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Retraction

Retracted: Identification of Voltage Sag Sources in the Electrified Railway Power Supply System Based on CNNs

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1].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] Y. Liu, J. Zhang, H. Jia, L. Yuan, and M. Zhou, "Identification of Voltage Sag Sources in the Electrified Railway Power Supply System Based on CNNs," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 4602187, 7 pages, 2022.

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Research Article

Identification of Voltage Sag Sources in the Electrified Railway Power Supply System Based on CNNs

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In order to solve the problems of long classification time and low accuracy of traditional voltage sag source identification methods, on the basis of CNNs, the author conducts an in-depth study on the identification of voltage sag sources in the electrified railway power supply systems. Firstly, study and research from three methods of line fault analysis, simulation verification method, and power quality analysis method are conducted. In order to improve the classification and identification of compound-voltage sag sources when the distribution network contains harmonics, the author proposes a new method for the classification and identification of compound-voltage sag sources based on the eigenvalue synthesis method. Among them, according to the different voltage sag waveform characteristics caused by different composite voltage sag sources, the three-phase voltage unbalance is defined, and the result is obtained by combining the compound-voltage sag source including single-phase grounding with the voltage sag source compounded by induction motor startup and transformer input. After experiments and research, the proposed method is verified by simulation experiments, the results show that the method can classify and identify the types and fault sequences of the compound-voltage sag sources well, and the identification accuracy rate is higher than 96%.

1. Introduction

In the development of the railway industry, the high-speed railway plays a very important role in the improvement of the national economy. By building an electrified railway power supply system, the railway system can be realized. However, in the operation process of the specific electrified railway power supply system, it will be affected by power quality problems such as nonlinearity, pulse, and voltage fluctuation, which will affect the operation efficiency of the electrified railway power supply system and limit the sustainable development of the electrified railway power supply system industry. In response to these problems, a new method is proposed to solve the problem of classifying time extension and identifying traditional voltage sag sources with low resolution methods, namely, limit theory (CNNs). Firstly, the modulo-time-frequency matrix of generalized S transform is used to effectively extract the starting and ending time of voltage sag, sag depth, phase jump, and other characteristic quantities, and then, the genetic algorithm is used to optimize the input weights and hidden layer thresholds of CNNs, and then, the CNN-based CNNs are constructed, and the voltage sag source identification model is developed to realize the identification of the voltage sag source. Through MATLAB/Simulink simulation, the signal generation results of voltage sag source based on neural network are compared. Indeed, the actual detection of voltage sag source as neural network is higher than that of primary elm and BP neural network. In order to identify the position of combined voltage sag in distribution system, a relationship, classification, and analysis model based on eigenvalue synthesis method is proposed. Firstly, according to the characteristics of different voltage sag waveforms caused by different voltage sag waveforms, the three-phase voltage inequality is defined. Sag sources are distinguished. Then, the cross unbalance degree is defined and combined with the second harmonic voltage content, and various types of composite voltage sag sources including single-phase grounding faults are distinguished. Figure 1 is the planning diagram of the railway circuit system.

2. Literature Review

It is believed that in the IEEE standard, the voltage sag is defined as the voltage value at a certain point in the power supply system, which immediately drops to 0.1~0.9 pu and then recovers after a while, time from half a minute to one minute [1]. Xiong and Yang proposed that in the actual power grid, the reasons for the formation of voltage sags are complex, and the waveforms of various voltage sags are different. Under normal circumstances, when there are events such as lightning strikes or the startup of high-power equipment in the power grid, voltage sags can be caused [2]. Kumar et al. said that voltage sag sources can be divided into single-voltage sag sources and compound-voltage sag sources [3]. Serikov and Rubtsov proposed that the identification of voltage sag sources is mostly for a single-voltage sag source [4]. It mainly includes principal component analysis reduction, combination of HHT and wavelet packet energy spectrum, Mamdani fuzzy inference, semisupervised learning of label propagation, minimum coefficient of variation, combination of EMD and SVM, and combination of effective value and FFT. Wang et al. proposed that due to the different reasons for the sag, the amplitude and duration of the sag are different, and the impact on the user is also different, and the corresponding compensation strategies are also different [5]. Selva et al. proposed that ship energy efficiency is a branch of many fields of energy efficiency. For ships in operation, IMO proposes the ship energy efficiency operation index (EEOI) in SEEMP to measure the energy efficiency level of ships in operation [6]. Tschopp et al. said that voltage sag source identification can be divided into sag source signal processing, sag disturbance signal feature extraction, and sag source identification [7]. Tanta et al. proposed to analyze the application status of the electrified social power system, summarize the technical advantages of their compensation, aim to research various influencing factors, and solve the power quality problem of the electrified railway. In order to comprehensively improve the application effect of the electrified railway power supply system, it provides support for the steady operation of the industry [8]. Aksenov et al. said that in the operation of the electrified railway industry, in order to better improve the transportation capacity of the railway and achieve the purpose of environmental protection, it is necessary to reduce the use of fossil materials, and through the reasonable distribution and effective treatment of power resources in the order, sufficiently ensure the rapid and healthy development of the national economy and enhance the core competitiveness of the railway industry [9]. Chen et al. used the improved *S*-transform method to identify the compound-voltage sag source, but this method is only for the voltage sag caused by some compound sags caused by composite voltage sag sources not mentioned by the authors, and this method is not necessarily applicable [10]. And the identification method of the compound-voltage sag source is proposed based on the ideal distribution network, and harmonics in the actual distribution network are not considered.

