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Research on Fault Diagnosis and Transient Stability Evaluation of Power System Based on Machine Learning

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Abstract: In recent years, with the increasing scale and complexity of power systems, traditional fault diagnosis and stability assessment methods have been unable to meet the actual needs. Therefore, it is of great significance to use machine learning technology to solve the problem of fault diagnosis and transient stability evaluation of power system. In the power system fault diagnosis, machine learning algorithm can automatically identify and predict the possible fault types in the power system by learning and analyzing a large number of historical fault data, improve the accuracy and efficiency of fault diagnosis, and reduce the impact of faults on the power system. In view of this, based on the power system fault diagnosis method and the power system transient stability evaluation method, the power system fault diagnosis and transient stability evaluation under the background of machine learning are deeply studied.

1. Introduction

Power system is an important infrastructure in modern society, and its safe operation is very important to ensure the stable development of social economy. However, due to the influence of many factors, the power system often fails, which leads to the stability of the system. Fault diagnosis and transient stability evaluation are the key to ensure the safe operation of power system. Traditional fault diagnosis and transient stability evaluation methods are limited and cannot meet the needs of practical applications. Therefore, the purpose of this study is to improve the fault diagnosis and transient stability evaluation methods of power system by using machine learning algorithms, so as to provide support for the smooth operation of power system.

2. Method of fault diagnosis and transient stability evaluation of power system

2.1 Power system fault diagnosis methods

In order to ensure the stability, safety and reliability of the power system and reduce the probability of problems, it is necessary to strengthen fault diagnosis and find the problems in the operation of the system in time. At present, there are many fault diagnosis methods commonly used in power system. For example, fault phenomenon analysis: we can observe and record the fault phenomenon, including the burning of power equipment, voltage abnormality, etc., to understand the nature of the fault and the reason for the emergence of the fault; another method is the fault elimination method: in accordance with the fault phenomenon and the characteristics of the equipment, gradually eliminating the possible points of failure, through the way of gradual tests and inspections, to make clear the point of failure, and on the basis of the understanding of the cause of the problem, to take a feasible way to repair it; the next is the fault simulation method: through the computer equations or actual simulation and other methods, simulating the operation of the power system, observing and analysing the system's response to the different fault conditions, so as to find out the point of failure. Fault identification method: Using the monitoring equipment and data of the power system, through the in-depth analysis of the system parameters and status, the potential fault point is accurately identified, and the use of feasible solutions and processing; Expert system method: Artificial intelligence technology and expert system are used to build a fault diagnosis knowledge base of power system, and the fault location can be quickly found out through comparison and analysis with the input data of the system [1].

2.2 Transient stability evaluation method

During the operation of power system, transient stability evaluation is the most important thing, which is mainly used to evaluate the stability of the system in the transient process. The commonly used methods include equivalent model method, direct method, spatial decomposition method and substation method. The specific analysis is as follows:

2.2.1 Equivalent model method

For the equivalent model method, the power system is abstracted into an equivalent model, and the transient stability of the power system is calculated through the model. This method is widely used in large-scale systems and can evaluate the stability of the system in a short time [2].

2.2.2 Direct method

The method is to solve the dynamic equation of the power system and obtain the stability of the system in the transient process. The direct method is accurate but computationally intensive, so it is suitable for small-scale systems.

2.2.3 Substation analogy

In this method, the substation in the power system is equivalent to a constant power load, and the system stability is accurately calculated through the equivalent model [3].The substation analogy can simplify the tedious calculation process, and is more suitable in the substation dense area, and can obtain good results.

2.2.4 Spatial decomposition method

This method divides the power system into several regions, evaluates the stability of each region separately, and then comprehensively evaluates the reliability of the system. The spatial decomposition method can comprehensively consider the distribution characteristics of the system, and the application effect is good in large-scale systems.

3. Advantages of power system fault diagnosis and transient stability evaluation based on machine learning

In the process of fault diagnosis and transient stability evaluation of power system, reasonable application of machine learning algorithm can present the following advantages:

3.1 High degree of automation and precision

The machine learning algorithm can automatically analyze the data of the power system and identify and diagnose faults without manual operation, which can improve the efficiency and accuracy of fault diagnosis [4].In addition, this algorithm is trained by using a large amount of historical data to learn the patterns and rules of different engineering types in the power system, provide accurate fault diagnosis results, and reduce the problem of false positives or missing positives.

