Deep Learning Based Circuit Breaker Non-Full-Phase Operation State Monitoring Method

Tao Tao
Rizhao Polytechnic, School of Mechatronics Engineering, Rizhao, Shandong, 276800 China
ttaomao@163.com

Abstract: To solve the problem of low accuracy of the traditional monitoring method, a deep learning based monitoring method is designed. A sensor is installed at the part that may cause the circuit breaker to run in non-full phase and the state data of the circuit breaker is collected through the sensor. Filter and digital-to-analog converter are used to reduce noise and digital-to-analog conversion of the signal transmitted by the sensor. After the data are standardized and normalized, input into the convolutional neural network. The parameters and weights of convolutional neural network are determined by training the sample data. After the training of convolutional neural network, the input neural network data are processed according to the determined parameters and weights. Output the processed results to the database, in the database classification algorithm after the data classification, sent to the circuit breaker operation control module, to achieve the circuit breaker operation status monitoring. Through the comparison with the traditional monitoring methods, it is verified that the designed deep learning-based state monitoring method has higher accuracy and can make up for the shortcomings of the traditional methods.

1. Introduction
In just a few years, deep learning has been constantly updated and iterated, abandoning the design ideas of traditional algorithms in many fields, and gradually forming an end-to-end network model based on a large amount of training data. This new structure enables it to directly output the final results. This innovation not only makes the whole system simpler, but also improves the accuracy by adjusting the characteristic information of each layer in the deep learning network. Now, with the help of the age of big data and electronic technology, deep learning has achieved leapfrog development. All kinds of massive data, whether labeled data, weak labeled data or just data itself, can be used by deep learning to completely and automatically learn abstract knowledge expression, which is actually the highly condensed and generalized original data [1].

The non-phase operation of circuit breaker is an asymmetric operation, which will generate negative sequence current, and negative sequence current will generate negative sequence rotating magnetic field. The magnetic field rotates in the opposite direction to the rotor and the relative speed of the rotor is about twice the synchronous speed. This will lead to the circuit breaker mechanical strength decline, affect its function, causing hidden dangers. The reasons for the non-full phase operation of the circuit breaker are mainly mechanical and electrical faults of the circuit breaker. Poor insulation of secondary circuit; Poor contact of transfer contact and insufficient pressure displacement make the opening and closing circuit blocked; Circuit breaker density relay blocking operation circuit. The mechanical failure is mainly the failure of the circuit breaker operating mechanism [2]. For circuit breaker open-phase
running state monitoring, the traditional method only monitoring circuit breaker three-phase is working correctly, not real-time monitoring the open-phase running will cause the circuit breaker of the source of this will lead to the traditional monitoring method can't timely and accurate to the circuit breaker open-phase running state monitoring, cause the entire operating system problems. In view of the disadvantages of traditional monitoring methods, this paper proposes a method to monitor the non-full phase running state of circuit breakers by using the advantages of deep learning.

2. Circuit breaker non-full-phase operation state monitoring method

The main reason why the circuit breaker is not in full phase operation is the mechanical and electrical fault of the circuit breaker. The overall block diagram of the non-full phase operation monitoring method for circuit breakers is shown in figure 1. The monitoring method of circuit breaker non-full phase operation proposed in this paper is designed for the fault source which may cause the circuit breaker non-full phase operation. All the working data that may cause faults are collected by the sensor, and the data are pre-processed such as filtering and noise reduction, and then input into the convolutional neural network for deep learning. Convolutional neural network requires repeated training at the beginning to determine the weight value of neural network. After determining the weight value, the convolutional neural network can monitor the non-full phase operation state of circuit breakers according to the data collected by the sensor and the algorithm in the database.

![Fig. 1 method block diagram of circuit breaker non-full phase operation monitoring](image)

2.1 Sensor data preprocessing

Sensor data collected usually work because all parts of the circuit breaker influence each other cause there are a lot of noise in the data, and data from the sensor contains circuit breaker open-phase running normal work and the work under the condition of the acquisition of data, the need of sensor data collected for noise reduction, format conversion, filtering, standardization and normalization processing.

