# Research on Application of Artificial Neural Network in the Network Loss Calculation of Power System

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*Abstract*—**Power losses in an electrical supply grid have significant economic implications for the performance of power system. In a vertically integrated power structure, the system operator can minimize the total network losses by adjusting active and reactive outputs of all generators connected the system according to the results of optimal power system. In a competitive environment, restructuring of the power system leads to unbundling of generation, transmission and distribution into various autonomous business units. So sharing of the network losses is no longer a simple job and its allocation among end-users is a challenging job. Based on the technology of artificial neural network (ANN), this paper presents a new approach for network lose calculation of power system. This method can realize complicated nonlinear mapping relations after training, which needs not write out the complex relationship between input and output, and so it reduces the amount of calculation and speeds up the calculation greatly. An calculation example showed its feasibility.**

*Keywords*—**artificial neural network, network loss, power system**

## I. INTRODUCTION

The power loss is one of the important economical indicators in electrical power system. In theory the instantaneous active power loss of power system can be obtained by power flow calculation and then the energy loss is got with time integral. But in fact, a electrical power system is a giant complex man-made system and the use of various nonlinear equipments results in not only the nonlinearity of system but also distort waveforms, complex the progress of the analysis and control, which lead to the power loss is hard to obtain. Artificial neural network can simulate the nonlinear relationship between a power system loss and its characteristic parameters and realize the nonlinear mapping between input and output without indicating the complicated relations. In order to improve calculation accuracy, samples are classified with Kohonen self-organize system before they are trained and so as to get the special ANN model used for the same type of power loss calculation. By training the input data in this special model, the power system loss can be obtained.

The calculation of system loss based on ANN, as other applications based on ANN, demands sufficient and representative samples for training. Experiments results show the ANN can simulate the complex nonlinear relationship between system loss and characteristic parameters and the method based on ANN has certain universality [1,2,3].

## II. MODEL OF SYSTEM

The power distribution loss is related to many factors within a certain period, such as active component, reactive component, as well as the capacity of transformer, circuital length, number and sectional area of distribution transformer, and so on[4]. In this case ,only the former four factors are considered as neuronal input.

### *A. Raw data procession*

In electrical power system, each variable has its range extension and unit. In order to avoid the influence of dimension, all variables are normalized according to the following equations.

$$Z_{ij} = (X_{ij} - X'_j) / \sigma_j \tag{1}$$

$$X'_j = \sum_{i=1}^{n} X_{ij} / N \tag{2}$$

$$\sigma_j^2 = \sum_{i=1}^{n} (X_{ij} - X'_{ij})^2 / (N-1) \quad i, j = 1, 2, \ldots N \tag{3}$$

Where, n is the number of the independent variables, N is the number of the training samples, $X_{ij}$ is the independent variable.

### *B. Sample Classification*

Simulations of relationship between independent variable and induced variable based on BP model require multi-layer implication nodes and quite long time for samples training. But after the data are classified, samples for training in a given classification reduced and training time is lessened.

During the course of training, if some node vector of neuron is matched to the input value, these neurons and the neurons neighbor to them are selectively activated and then the neural network change from random sequences to arranged sets according to mapping properties, which means neurons in a specific area are sensitive to a given input signal.

### *C. BP method*

BP method can minimize the difference the sum of squares of errors between reality value and expected value by weight vectors and thresholds adjustment. In calculation of power loss, the transfer function of neuron knot is S function can be written as

$$f(x)=\frac{1}{1+\exp(x-\theta)} \quad (4)$$

Where: $x$ is the input of neuron, $\theta$ is the threshold

## III. GENERAL ALGORITHM

General algorithm includes training stage and application stage[5,6,7].

### A. training stage

1) Input of training sample set (independent variable and induced variable), independent variable data procession.

2) The samples are classified by Kohonen method as following:

Step 1: Network Initialization. Suppose at t moment, the connected weight from neuron i to neuron j is $w_{ij}(t)$ $(1\le i\le n-1)$, minimize the initial weigh vector in n knots to random value.