3.2 Real-time monitoring and multidimensional data analysis

The machine learning algorithm can monitor the operating status of the power system in real time, diagnose and evaluate faults according to the real-time data, discover and solve potential faults and problems in time, and improve the operational reliability and stability of the power system. At the same time, the algorithm can also analyze multiple dimensions of data, including current, voltage, power and other parameters, which is helpful to comprehensively evaluate the transient stability of power systems and quickly find hidden problems in big data.

3.3 Intelligent decision support

Power system fault diagnosis and transient stability assessment based on machine learning can provide intelligent decision support for relevant personnel. By analyzing historical data and on-site real-time data, the system can give targeted suggestions and optimization methods to help personnel quickly manage and maintain the power system and promote the improvement of system operation reliability.

4. Application of machine learning in power system fault diagnosis

Machine learning, an important branch of artificial intelligence, is an interdisciplinary subject involving statistics, introduction, algorithm complexity theory and other fields. The application of machine learning in the fault diagnosis of power system can improve the accuracy of diagnosis, summarize and summarize with the help of computers, and accurately judge and predict faults by building models.In the process of power system engineering diagnosis, for the application of machine learning, the specific process is as follows:

4.1 Data collection and preprocessing

Collect all kinds of data during the operation of the power system, including voltage, current, power and other parameters, and collect equipment operating status data. All kinds of data collected should be cleaned and processed in a timely manner, such as data denoising, data smoothing, data alignment and other operations, so that the quality and consistency of data can meet the established requirements [5].

4.2 Feature Extraction

We can extract useful features from the preprocessed data to describe the operational status and equipment performance of the power system. These features can include frequency, phase, power factor, etc.

4.3 Simulation Training

We can also choose machine learning algorithms suitable for power systems or diagnostics, including support vector machines, decision trees, neural networks, etc. At the same time, the model is trained by using the data after preprocessing and feature extraction.

4.4 Fault Diagnosis and Prediction

The trained model is applied to fault diagnosis of the new power system data, and the data is input into the model. The model makes judgment according to the learned rules and characteristics, and gives the cause or classification of the fault. Based on historical data and existing models, machine learning algorithms are used to predict power system failures. By monitoring real-time data of the power system, possible failures of the system are predicted and timely repair or prediction is taken in a targeted way.

During the fault diagnosis of power system, the machine learning algorithm can be properly applied to detect the fault of power system quickly, and the data reflecting the operation quality of power system can be obtained directly or indirectly. Through the judgment and prediction of the data, the whole power system is monitored and the specific location of the fault is defined. At the same time, through machine learning algorithms, people can summarize and analyze the data and establish mathematical models. The faults in the power system are very different, and the fault modes are also very different. Therefore, it is necessary to collect the fault data sets in the corresponding mode in a centralized manner and input a large number of data sets into the machine learning algorithm model with the help of sensors. After repeated training and learning, the fault points can be accurately determined and finally resolved in a feasible way to improve the efficiency and accuracy of fault diagnosis. The hidden trouble will be contained at the root, so that the power system is always in a stable and efficient operation state.

5. Transient stability evaluation and analysis based on deep neural networks

5.1 Deep Learning

Deep learning is a kind of machine learning algorithm based on the theory and method of artificial neural network model. Through multi-level neural network structure, it simulates the connection between human brain neurons and the signal transmission process, and realizes high-level abstraction and representation learning of relatively complex data. In deep learning, deep neural network is a more common model, which is composed of multiple neural network layers, each layer contains multiple neurons, each neuron receives the output of the previous layer as input, and converts it into output through activation function. By constantly adjusting network parameters, deep neural network can automatically learn the features of input data. It can help people efficiently complete a variety of tasks, including prediction, classification, and so on.

Transient stability refers to the ability of power system to maintain stable operation after being subjected to external disturbance. By learning and analyzing the operation data of power system, the deep learning model can reasonably predict the transient stability of the system and provide reference and decision data for the operation of the system. In the process of application of this method, the deep neural network may be temporarily unstable due to the interference of data incompleteness, noise and other factors, resulting in inaccurate network output results. To solve this problem, the stability of the network can be improved by adding training data, adding regularization items and adjusting network structure. Or we can use optimization algorithms, such as adaptive learning rates, to improve the stability of the network.