3. Methods

3.1. Line Fault Analysis. Line short-circuit faults, induction motor starting, and air-dropped transformers are the main sources of voltage sags in power systems. Short-circuit faults are usually caused by strong wind, lightning, equipment failure, animals, poor insulation, etc. [11]. When the induction motor starts, its stator current increases rapidly, which increases the voltage division of the system on the impedance, resulting in a voltage sag. When the transformer is put into operation, due to the saturation effect of its iron core, the magnetizing inrush current generated by the transmission terminal is 8 to 10 times larger than the rated current, resulting in a voltage sag [12]. Compared with traditional railways, the electrified railways lack their own energy for the electric locomotives that drive the trains, and the power supply mainly gives and mainly relies on this system, the system mainly includes catenary and traction substation, and the main power supply methods of the former include suction transformer power supply mode, direct power supply mode with return line, and autotransformer power supply mode. The substations and high-voltage transmission lines in the power supply system serve as the power supply core of the electrified railway system, and the voltages of the traction stations in the substations are 110 kV, 220 kV, and 330 kV. Among them, the voltage level of the ordinary electrified railway is 110 kV, and it is used in the railway equipment system, which has the characteristics of high equipment power and long service time. However, in the operation of the CNN electrified power supply system, it is often affected by three-phase unbalanced factors, and in the design of high-speed railway power supply system, it is necessary to improve the reliability of the power supply system to enhance power quality and achieve the electrified railway power supply system [13]. At present, single-phase wiring, CNN wiring, and impedance balance wiring are mostly used for traction transformer wiring, of which the latter two belong to balanced transformer wiring. First of all, under normal circumstances, single-phase wiring is the preferred wiring method of the Ministry of Railways, this type of transformer is mostly used in 220 kV traction substations in my country, its operation is simple and the capacity utilization rate can reach 100%, and in the specific operation process, it cooperates with the autotransformer power supply mode, thereby increasing the power supply radius of the traction substation, and can effectively reduce the construction cost and operating cost. When the traction power supply system is in operation, local models of electric locomotives need to operate according to the characteristics of the traction transformer, and the electrical energy is transmitted to the catenary through the traction line feeder, in order to ensure the normal operation of the electric