Step 2: Data Input. Assume the input value is $[x_0(t),x_1(t),...,x_{n-1}(t)]^T$ for node i, at t moment

Step 3:Calculate the distance between input and output node j and work out minimal distance following equation

$$d_j=\sum_{i=0}^{n-1}[x_i(t)-w_{ij}(t)]^2 \quad (5)$$

Step 4: Weight adjustment, return to step 2 and repeat the process if it is needed.

3) BP model Training as following:

Step 1: Initialize all weight coefficients and threshold.

Step 2: Input training samples.

Step 3: Work out the output data by input and weight coefficient and threshold. If sum of squares of errors between reality value and expected value is less than a given value the process stop, otherwise continues.

Step 4: Adjust weights and thresholds by error back propagation algorithm, which is described:

$$W_{ij}(t+1)=W_{ij}(t)+\eta\delta_j X'_i+\alpha[W_{ij}(t)-W_{ij}(t-1)] \quad (6)$$

$$\theta_j(t+1)=\theta_j(t)-\eta\delta_j+\alpha[\theta_j(t)-\theta_j(t-1)] \quad (7)$$

Where $w_{ij}$ is weight of connection of $i$ , $j$ nodes, and $H_j$ is threshold value of node $j$ after $t$ times circulation. If $i$ is node of hidden layer, we call $X'_i$ the output of node $i$ . If $i$ is node of input layer, we call $X'_i$ the input of node $i$ , $\eta$ is learning rate, $\alpha$ is parameter of impulse, $0<\alpha<1$ , when $j$ is node of output layer, then:

$$\delta_j=d'_i(1-d'_j)(d_j-d'_j) \quad (8)$$

where $d_j$ is the expected value of output of node $j$ . $d'_j$ is the calculating value of output of node $j$ .If $j$ is node of hidden layer, then:

$$\delta_j=X_j(1-X_j)\sum\delta_k W_{jk} \quad (9)$$

After finish calculation of formula, return to step 3.

### B. Application Stage

Step 1: Input characteristic parameters of lines for network losses calculation.

Step 2: Process the raw data of independent variable according former method.

Step 3: Identify the Neuron activated by input vector corresponding to the characteristic parameter of the given line and distinguish the category of the Neuron with the Kohonen model. If the Neuron does not belong to any existing category, identify the category of it's first-order neighbor neurons. If some of neighbor neurons belong to P category, the rest does not belong any category, determines the Neuron belongs to P category. But if some of it's first-order neighboring Neurons belong to A category, some of it belong to B category. We can determine the Neuron belong to A and B category according to weights.

Step 4: Calculate the network loss with BP neural network. If Neuron is determined to belong to several categories, calculate the network loss with corresponding BP neural network, Sum the production of the network losses and their respective weights to get the finally result.

## IV. CALCULATION EXAMPLE

The network loss of 22 lines in a given area has been precisely calculated and the results are used as samples. The work here is to find out the statistical rules of these 22 lines so as to realize the fast calculation of network loss of the remains lines. Supposed N=10.X1 is active power(KW • h), X2 is reactive power(KW • h), X3 is total capacity of distribution transformer (KW • A), X4 is total length of lines(Km), d is the total network loss(KW • h), d* is correspond to output of d in BP model, EA is absolute error (d-d*); EA is percentage of absolute error, EC is percentage of relative error, which satisfied EC=EA/d*; ES is absolute error sum of squares after the samples have been trained.

The result that 22 samples are classified following Kohonen model is showed in Table1.

TABLE1 22 SAMPLES ARE CLASSIFIED BY KOHONEN MODE

| category | The number of feeder |
|---|---|
| A | 3,6,8,15,18,22 |
| B | 1,4,9,13,17,20 |
| C | 2,5,7,11,21 |
| D | 10,12,14,16,19 |

When 4 similar categories BP models are trained, only one hidden layer is adopted, weight sand thresholds are uniform random number between -0.5 and 0.5. The raw data and the sorted data of 4 categories are shown in Table2~ Table4.