5.2 Deep neural network model

At present, deep neural networks are widely used in various fields of power system. In the process of using deep neural network to evaluate transient stability of power system, it is necessary to construct the model scientifically, collect and preprocess the data.

5.2.1 Data collection and preprocessing

In the process of model construction, the transient data of the system, including the time series data of input and output variables, should be collected first. These data can be obtained through self-experimental measurements or simulation. After that, the collected data is preprocessed, such as data cleaning, normalization and feature extraction, so as to achieve the best quality and applicability of the data.

5.2.2 Network structure design

We can also choose the appropriate neural network structure to build the model, commonly used structures include multi-layer perceptron, convolutional neural network, recurrent neural network, etc. According to the characteristics and needs of specific problems, the neural network is selected to ensure the feasibility and rationality of the model construction.

5.2.3 Parameter Settings

People use it to determine parameters in the network, including learning rate, regularization parameters, activation functions, etc. These parameter values will have a direct impact on the performance and stability of the model, so it is necessary to ensure the rationalization of the Settings.

5.2.4 Model training

The pre-processed data is used to train the neural network model, and the weight and bias of the network are updated by the backpropagation algorithm to ensure that the model can fit the data efficiently and quickly in a short time.

5.2.5 Model evaluation and optimization

The test data is used to evaluate the trained model, and the accuracy, accuracy and recall rate of the model are calculated accurately. In the process of model evaluation, methods such as investigation and verification can be adopted. At the same time, the model can be optimized according to the evaluation results, and the network structure and parameter Settings can be adjusted to ensure the overall improvement of model performance and stability.

5.3 Analysis of numerical examples

Based on the analysis of deep neural network model and deep learning, in this study, Python language is used and Keras is used as the framework of deep learning. An AC-DC hybrid system is used as the test system of this paper, and the PSD-BPA program based on PSDEdit-PSD platform is applied to simulate and obtain the required raw data. Then, the calculation formula of the original feature set is programmed through excel table, and the simulation data is brought into the original sample set and stored. At the same time, the calculation example is analyzed, and the formula used is as follows:

$$P_{LA} = \frac{F_{us}}{N_{testing}}$$

$$P_{FA} = \frac{F_s}{N_{testing}}$$

$$P_{ACC} = \frac{T_s + T_{us}}{N_{testing}}$$

In the formula, T_s、F_{us} represents the number of correctly and incorrectly classified transient stable samples; T_{us}、F_s representative is the number of transient destabilized samples that are correctly and misclassified; $N_{testing}$ represented is the total number of test samples；The leakage of alarm rate P_{LA} represents the proportion of the number of samples that wrongly judge the stable samples as unstable samples to the total number of test samples; Misalarm rate P_{FA} represents the proportion of the number of samples that wrongly identify the unstable samples as stable samples to the total number of the samples tested；Evaluation accuracy P_{ACC} It represents the proportion of the number of samples correctly classifying stable and unstable samples to the total number of tested samples.

In the research, the deep neural network model is calculated by CPU, and the number of layers of the deep neural network model is determined by trial-and-error method. The number of neural units in each layer is reduced layer by layer. Relu activation function is used in the hidden layer, and softmax function is applied in the classification process of the output layer. At the same time, in order to improve the defects of the previous gradient descent algorithm, we choose to use adam algorithm to improve the deep learning algorithm.

In the process of transient stability evaluation of power system using deep neural network, hyperparameters are very important. In this study, emphasis is placed on the selection of introduction rate, batch training sample number and iteration number of hyperparameters.

The influence of different initial learning rates on the evaluation accuracy of the test sample set by the deep neural network model is analyzed and compared, as shown in Table 1.During the training of the adam algorithm, because the learning rate can be automatically adjusted to adapt to different parameters, the classification accuracy of the adam algorithm model will not be greatly interfered with during the selection of the initial learning rate. Through multiple simulation experiments on different learning rates, the learning rate learning_rate=0.001 is finally selected for the consideration of accuracy and loss function.

