Transformer optimization system design based on deep learning and evolutionary algorithm

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Abstract: A single shallow learning algorithm cannot fit the characteristics of high-voltage reactors well. Aiming at the above problems, this paper uses the error back propagation neural network and the particle swarm algorithm optimized by adaptive inertia weight to optimize the combined prediction model B for data training, verification and testing are carried out to achieve the purpose of effectively reducing the manufacturing cost of high-voltage reactors. Through experimental verification, the maximum error between the predicted value and the true value is 2.9%, and the minimum error is 0.05%. This provides certain technical support and inspiration for future devices such as optimizing high-voltage reactors.

1. Introduction

In recent years, scholars and experts from different countries have successfully applied algorithms in the optimal design of power transformers[1]. Research on the application of intelligent systems in the design of power transformers, such as the study of the application of intelligent systems in the design of power transformers by Geromel Luiz H.[2], Wang Zhurong's genetic optimization of special transformers[3], and Duan Houfeng used genetic algorithm BP neural network to diagnose transformer faults[4], Jin Ming et al. used genetic annealing algorithm to optimize the design of power transformers. It can be seen that the use of algorithms to achieve the optimal design of high-voltage reactors has become an effective means. Based on the theoretical basis of high-voltage reactor design, this paper establishes a mathematical model of the reactor, and describes the reactor design problem as a mathematical programming problem. The calculation program searches automatically and selects the relatively optimal design plan.
2. System overall design

2.1 BP neural network
BP neural network is the most common artificial neural network model, it is named because the training algorithm propagates back according to the error [5]. The topological structure diagram of BP neural network is shown in the figure below.

![Figure 1: Topological structure of BP neural network](image)

After such continuous learning, training, and modification of the calculated weights, until the final calculated error meets the requirements, or the number of cycles exceeds the set value, some parameters need to be reset to adjust the network and retrain. The specific process is shown in the figure below.

![Figure 2: The specific process of BP neural network](image)
3. Algorithm research and implementation

3.1 The specific steps of the BP neural network algorithm are as follows:

(1) Initialization data: The input and output of the neural network form a sequence, denoted as \((X, Y)\). From this sequence, we can get the number of nodes in the input layer, output layer and output layer of the network as \(n, l, m\), then initialize the weights and thresholds, set the connection weights between the input layer and hidden layer neurons to be \(W_g\), The connection weight between the hidden layer and the output layer neurons is \(W_{jk}\), The thresholds of the hidden layer and output layer are \(a\) and \(b\) respectively. Finally, give the neuron activation function of the neural network \(f(x)\) and learning rate \(\eta\) [6].

(2) Calculate the output of the hidden layer:

\[
H_j = f(\sum_{i=1}^{n} W_{ij} x_i - a_j) \rightarrow j = 1, 2, L, l
\]  

(3) Calculate the output of the output layer: BP neural network predicted output \(O_k\) is

\[
O_k = \sum_{j=1}^{l} H_j \omega_{jk} - b_k \quad (k = 1, 2, L, m)
\]  

(4) Calculate the error, and calculate the prediction error \(E_k\) of the network as:

\[
E_k = Y_k - O_k \quad (k = 1, 2, L, m)
\]  

(5) Update weight: Among them, \(E_k\) is the learning rate of the neural network.

\[
w_{ij} = w_{ij} + \eta H_j e_i (j = 1, 2, L, l; k = 1, 2, L, m) \quad (5)
\]

\[
w_{ij} = w_{ij} + \eta (1 - H_j)^{x(i)} \sum_{i=1}^{m} \omega_{jk} e_i (i = 1, 2, L, m; j = 1, 2, L, l) \quad (6)
\]

(6) Update threshold:

\[
a_j = a_j + \eta H_j (1 - H_j) \sum_{k=1}^{m} \omega_{ij} e_k (j = 1, 2, L, l) \quad (7)
\]

\[
b_k = b_k - e_k (k = 1, 2, L, m)
\]

(7) Determine whether the algorithm iteration end condition is met, if not, go back to step (2).
3.1.1 Application of BP neural network algorithm in this article

First, take the corresponding parameters of the high-voltage reactor explored in this article as input X and the output result as Y, construct a sequence (X, Y), and import it into the neural network for training. In the neural network of this article, 4 hidden layers are taken, and the number of nodes in each hidden layer is set to 10. Figure 2 below shows the structure of the neural network of this article, from left to right are input signal, input layer, hidden layer, hidden layer, hidden layer, output layer, output signal [7].

![Figure 3 Neural network structure diagram](image)

3.2 Application of particle swarm algorithm in this paper

3.2.1 Steps of particle swarm algorithm

As an optimization tool, the first step of particle swarm optimization is to clarify the range of the particle population and initialize the speed and position of all particles. Then the particles are evolved according to the evolution rules. The speed and position of each particle are determined by the last evolution speed and position, as well as the local optimal solution and the global optimal solution. After multiple optimizations, the global optimal solution can be found. The flow chart of the particle swarm algorithm is shown in Figure 3 below.

![Figure 4 Flow chart of particle swarm algorithm](image)

The optimization steps of particle swarm are as follows:

1. Initialize the particle position and velocity. Randomly generate n particles in the D-dimensional search space, initialize the positions and velocities of all particles, and the maximum speed of the particles during the search \( V_{max} \). Make settings, \( V_{max} \). Generally artificially set according to specific
problems, and its role is to coordinate global and local search capabilities[8].

(2) Evaluate all particles according to the fitness of the constraint and the fitness of the objective function.

(3) Record two extreme values, record the current individual extreme value $P_{besti}$ and objective function value $f(P_{besti})$ of particle $i$. Determine the overall extreme value $g_{besti}$ from $P_{besti}$, and record the objective function value $f(g_{besti})$ corresponding to $g_{besti}$.

(4) Update, particle $i$ gradually flies to $P_{besti}$ and $g_{besti}$ to update the particle position.

(5) Calculate the corresponding objective function value after each particle is updated, and judge whether $P_{besti}$ and $g_{besti}$ need to be updated.

(6) Determine whether to converge. If the preset maximum number of iterations is reached or the error requirement is met, the program terminates; otherwise, it returns to step (4).

4. Test results and analysis

By constructing the BP nerve to build the high-voltage series reactor relationship[9], and then using the particle swarm algorithm to find the optimal solution, on the premise of not destroying the performance of the reactor[10], under the control of the coil temperature rise and the iron core temperature rise, the parameter with the lowest total manufacturing cost of high voltage reactor. The result of the calculation is shown in the figure below:

Figure 5 mse mean square error graph

Figure 6 Training State display diagram
In regression, the true value is represented by the abscissa, the actual value is represented by the ordinate, the straight line represents the true value, and the small circle represents the predicted value, respectively representing the training sample, the verification sample, the test sample, and the overall prediction. Finally, the overall data is subjected to regression coefficient changes [11]. The closer the R value is to 1, the better the model. According to the analysis of the graph and table, the maximum error between the true value and the predicted value is 2.9%, and the minimum error is 0.05%.

### 5. Conclusions

It can be seen from the experiment that after 100 iterations, the smallest error between the true value and the predicted value can be regarded as close to 0.05%, and the largest error is 2.9%, which can greatly reduce the manufacturing cost of the high-voltage reactor and the pre-set goal was fulfilled well. Of course, this article is not enough to study the external data affecting high voltage reactors, the data processing is not complex enough, and the innovation of the model needs further study. But in general, this paper verifies the accuracy of the combined model through experiments and provides new ideas for future passenger flow research.

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