TABLE2 RAW DATA AND SORTED TABLE OF A CATEGORY

| The number of feeder | X1 | X2 | X3 | X4 | $d$ | $d''$ | $E_A$ | $E_c$ |
|---|---|---|---|---|---|---|---|---|
| 3 | 68.5 | 62.5 | 2534 | 12.9 | 4.620 | 4.851 | -0.231 | -0.048 |
| 6 | 82.6 | 90.8 | 4213 | 12.4 | 9.960 | 9.964 | -0.004 | -0.038 |
| 8 | 125.3 | 120.4 | 6800 | 21.5 | 8.120 | 8.123 | -0.003 | -0.036 |
| 15 | 190.3 | 123.4 | 7841 | 52.4 | 7.310 | 7.315 | -0.005 | -0.071 |
| 18 | 45.6 | 61.4 | 8512 | 22.6 | 7.620 | 7.615 | 0.005 | 0.063 |
| 22 | 104.9 | 41.2 | 6136 | 40.6 | 7.110 | 7.110 | 0.000 | 0.000 |

From Table2, it can be seen that absolute error of A feeder EA is 0.0413, relative error EC is 0.0427, absolute error sum of squares ES=0.01322 after the samples is trained.

TABLE3 RAW DATA AND SORTED TABLE OF B CATEGORY

| The number of feeder | X1 | X2 | X3 | X4 | $d$ | $d''$ | $E_A$ | $E_c$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 51.4 | 51.7 | 3080 | 12.7 | 4.390 | 4.503 | -0.113 | -2.574 |
| 4 | 148.5 | 15.4 | 6823 | 26.5 | 5.160 | 5.162 | -0.002 | -0.046 |
| 9 | 35.4 | 56.4 | 5214 | 98.3 | 5.821 | 5.820 | -0.001 | -0.023 |
| 13 | 45.1 | 74.2 | 7542 | 45.4 | 5.600 | 5.606 | -0.006 | -0.103 |
| 17 | 40.3 | 41.5 | 4825 | 28.3 | 7.240 | 7.243 | -0.003 | -0.037 |
| 20 | 148.4 | 24.2 | 3120 | 23.8 | 5.400 | 5.438 | -0.038 | -0.712 |

From Table3, it can be seen that absolute error of B feeder EA is 0.0272, relative error EC is 0.0593, absolute error sum of squares ES=0.0864 after the samples is trained.

TABLE4 RAW DATA AND SORTED TABLE OF D CATEGORY

| The number of feeder | X1 | X2 | X3 | X4 | $d$ | $d''$ | $E_A$ | $E_c$ |
|---|---|---|---|---|---|---|---|---|
| 10 | 15.9 | 20.5 | 1753 | 38.6 | 1.690 | 1.726 | -0.036 | -2.017 |
| 12 | 20.8 | 28.6 | 1123 | 30.3 | 1.320 | 1.214 | 0.106 | 8.006 |
| 14 | 32.4 | 45.6 | 2350 | 41.6 | 2.370 | 2.368 | 0.002 | 0.073 |
| 16 | 42.6 | 25.3 | 1350 | 36.1 | 4.100 | 4.121 | -0.021 | -0.518 |
| 19 | 27.5 | 27.3 | 3516 | 64.2 | 3.320 | 3.319 | 0.001 | 0.038 |

From Table4, it can be seen that absolute error of D feeder EA is 0.0332, relative error EC is 2.120, absolute error sum of squares ES=0.02564 after the samples is trained.

C is similar to D, ES=0.00028.

## V. CONCLUSION

Numerical calculation shows that the training precision can be improved by Kohonen network classification, Table 2~4 show the error sum of squares of 22 samples is 0.12562 while the result is 1.004 with regression method according to the same classification. Obviously the approach based on ANN for network loss calculation hold high accuracy.


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