The data transmitted by the sensor is usually an analog signal, which contains a lot of noise. Before the data collected by the sensor is transferred to the database, noise reduction and format conversion are required. Filter is used to set the filter interval, and the data transmitted by the sensor is filtered to remove noise [3]. The data after noise removal needs to be converted into digital signals through digital-to-analog converters to facilitate subsequent data processing. Using AD converter, the data wave is converted into a digital signal composed of binary digital code, which is stored in the database.

The data stored in the database is the data processed by filter and converted from analog signal to digital signal by digital-to-analog converters. At this point, the data in the database contains all state data of the circuit breaker during normal operation and non-full phase operation, which is not convenient for monitoring the non-full phase operation of the circuit breaker [4]. Therefore, all the data in the database needs to be filtered. Filtering algorithm is used in database to filter data. The filtering algorithm classifies the data in the database according to the set filtering standard parameters, and sends the filtered circuit breaker non-full phase operation state data to the data processing department. The circuit breaker normal working state data is taken as reference and retained, and it is cleaned regularly according to the storage space of the database.

All the filtered data are the status data of the circuit breaker when it is running in non-weight phase. The filtered data needs to be standardized and normalized [5]. Firstly, the filtered data are standardized according to formula (1) to remove data errors caused by sensor accuracy and other problems.
is the standardized data value, and the data processed by the above methods will fall within a certain interval. Because the filtered data may still contain a very small part of the circuit breaker's normal working data, in order to reduce the impact of miscellaneous data in the subsequent monitoring and processing, the interval is set as the data interval collected by the sensor except the circuit breaker's normal working, so the data outside the interval will be considered as abnormal data and eliminated [6]. After data standardization, in order to facilitate the rapid processing of subsequent convolutional neural network, normalized processing of standardized data is required.

Suppose the standardized data is \( x \), and the set of all standardized data is \( W \). After filtering, the maximum value is \( x_{\text{max}} \) and the minimum value is \( x_{\text{min}} \), and the data are normalized according to formula (2).

\[
X'_i = \frac{X - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}} \tag{2}
\]

According to the above equation, the normalized data \( x_i \) is the value of the interval of [0,1], and the input interval of [0,1] is convenient for neural network processing. Meanwhile, the storage space of the convolutional neural network server is also reduced.

2.2 Train the convolutional neural network

Convolutional neural network is a kind of deep learning. Convolutional neural network is an important part of deep learning. Object recognition and detection through convolutional neural network is an important research direction at present. Convolutional neural network mainly includes input layer, convolution layer, and pooling layer [7]. The figure is the process diagram of convolutional neural network processing data. The convolutional neural network extracts the characteristic parameters through the input layer, convolution layer and pooling layer with different quantities of data, and completes the identification of the operating state of the circuit breaker through the classifier.

\[
X' = \frac{X - \bar{X}}{S}, S = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n-1}} \tag{1}
\]

\( X' \) is the standardized data value, and the data processed by the above methods will fall within a certain interval. Because the filtered data may still contain a very small part of the circuit breaker's normal working data, in order to reduce the impact of miscellaneous data in the subsequent monitoring and processing, the interval is set as the data interval collected by the sensor except the circuit breaker's normal working, so the data outside the interval will be considered as abnormal data and eliminated [6]. After data standardization, in order to facilitate the rapid processing of subsequent convolutional neural network, normalized processing of standardized data is required.

Suppose the standardized data is \( x \), and the set of all standardized data is \( W \). After filtering, the maximum value is \( x_{\text{max}} \) and the minimum value is \( x_{\text{min}} \), and the data are normalized according to formula (2).

\[
X'_i = \frac{X - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}} \tag{2}
\]

According to the above equation, the normalized data \( x_i \) is the value of the interval of [0,1], and the input interval of [0,1] is convenient for neural network processing. Meanwhile, the storage space of the convolutional neural network server is also reduced.