Table 1: Comparison of the accuracy of the different learning rates

learning rate	Test the sample set accuracy
0.001	99.33%
0.005	98.57%
0.01	99.03%
0.05	98.62%
0.1	98.75%
0.5	98.92%
1	98.63%

The size of the batch training samples will have a direct impact on the optimization effect and speed of the deep neural network model. If the number of batch training samples is too small, the loss function will not converge, and the training speed will also decrease, as shown in Figure1.

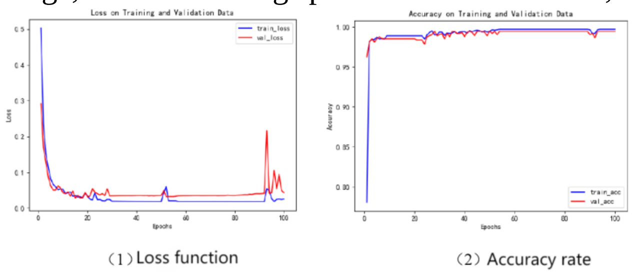

Figure 1: Loss function and accuracy change for the number of small-batch training samples

If the number of batch training samples is too large, the number of iterations required will increase with the same accuracy, and the network will converge to the local optimum, as shown in Figure 2.

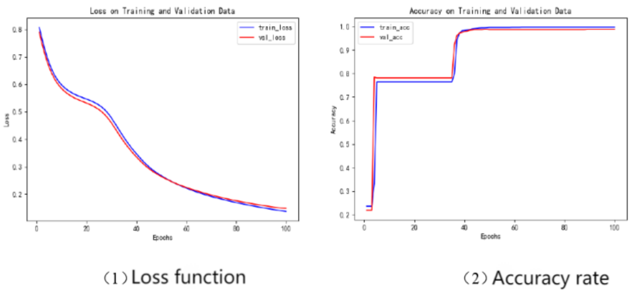

Figure 2: Loss function and accuracy change of the number of training samples in large batches

After several simulation experiments, the number of batch training samples was 20. Specifically, as shown in Figure 3, when the number of iterations is close to 100, the change curve of the loss function and accuracy stabilizes, and no fitting phenomenon occurs. Therefore, the number of iterations is selected as 100.

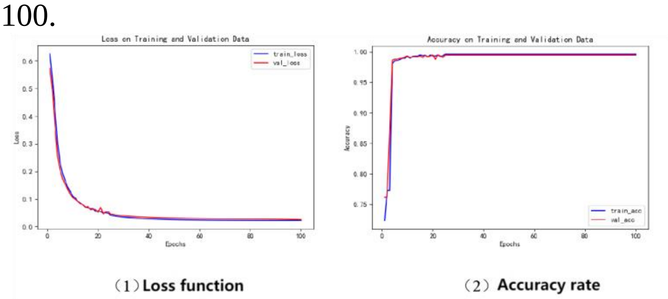

Figure 3: Loss function and accuracy change of the iterative process of the deep neural network model training

Combined with the calculation of the above formula, the accuracy of different model classifiers was compared, as shown in Table 2.By analyzing the data in Table 2, it can be seen that the evaluation accuracy of deep neural network model (DNN model) is the highest, 99.33%, followed by PCA-SVM model, 98.53%, and BP neural network is the lowest, 94.36%.The simulation time is 0.77s higher than BP neural network. Overall, the deep neural network model has good performance, high accuracy, strong generalization ability, and can take into account the accuracy of evaluation.

Table 2: Comparison of accuracy of different models

classifier	P_{ACC} /%	P_{LA} /%	P_{FA} /%	time/s
BP neural network	94.36	3.44	2.20	15.12
ELM	94.78	3.14	2.08	14.63
DT	95.67	2.56	1.77	14.35
standard SVM	95.82	2.15	2.03	14.25
PCA-SVM	98.53	0.56	0.91	67.23
DNN	99.33	0.28	0.39	14.89

6. Conclusion

In summary, in the process of fault diagnosis and transient stability evaluation of power system, the reasonable application of machine learning algorithm can learn and analyze the historical operation data of power system, predict the transient stability of power system under different fault conditions, and take corresponding measures in advance to ensure the stable operation of power system. Therefore, in the future development, we should pay attention to the research and utilization of machine learning algorithms, deeply integrate with the power grid industry, actively respond to the failure problems during the operation of the power system, and improve the operation efficiency of the power system.

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