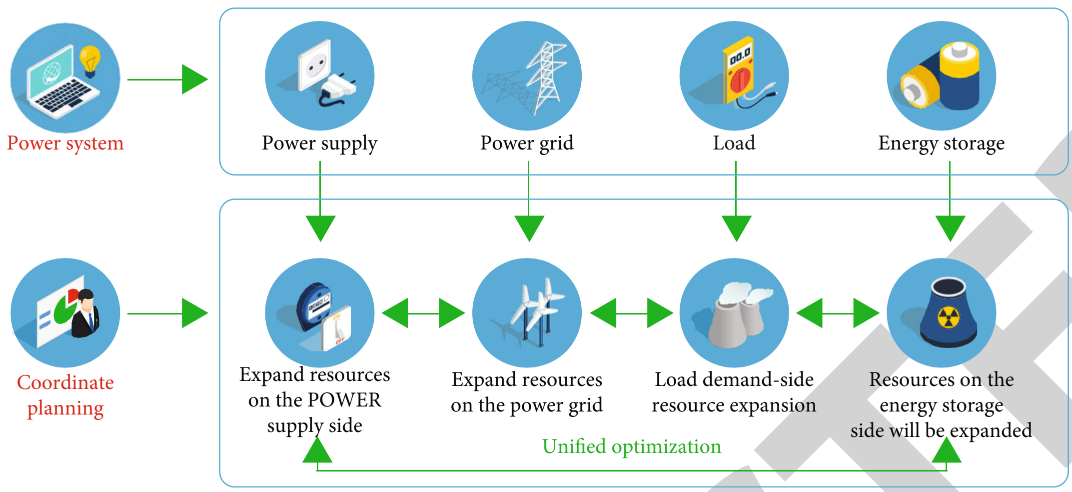

Figure 1: Planning diagram of railway circuit system.

locomotive system and in order to achieve the operation purpose of the electrified railway power supply system [14]. In the short-circuit fault of the power system, the probability of single-phase-to-ground short-circuit occurrence is 66%, and if the induction motor starts at the same time as the single-phase-to-ground fault occurs, a superimposed voltage will be generated at the monitoring point. The mathematical calculation (Equation (1)) of CNNs with N different samples, L hidden layer neurons, and activation function $g(x)$ is as follows:

$$yi = \sum \beta jg(wjxi + bj), \quad (1)$$

where j is the weight of voltage sag source to identify input and hidden layer neurons, bj is the threshold of voltage sag source to identify hidden layer neurons, βj is the weight matrix of hidden layer and output layer neurons, and g is the voltage sag source to identify the output of the hidden layer neurons. A large amount of amplitude information and phase information can be obtained from the modulo-time-frequency matrix of CNNs [15]. Short-circuit faults that cause voltage sags, induction motor start, and air-drop transformers have obvious differences in amplitude changes, phase jumps, and durations; therefore, the purpose of extracting characteristic indicators such as amplitude, phase, and time can be achieved by extracting the curve from the MTFM of the sag signal. It reflects the variation of the amplitude of the disturbance signal at the fundamental frequency with time, and its equation is as follows:

$$S0(t) = S(jT, f0). \quad (2)$$

The characteristic index P_1 is to define the sag depth as follows:

$$P_1 = \frac{\min\,(S(jT, f_0))}{\max\,(S(jT, f_0))}. \quad (3)$$

The characteristic index P_2 is defined as the mean value of the fundamental frequency amplitude as follows:

$$P_2 = \frac{1}{N}\sum_{k=0}^{k-1} S_0(k). \quad (4)$$

The characteristic index P_3 is defined as the standard deviation of the fundamental frequency amplitude curve. Equation (5) is as follows:

$$P_3 = \sqrt{\frac{1}{N}\sum_{N=0}^{N-1}[S_0(K) - P_2]}. \quad (5)$$

The characteristic index P_4 is the root mean square value that defines the fundamental frequency amplitude curve. Formula (6) is as follows:

$$P_4 = \sqrt{\frac{1}{N}\sum_{N=0}^{N-1}[S_0(K)]}. \quad (6)$$

The maximum value of the phase jump curve is defined as the characteristic index p_5 as shown in the following equation:

$$P_5 = \max\,(PH_X). \quad (7)$$

The probabilistic neural network is essentially a classifier, the Mahalanobis distances of various composite voltage sags are input into the probabilistic neural network, and the types of various composite voltage sag signals are used as the output of the probabilistic neural network, which can realize faults in the composite voltage sag source, sequential classification recognition [16]. Like the single hidden layer neural network, Equation (8) can be expressed as follows:

$$H\beta = T. \quad (8)$$

The output weight matrix (Equation (9)) can be obtained as follows:

$$\bar{\beta} = H + T. \tag{9}$$

It can be changed to solve the least squares solution problem of the weight matrix, that is,

$$\left(H\bar{\beta} - T\right) = \min\left(H\beta - T\right). \tag{10}$$

Figure 2 shows the multilevel voltage sag waveform caused by the change of line ground fault type.

