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Research on Energy Saving and Loss Reduction Strategy Based on Reasonable Line Loss Interval of Low-voltage Distribution Network

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ABSTRACT

It is difficult to calculate the theoretical line loss of low-voltage distribution transformer area and the evaluation index of transformer line loss is extensive. In this paper, a reasonable interval calculation model of line loss is established based on the convolutional neural network based on the data of electricity information acquisition system. The model can estimate the reasonable line loss interval according to the operation data of different transformers. On this basis, the line loss evaluation system is established and the rectification plan of abnormal line loss is formed. The method in this paper can improve the quality and efficiency of line loss lean management and produce certain effect for saving electric energy and improving economic benefit of power supply.

Keywords: line loss interval, convolutional neural network, line loss management, loss reduction

NONMENCLATURE

Abbreviations	
CNN	Convolutional Neural Network

1. INTRODUCTION

In recent years, the research on line loss calculation and loss reduction measures of distribution networks have been paid more and more attention by power grid companies and researchers at home and abroad. Some researchers have proposed more reasonable solutions to some specific problems. In literature [1], the line loss calculation method of each branch line loss is obtained by using on-site monitoring terminals and based on the loss calculation of traditional power. This method is not applicable in the current distribution network with complex and opaque structure. In literature [2], RBF network is used to calculate line loss and dynamic clustering algorithm is used to find the optimal parameters to speed up network training and convergence. Literature [3] analyzes the line loss on the physical layer through traditional electric power calculation. Literature [4] proposes a network topology identification method based on fuzzy clustering, improves adaptive programming, and establishes a power grid state assessment model based on direct neural dynamic programming for theoretical line loss calculation. In literature [5], the core vector machine was used to calculate the line loss, and quantum genetic algorithm was used to assist the search of optimal parameters to improve the accuracy. Literature [6] USES gray model and neural network integrated model to predict line loss rate.

For the above research methods, when the communication automation equipment of distribution network has not been completely covered, or partial distribution network local topological relationship is not transparent, the more accurate theoretical line loss cannot be obtained. Therefore, it cannot provide strong support for the establishment of line loss evaluation system and the troubleshooting and rectification of abnormal line losses.

In this paper, the model of convolutional neural network is introduced into the problem of calculating the reasonable line loss interval of low-voltage distribution transformer, and the monthly theoretical line loss interval calculation model based on the convolutional neural network is established. Based on the reasonable line loss interval to guide the work of abnormal line loss control. The approximate interval will be closer to the real interval with the iteration of the model and the rectification of the platform

2. MATHODS

2.1 Introduction to the principle of convolutional neural network algorithms

CNN (convolutional neural network) is a supervised deep learning network model, which is composed of input layer, convolutional layer, sub-sampling layer, full connection layer and output layer. Among them, convolutional layer and pooling layer are usually selected and set alternately. The network structure is shown in Fig1. The convolutional layer is composed of several convolution units. Feature extraction is carried out through convolution operation, and more layers can usually extract more complex features. The sub-sampling layer reduces the high-dimensional features obtained by convolution, and obtains new features with small dimensions by taking the mean value or the maximum value. The whole connecting layer combines all local features into global features, which is convenient for subsequent calculation and discrimination. Compared with other neural networks, the characteristic of CNN is that the features of each layer are obtained by the local region of the previous layer through convolution kernel excitation of Shared weights, which greatly reduces the network parameters, making it particularly suitable for image feature learning and extraction.

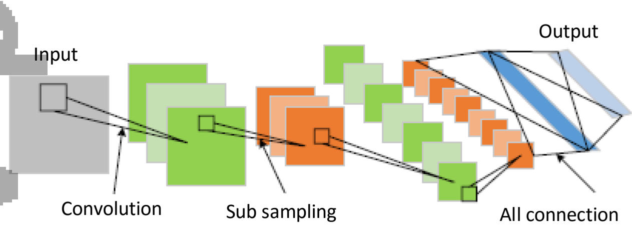

Fig 1 Structure of convolutional neural network

2.2 Monthly line loss calculation model

2.2.1 Monthly data description of low voltage distribution transformer area

The experimental data used in this paper are from 1500 low-voltage distribution transformers of a power supply company. The data includes the three-phase voltage, three-phase current and three-phase power factor of 24 data collection points in each transformer every day for a whole year. The information of 1500 transformer areas, including the type of supply, capacity of transformer and CT ratio; The settlement of electricity supply, settlement of electricity consumption and line loss rate of 1500 stations at 24 hours a day, among which the electricity supply is the transformer side and the electricity consumption is the sum of electricity meters at the user side. The information composition of each sample data is shown in Fig 2.