2.2 Train the convolutional neural network
Convolutional neural network is a kind of deep learning. Convolutional neural network is an important part of deep learning. Object recognition and detection through convolutional neural network is an important research direction at present. Convolutional neural network mainly includes input layer, convolution layer, and pooling layer [7]. The figure is the process diagram of convolutional neural network processing data. The convolutional neural network extracts the characteristic parameters through the input layer, convolution layer and pooling layer with different quantities of data, and completes the identification of the operating state of the circuit breaker through the classifier.
convolutional neural network training. The calculation formula of data processing in the convolution layer is as follows:

\[ X^l_j = f \left( \sum_i X^l_{i-1} * K^l_{ij} + b^l_j \right) \]  \( 3 \)

\( X^l_j \) and \( b^l_j \) represent the output operating state of the \( j^{th} \) neuron in the current layer; \( K^l_{ij} \) represents the convolution kernel of the \( J^{th} \) neuron in the current layer when convolved with the input \( I \) operating state; \( X^l_{i-1} \) represents the \( i^{th} \) operating state of the input in the current layer; function \( f \) is a nonlinear activation function, introducing nonlinearity into the neural network [9]. Through a series of convolution calculations, the convolutional layer outputs the processed circuit breaker non-full phase operation state data to the pooling layer. The dimension of the input data of the pool is reduced to simplify the computational complexity of the convolutional neural network and avoid the occurrence of overfitting to a certain extent. Meanwhile, feature compression is carried out to extract the main features and determine the weight. Complete a training of convolutional neural network. When designing the network, the weight number of each layer of the network is greatly reduced, and the complexity of the network is greatly reduced. In this way, more layers of the network can be designed, so that the task accuracy is greatly improved, and the training time and recognition time are greatly reduced. The convolutional neural network is trained repeatedly until the parameters and weights are determined by the convolutional neural network, which can achieve the processing accuracy of the operating state data of circuit breakers.

2.3 Implement running status monitoring

After training the convolutional neural network determines the parameters and weights, it can monitor and process the operating state data of circuit breakers. The data collected by the sensor are pre-processed into the convolutional neural network, and the powerful learning ability of the convolutional neural network is utilized to carry out feature extraction, recognition and other operations on the input data [10]. The convolutional neural network will determine the state data of circuit breaker non-full phase operation and input it into the database. Because of the circuit breaker the open-phase running short time does not affect their normal work, therefore, to input data in the database are classified, according to the set classification standard, classification algorithm firstly will seriously affect the circuit breaker working data classification, sent to the circuit breaker control module, control processing, in order to avoid circuit breaker will not work, will affect the safety of the work environment. After sending the data that seriously affects the operation of the circuit breaker to the operation control module in the circuit breaker, the input data is monitored in real time in the database. Since the sensor is constantly measuring the working data of the circuit breaker when it is working, the input data of the convolution-neural network should be classified and searched in real time in the database. Fast processing of circuit breaker running state data through convolutional neural network, accurate transmission of circuit breaker running state data to circuit breaker controller, timely control of circuit breaker running state, so as to complete the monitoring of circuit breaker non-full phase running state.

3. Verify the performance of the monitoring method

In order to verify that the deep learning-based non-full phase monitoring method of circuit breaker can accurately, timely and effectively monitor the non-full phase operation of circuit breaker, a comparison experiment is designed with the traditional monitoring method. The following are the experimental procedures and results.

3.1 Experimental steps

In practice, it is difficult to generate the same fault data manually because of the different causes of circuit breaker faults, which will affect the accuracy of the comparison experiment. Therefore, the data collected by the sensor when the circuit breaker is not running in full phase is used as the experimental
variable. In the experiment, a computer simulation is used to simulate the data collected by sensors placed in each component under non-full phase operation of circuit breakers. Taking the traditional monitoring method as the control group and the deep learning based monitoring method designed in this paper as the experimental group, the computer simulated data are processed and monitored by two monitoring methods respectively. By comparing the monitoring accuracy of the two monitoring methods, the advantages and disadvantages of the two monitoring methods can be judged.