3.2. Simulation Verification Method. The power sag simulation system is shown in Figure 3 (CNN-based voltage sag simulation system). Change the fault, location, start-stop time, and load size and obtain short-circuit fault line information; change the startup time of the motor, the line load, and the capacity of the high-phase transformer to obtain the characteristic data when the induction motor starts, delivery time, and line load and obtain the characteristic data of the transformer when it is put into operation, in order to construct the training and test sets for the CNN-based voltage sag source identifier [17]. However, the probability of negative sequence current generation is relatively large, which has an adverse effect on the power quality of the power system. Secondly, the transformer has two arms. If it cooperates its autotransformer mode, the distance increased by the radius of the traction substation will even exceed the distance increased by the single-phase transformation, but its cost will increase compared with the latter, and if the comprehensive analysis considers the user and the overall situation of the power grid, its application value is still high. Finally, the impedance matching balanced wiring transformer is independently developed by my country, and in the operation of the neutral point grounding system, the staff adjusts the current and voltage to make the two-phase or three-phase transformation reach a balanced state. Based on the above analysis, in order to meet the needs of classification and identification of voltage sag sources under complex working conditions, the authors proposed a new method for the harmonics in the distribution network [18]. Firstly, the composite voltage sag sources are preliminarily classified according to the comprehensive eigenvalues of the three-phase voltage sag signals. Then, the Mahalanobis distance and probability neural network are used to identify the fault sequence of the composite voltage sag sources. Finally, a large number of data obtained by simulation are used to verify the effectiveness of the method proposed by the authors.

Combined with the operation core of the electrified railway system, the characteristics of the electric locomotive core of the electrified railway system usually include "AC-DC" type and "AC-DC-AC" type: (1) the "AC-DC" type electric locomotive adopts the multistage bridge phase-controlled rectification method, and in the case of no functional compensation, the average power factor of the system is relatively low; moreover, when the system is normal, harmonics will be generated, mainly due to levels 3, 5, and 7 are the core. (2) In the "AC-DC-AC" type of motor vehicle, the

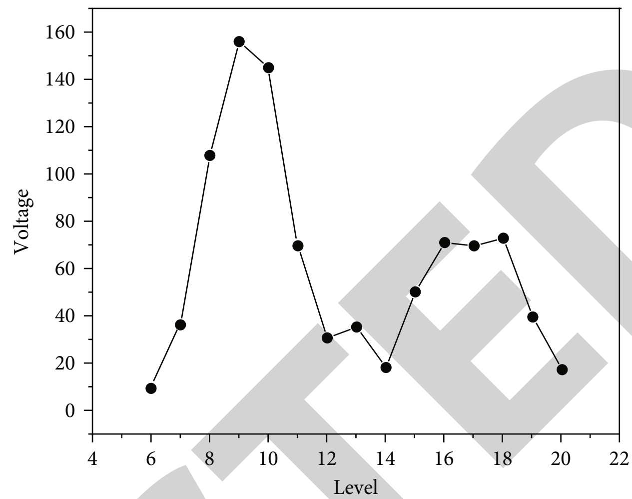

Figure 2: Multilevel voltage sag waveform.

content of harmonics is relatively low, and there is an advantage of high power factor. However, most of the single-phase "AC-DC-AC" electric locomotives, when the power is greatly increased, will have a lot of this three-phase grid side, and the stability of electric locomotive operation cannot be improved [19]. The above is synthesized through the characteristics of unbalance, cross unbalance, and second harmonic voltage content, and the identification of each type of compound-voltage sag source is achieved. For the combined action of single-phase ground fault and induction motor starting, this kind of compound-voltage sag can only occur at the same time, and no further identification of the fault sequence is required [20]. Therefore, the authors will study the sequence of occurrence of a single-sag source in two types of composite voltage sag sources, such as single-phase ground fault and transformer input, and induction motor startup and transformer input.

3.3. Power Quality Analysis. With the development of the electrified railway industry and comprehensive use of its own gravity supply system and the superior power system, it will cause harmonic interference to power users and will also reduce power quality, which cannot improve the power processing effect of the electrified railway power supply system. According to the operation characteristics of the electrified railway system, the system will be affected by many factors such as load and line conditions, locomotive type, and operation diagram, resulting in the traction force being affected by the distribution factors such as load space and time, and the purpose of comprehensive management of the electrified railway power quality cannot be achieved. In the electrified railway power supply system, in order to reduce the load of railway and highway controllers and save project costs, in the system optimization process, active railway power controllers and thyristor controllers are usually selected, and the compensation system is formed when the two systems are used comprehensively, in order to improve the operational efficiency of the electrified railway systems. Figure 4 shows the electrical operating efficiency trend shown below. For the converter system in it, when the