2.2.2 The method for making imitation pictures of data samples

For the monthly operation data of a single transformer area, taking voltage data and 30 days per month as examples, there will be 24×30 collection points, and each collection point has its specific time attribute and physical significance.

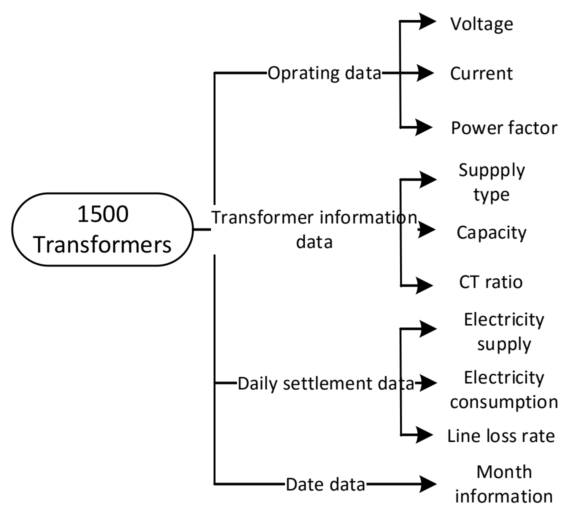

Fig.2 Sample data information composition diagram

In this paper, by using the sample making method of imitated images, data from 24×30 collection points of voltage, current and power factor are respectively mapped to three-dimensional space, so as to form a 3×30×24 Tensor. The structure is shown in Fig 3.

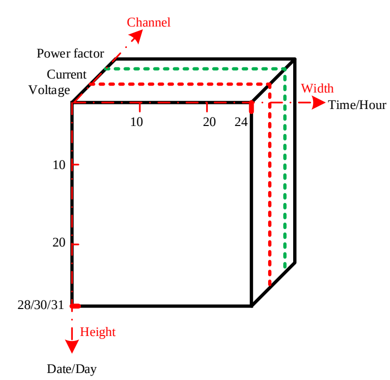

Fig.3 Structure display of monthly operating condition data sample

The Tensor has three passages, 28, 30 or 31 high and 24 width. The 24 points of the width represent the 24 collection points of the day. The height represents the collection date of each month, which is determined by the number of days in that month. The three channels represent voltage, current, and power factors, respectively.

In a certain channel, 24 points at the same height represent the collection information of 24 time periods of the day, and the time sequence information is mapped to spatial position information from left to right. Twenty-eight, thirty, or thirty-one points of the same width represent the data changes of each day in the same period of time. The points of the same width and height, on different channels, respectively represent the information of voltage, current and power factor at that time.

By the above method, the voltage, current and power factor information containing 24×28/30/31 collection points in a month can be mapped into a sample format of a mock image, while retaining the original timing information and physical significance.

2.2.3 Establish monthly reasonable line loss interval calculation model

A reasonable interval calculation model of line loss is established based on convolutional neural network. The model inputs are Tensor images which comprise the temporal voltage, current and power factors of the transformer. Information extraction is carried out by convolutional neural network and a one-dimensional vector is output by global average pooling. Finally, the classifier is connected to carry out the classification task.

The model output label corresponds to a reasonable line loss interval. The monthly theoretical line loss interval calculation model modeling flow chart is shown in Fig 4.

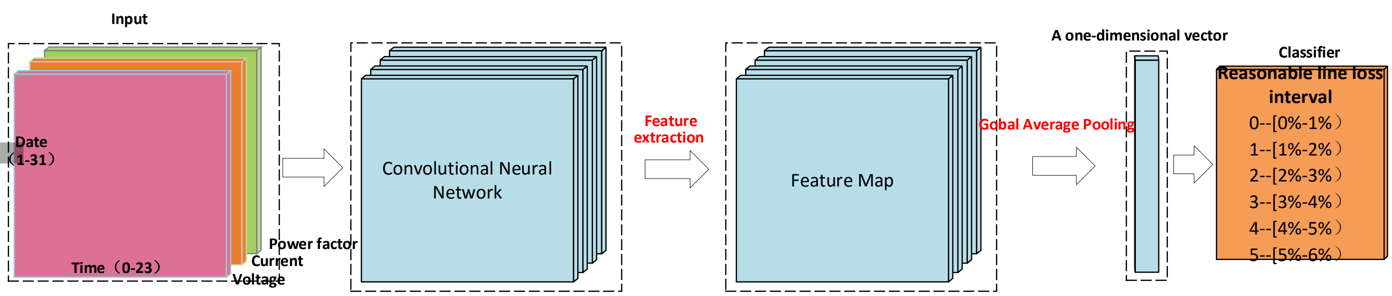

Fig 4 Modeling flow chart of monthly reasonable line loss interval calculation model

2.3 Line loss evaluation system and improvement process

2.3.1 Establish line loss evaluation system

In this paper, based on the current situation of the low-voltage distribution desk area in a certain region and the current assessment indicators, this evaluation system is developed through communication with relevant staff and the measurement accuracy and possible information transmission errors of the on-site acquisition equipment.