3.2 Experimental results
The two monitoring methods monitor the non-full phase operating state data of circuit breakers simulated by computer, and the comparison of monitoring accuracy is shown in figure 3.

![Fig. 3 comparison of monitoring accuracy of the two methods](image)

According to the monitoring accuracy data in figure 3, the monitoring accuracy of the experimental group on the non-phase operation state of circuit breakers is significantly higher than that of the control group. According to the recorded values, the values of the experimental group are nearly 10% higher than those of the control group on average, indicating that the monitoring method of the experimental group is superior to that of the control group. That is to say, compared with the traditional monitoring method, the deep learning based non-full phase operation monitoring method proposed in this paper can monitor the non-full phase operation of circuit breakers more accurately and effectively, and make up for the shortcomings of the traditional monitoring method in monitoring the non-full phase operation of circuit breakers. In conclusion, the comparison experiment proves that the circuit breaker non-full-phase operation state monitoring designed in this paper is more advantageous and can be popularized.

4. Conclusion
In this paper, the learning property of convolutional neural network is used to monitor the non-full phase running state of circuit breakers. Through the comparison with the traditional monitoring method, it is proved that the monitoring method proposed in this paper can monitor the non-full phase running state of circuit breakers quickly and accurately, and has more advantages. The non-full phase operation of circuit breakers will bring hidden dangers to the whole operating system. Therefore, in the future research progress, new technologies and theories still need to be paid attention to to monitor the non-full phase operation state of circuit breakers.

Reference
[1] Zhu zijiao, Yang Tao, Wang huifang ,Huang xiaoming. Calculation method and protection scheme of power plant non-phase operation electricity volume [J]. Journal of power system and automation, 2018, 30(10):101-107.
[2] Ge baojun, Yin jiwei, Tao dajun, et al. Effect of YNd and Yd transformer wiring group on non-phase running current of generator [J]. Journal of electrical machinery and control, 2017, 21(4):95-104.
[3] Wang shaohuai, Li jianming, Yan chenfan. A remote monitoring scheme for circuit breaker with leakage protection in Taiwan area [J]. Electrical measurement and instrumentation, 2017, 54(3):116-119.
[4] Liu ronghai, Yang yingchun, Cheng lifeng, et al. Simulation and stress analysis of spring operating mechanism of CT14 high voltage circuit breaker based on ls-dyna [J]. High voltage appliances, 2017(10):35-41.

[5] He yigang, Wang Tao, Shi tiancheng, Tong jin. Research on transformer state monitoring method based on RFID sensor tag and deep learning [J]. Journal of electronic measurement and instrumentation, 2018(9):72-79.

[6] Yu xiaojun, Liu zhiyuan, Yu xiaoyan, et al. Circuit breaker non-full phase protection method based on dual position relay [J]. Power system protection and control, 2018(1):138-142.

[7] Jiang zhihan, Ma yingxin, Gao Xu, et al. Reliability analysis and secondary circuit improvement of three-phase inconsistent protection of circuit breakers [J]. Power system automation, 2017, 41(11):169-172.

[8] He rufei, Li heting. Research on new non-full phase protection criterion for generator end circuit breakers [J]. Power system protection and control, 2018, 46(17):174-179.

[9] Liang zhenfeng, Li wenrui, Zhang huizhi, Kang xiaoling. Line parameter calculation using fault recording data of incomplete phase operation [J]. Journal of xi'an jiaotong university, 2018, 52(12):111-116+141.

[10] Li Yi, Jiang Hao, Gong fugao, et al. Research on online monitoring system of intelligent circuit breaker [J]. High voltage appliance, 2017(10):19-23.