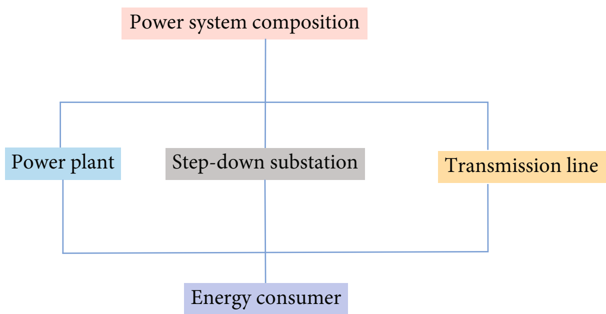

Figure 3: The composition of the voltage simulation system.

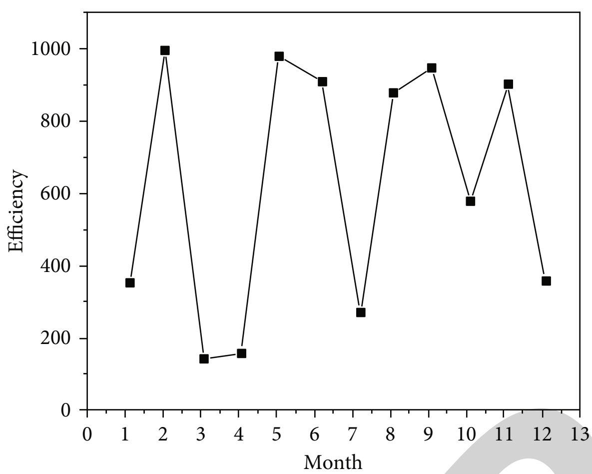

Figure 4: Trends in electrical operation efficiency.

inductance single-phase step-down and the transformer are turned on, the supply arm will be connected in parallel with the power control system. To improve the energy efficiency of rail power systems, it is usually necessary to establish a mathematical modeling system of CNNs, railway power conditioners, and conventional CNNs AC side compensation power control system, usually in the form of two-phase dp rotation coordinates, and it is necessary to establish a two-phase rotation coordinate model of CNNs.

According to the different categories of single-voltage sag sources, the compound-voltage sag sources can be divided into various types, and considering the actual situation, in the ground fault, the probability of a single-phase ground fault is much greater than the probability of the other two types of ground faults; therefore, the authors only study the following types of compound-voltage sags: multilevel voltage sags caused by grounding faults, the combination of single-phase grounding and induction motor starting, the combination of transformer switching and single-phase grounding, and the combination of transformer switching and induction motor starting. One of the causes of multilevel voltage sags is a change in the type of line ground fault. For example, when a single-phase ground fault occurs in the line, the arc at the fault point may burn out the equipment, and it may become a two-phase short-circuit ground fault. In the operation of a single-phase system, the negative sequence and harmonics usually rely on the instantaneous power theory, and after the two voltage signals and the real-time current product are added together, the numerical compensation of the power supply system will be realized in the case of low-pass filtering to meet the compensation requirements, uniform treatment of the last two-phase supply arms. Usually, in the reactive power detection of negative sequence and harmonics, it is necessary to do the following: (1) in the operation of the railway and highway controller system, it is not necessary to undertake all the reactive power compensation, but in the separate reactive current inspection, the superposition processing of the active current reduces the load current of the power supply arm, so as to obtain the final negative sequence harmony wave reference value. (2) In the analysis of the load current of the power supply arm, multiply it by the $\pi/2$ signal of the voltage of the y arm, and the peak value of the product of the load current of the power supply arm and the $\pi/2$ signal of the voltage will appear, and in the case of the low-pass filter being DC, it is subjected to shunt filtering. (3) In the case of reactive current at both ends of the system, it is necessary to adopt the reactive power detection technology of negative sequence and its own harmonics, and through the processing of DC and component filtering, the filter compensation amount and the negative sequence compensation amount can be eliminated and provide data support for the high-quality operation of the system. ④ Combined with the operating state of the electric railway system, the harmonic compensation amount is used as the negative value of the load harmonic current, and then, the reactive power phenomenon of the system will be eliminated in the case of reactive power compensation, and the operation effect of the electric railway current load will be improved. According to the analysis of the proposed method for them, the specific implementation flowchart of the proposed method can be synthesized, as shown in Figure 5.