The line loss interval evaluation system of the low-voltage distribution platform in this region is divided into 5 sections, namely, the reasonable interval of high confidence, the reasonable interval of low L confidence, the reasonable interval of low H confidence, the low loss interval, the moderate loss interval, the high loss interval and the ultra-high loss interval. As shown in Fig 5

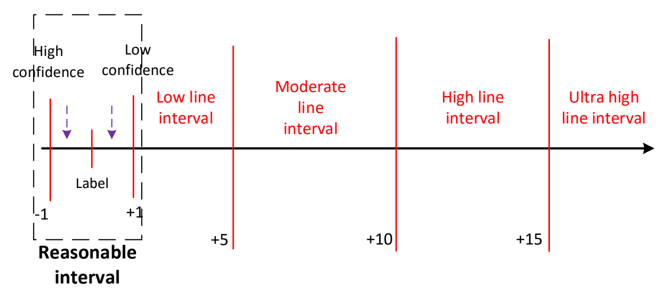

Fig 5 Schematic diagram of interval division of line loss evaluation system

Based on the high-precision model obtained by training, when the data of any transformer is input into the model from the test set, the model will automatically output the theoretical line loss interval of the model, which is the reasonable interval with the highest confidence. But considering the actual operation process, because the meter gauge measuring accuracy error of about 10%, and the data transmission of data may occur in the abnormal and the accuracy loss, make the input data will be more or less some disturbance, caused by model results and the actual existence of some error, and, in certain extreme conditions may appear the situation of the regional, such as theoretical line loss interval was 4.98%, (4%-5%) courts may be model judgment was 5.00%, (5%-6%), Or the platform area with a theoretical line loss interval of 5.99%, [5%-6%] may be judged by the model as 6.00%, [6%-7%].

Therefore, on the basis of the theoretical line loss interval output by the model, ±1 can obtain a reasonable line loss interval with low confidence. When the theoretical line loss interval of model output reaches +5 on its basis, the mild line loss interval is obtained. In the theoretical line loss range of model output +5 to +10 is the moderate line loss range; The theoretical line loss range of model output +10 to +15 is the heavy line loss range. The theoretical line loss interval of model output above +15 is the ultra-high loss interval.

For example, if the predicted value of the model is 5, that is, the predicted theoretical line loss interval is 5%-6%, if the actual line loss rate of the platform area falls into the interval,

a) 4-6, namely [4%,7%], is the platform area of the reasonable line loss range;
b) 7-10, namely [7%,11%], is the light damage range;
c) 11-15, that is [11%,16%], is the intermediate loss range.
d) 16-20, i.e. [16%,21%], is the heavy loss area;
e) Above 20, i.e. [21%, --), is the ultra-high loss range.

The optimal model evaluated by the training set and the validation set is applied to the test set. The test set is 1500×12×0.3, with a total of 5400 platform sample data. By calculating the line loss interval of the model and combining with the line loss evaluation system, the line loss evaluation distribution map of the test bench area is obtained, as shown in Fig 6.

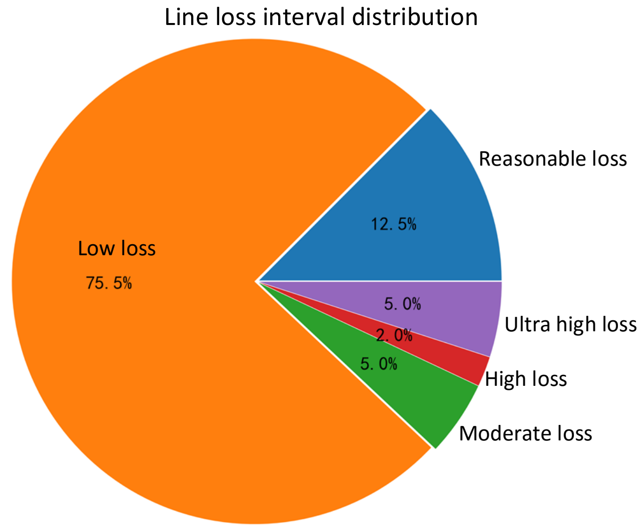

Fig 6 Distribution map of line loss evaluation in test set

By the picture above, among the 5,400 samples, 675 samples (12.5%) showed reasonable loss (no power theft or leakage), 4,077 samples (75.5%) showed low loss, 270 samples (5.0%) showed moderate loss, 108 samples (2.0%) showed high loss, and 270 samples (5.0%) showed ultra-high loss

The distribution is in line with the loss distribution in the area under the jurisdiction of the electric power company, which proves the correctness and rationality of the self-adaptive evaluation method for low-voltage distribution station based on the theoretical line loss interval calculation model and evaluation system proposed in this paper.

