown in Figure 5.

2.9.4. Identification of Switch Position. During the AI image recognition of the power supply equipment for determining the position of the switch, it is first necessary to determine the true position of the switch and manually observe to eliminate general faults or provide maintenance. Meanwhile, the corresponding on and off signs shall be set up to identify the change of the switch position, that is, it can automatically determine whether the switch is on.

2.9.5. Identification of Oil Level Position of Transformers. The oil level of the transformer increases with the increase of the internal temperature of the transformer. Although the transformer generally has a thermometer to detect the temperature of the transformer and transmit the detected temperature data to the substation automation system, the detected temperature data cannot directly reflect the position of the oil level inside the transformer. The AI image recognition technology can be used to effectively detect the position of the oil level of the transformer. The original drawing and the preprocessing results of the transformer oil level are

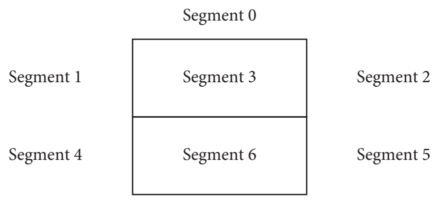


Figure 4: 7-segment digital structure.

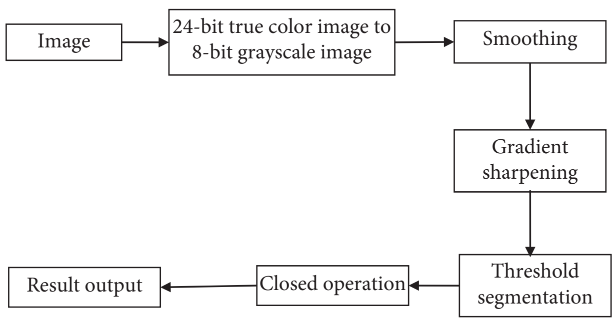
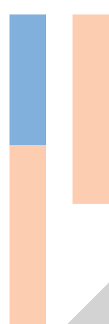


Figure 5: The processing process of the pointer image.



(a) (b)

Figure 6: Oil level and pretreatment results of the transformer. (a) Power transformer oil pipe diagram. (b) Oil level pretreatment results.

shown in Figure 6. Only the horizontal projection can be used to identify the position of the oil level of the transformer.

During the image recognition process, the targets need to be monitored in sequence at first relying on AI image recognition technology. Once the threshold is found to be exceeded, an audible alarm will be issued, the event and time will be recorded in the database, and the image will be saved simultaneously, so that the parameters of image and relevant databases are linked together for later call and view.

3. Conclusions

The AI image recognition system not only has a remote viewing function but also has a signal monitoring and recognition function. Since it can monitor the actual condition of the equipment, it can perform equipment maintenance and troubleshooting in time. Image recognition is performed integrating with power system recognition relying on AI in this paper, and the position of the circuit breaker switch and the position of the transformer oil level are identified. The former enables the dispatcher to understand the true position of the switch, making the dispatching command more accurate and timelier and provide more direct detection methods for an event analysis after the events and fault diagnosis; the latter enables maintenance personnel to immediately overhaul the transformer to eliminate hidden troubles, thereby ensuring the safe and stable operation of the transformer.

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 no conflicts of interest.

Acknowledgments

This research study was sponsored by the State Grid Corporation of China Science and Technology Project: Research on Intelligent Management and Control Technology of Distribution Network Terminal Equipment Detection (TSS2020-15). The authors thank the project for supporting this article.

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