4. Results and Analysis

During the operation, the negative sequence current will affect the normal operation of the generator, resulting in asymmetrical operation, which limits the output of the generator. Relay protection devices controlled by negative sequence components are relatively common in power systems, and under the influence of negative sequence current, such devices may malfunction, and under the influence of prolonged negative sequence current action time, conventional distance protection will be in a blocking state, and in severe cases, the distance protection may even be out of operation. In addition, the transformer will be affected by the negative sequence current, and one phase of the three-phase current will increase, which will affect the rated output of the transformer, reduce the additional amount of the transformer, and make the iron core magnetic circuit in the transformer additionally generate heat. If there is a negative sequence current in the transmission line, it will not do work, but will lose electrical energy, which will lead to increased network loss, which in turn affects the transmission capacity of the transmission line in the power system. In the specific operation process, the selection of the grid operation mode is affected by the mode of the negative

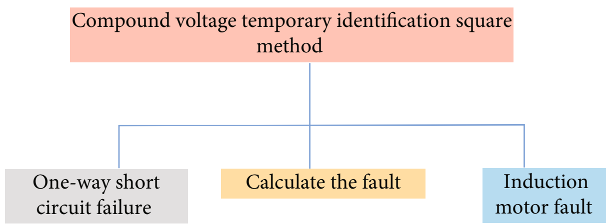

Figure 5: Classification and identification method of voltage sag sources.

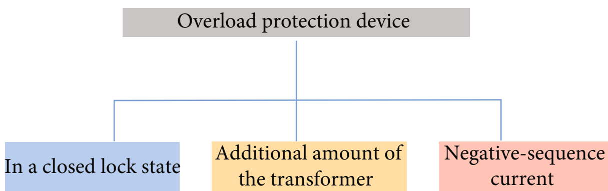

Figure 6: Relay protection device.

sequence current, and when the negative sequence current is obviously temporary or transitional, the temporary grid operation mode is selected, such as switching a certain section of the grid or the transformer, the input and withdrawal of, and then realize the change of the negative sequence current distribution in the system; usually, this method is suitable for areas where the power grid structure is relatively weak. Figure 6 is a relay protection device. In addition, a line protection device should be installed in the substation of the external power supply of the electrified railway, and the line distance protection oscillation blocking mode should be adjusted, mainly to highlight the quick reset function, and it is ensured that the distance protection can quickly enter the protection state when the shock load occurs.

In the electrified railway traction substation, when no locomotives pass through, the substation will send reactive power to the power grid; therefore, in the electrified railway traction substation, the dynamic compensation mode should be selected for reactive power compensation and should be combined with the actual situation of the traction substation, organically combine reactive power compensation and harmonic current management to ensure the safety of the power system. In the adjustment of the traction substation after the accident, technical measures for reactive power compensation were introduced, among which three-phase dynamic reactive power compensation devices, single-phase fixed compensation and filtering devices, etc. are relatively common reactive power compensation devices. In the voltage sag source identification model of CNNs, because it is random, the accuracy of the CNN model identification is reduced, and some values may be 0, causing some hidden layer nodes to fail, thus affecting the performance of the CNN network.

5. Conclusion

During the operation of light rail system, in order to improve energy efficiency management, power companies and railway stations must carry out the research, efficiency, and operation of electric rail in combination with the characteristics of light rail and motor work, improve the electrical efficiency of motor, and meet the needs of continuous improvement of energy efficiency by integrating power generation technical support and taking advantage of cost-effectiveness. According to the special operation conditions of electric locomotive, the power supply mode may be negative due to the harmonic and positive energy problems in the system, which may lead to signal safety failure. By maintaining the safety of energy efficiency and power efficiency, the payment cost can be reduced and the stable operation of the system can be ensured. Different voltage sag waveforms produced by different composite voltage sag sources are different. For the same type of hybrid voltage sag source, when a voltage sag source appears in different orders, the resulting composite voltage sag waveform will be different. GA optimizes CNNs. The author describes power rating as CNNs. Therefore, this section will first distinguish four different types of voltage sag sources according to the characteristics of the composite voltage sag waveform. Then, the sequence of a single sag source in the same type of composite voltage sag source is identified, and finally, a complete new method for classification and identification of the composite voltage sag source is formed.

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.

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