2.3.2 *Loss reduction and improvement process*

The thresholds for each interval are based on the current situation. With the low-voltage line loss improvement has begun to take effect, then the threshold value can be adjusted and updated according to the actual situation. The loss reduction strategy based on the reasonable line loss interval calculation model is shown in Fig 7.

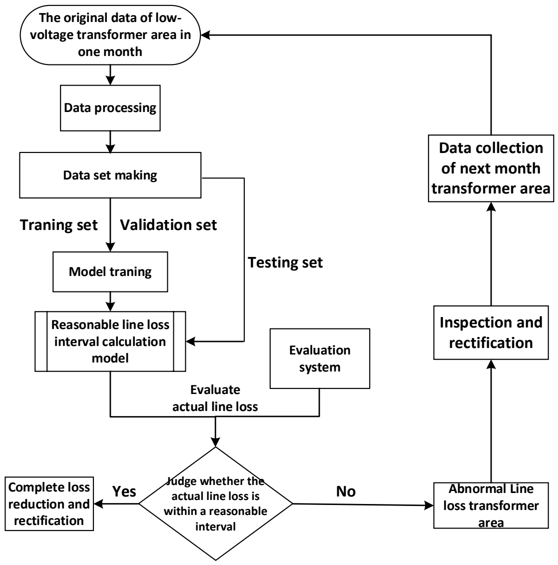

Fig 7 Loss reduction strategy based on theoretical line loss interval calculation model

Based on the monthly reasonable line loss calculation model, the steps of line loss rectification in the low-voltage area are as follows:

(1) Data acquisition: The voltage, current, power factor, monthly line loss and basic data related to the billiard area of the low-voltage transformer for one month are collected through the electricity information acquisition system.

(2) Data set making: Divide the data set according to the "7-3" criterion, and take 70% samples as the training set for the training of reasonable line loss interval model. With 30% samples as the test set, the reasonable line loss interval of corresponding distribution area is calculated by the model.

(3) The output results of the model are compared with the actual line loss, and the differential rectification and loss reduction management are carried out by referring to the line loss evaluation system.

(4) After the transformer area is reformed, the iterative process of data acquisition, data set division and model training will be repeated in the next month. The rectification will be completed until the line loss level of all stations reaches a reasonable line loss range.

At present, it is known that the power company's screening plan for abnormal losses is to conduct door-to-door screening one by one. Although the method is detailed, the time cost and labor cost are too expensive. And low efficiency, long inspection and rectification cycle, is not conducive to the low voltage distribution transformer area rapid loss reduction. At the same time, it is impossible to inspect hundreds of stations one by one every month. Therefore, reasonable screening schemes should be formulated for abnormal stations of different degrees, so as to greatly improve the work efficiency of loss reduction and energy saving.

2.4 Conclusions

This paper uses the time series data collected by the power consumption information acquisition system of the distribution network and establishes a reasonable interval calculation model for line loss of low-voltage transformer based on the convolutional neural network. According to the reasonable line loss interval, the line loss evaluation system can be established for different stations. The research results are helpful for power supply companies to realize the differential management and rectification of line loss in the station area. The refinement and economy of line loss management are improved.

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REFERENCE

[1] F Zhu. Loss Calculation Method for Distribution Network with Information form Field Terminal Units[J]. Power System Technology. 2001, 25(05): 38-40.

[2] H Jiang, M An, X Liu, et al. The Calculation of Energy Losses in Distribution System Based on RBF Network with Dynamic Clustering Algorithm[J]. Proceedings of the CSEE. 2005, 25(10): 35-39.

[3] H Bao, Q Ma. Physical Distribution Mechanism of Network Loss for Power System[J]. Proceedings of the CSEE. 2005, 25(21): 85-89.

[4] Z Lu, S Li. Power System State Estimation and Theoretical Line Loss Calculation Based on Direct Neural Dynamic Programming[J]. Power System Technology. 2008, 32(23): 50-55.

[5] Y Peng, K Liu. A Distribution Network Theoretical Line Loss Calculation Method Based on Improved Core Vector Machine[J]. Proceedings of the CSEE. 2011, 31(34): 120-126.

[6] Q Zhang, B Zhou, N Lin, et al. Line Loss Rate Forecasting Based on Combination of Grey Model and Neural Network[J]. Proceedings of the CSU-EPSA. 2013, 25(05): 162-166.

