Genetic Algorithm-Based RBF Neural Network
Load Forecasting Model

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ABSTRACT - To overcome the limitation of the traditional load forecasting method, a new load forecasting system basing on radial basis Gaussian kernel function (RBF) neural network is proposed in this paper. Genetic algorithm adopting the real coding, crossover probability and mutation probability was applied to optimize the parameters of the neural network, and a faster convergence rate was reached. Theoretical analysis and simulations prove that this load forecasting model is more practical and has more precision than the traditional one.
KEYWORDS- Load Forecasting; RBF Neural Network; Real Coding; Genetic Algorithm; Convergence Rate

INTRODUCTION

Accurate load forecast is economical, reliable and safe power system operation and planning basis, It is directly related to the planning and production of electrical power systems for short-term operation mode of arrangement. For a power system, the improvement of the safety and economic operation of power grids, and of the power quality, depend on accurate load forecast. Moreover, to development, load forecasting is a necessary condition for achieving the electricity market and have important theoretical and practical value.

Over the past few decades, scholars at home and abroad to power load forecast have a more thorough study[1-3], these studies can be divided into two categories: (1) the traditional load forecasting algorithm, such as time series, regression analysis, gray model. Such research is on the loading sequence patterns; (2) the modern load forecasting algorithm, neural networks, intelligent load forecasting expert system are introduced in the field, instead of the traditional method of load forecasting, to improve the accuracy of load forecasting.

Radial Basis Function neural network (RBF) as an important branch of neural network, has the best approximation and the best overall performance. These advantages have enabled the RBF neural networks in nonlinear time series prediction has been widely applied. Genetic Algorithms because of their extensive global optimization capability, are successfully applied on neural network, and so on. This paper will introduce RBF neural network into load forecasting [4-5], and use the genetic algorithm to optimize RBF network parameters, and achieved good results.

Before the establishment of RBF neural network load forecasting model, we must first understand the structure of the RBF neural network.

THE BASIC STRUCTURE OF RBF NETWORK

RBF is a three-layer neural network. The input layer is made up of the signal source node. The second tier is hidden layer, as described in its modules are based on the needs and problems. The third tier is the output layer, which responded to the role of imported models. If the network input modules is n, q and m is crackdown module and output modules, its topology is shown in Figure 1.
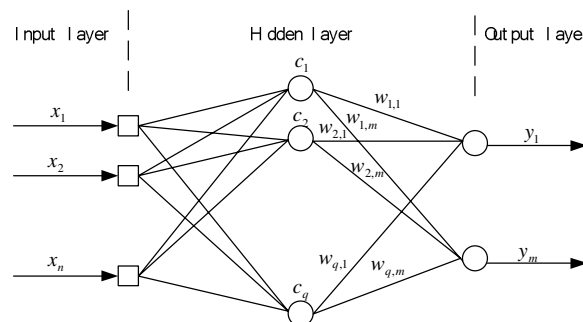
Fig.1 Topology of RBF Neural Network

RBF implied by the input space to transform the hidden space is non-linear, from the hidden layer and

output layer space to transform the output space is linear. The transformation function of hidden units is Radial Basis Functions, and the network can achieve the following mapping between the input and output :

$$y_i = \sum_{j=1}^{q} w_{j,i} \phi(\|x - c_j\|) \quad i = 1, 2, \ldots, m \quad (1)$$

Including $x = (x1, x2, \ldots x_m)^T$ is input vector, y_i is the output value for the i units, $w_{j,i}$ is the value from the j hidden units to the i output units. $\|.\|$ is Euclidean norm. $\phi()$ is radial basis functions, c_j is the central element vector of the j hidden units.

Radial Basis Function is a local distribution center of the radial symmetry of the non-negative non-linear attenuation function, Gaussian function is relatively common :

$$\phi(v) = \exp(-v^2 / 2\sigma^2) \quad (\sigma > 0, v \geq 0) \quad (2)$$

Theory shows that the Radial Basis Function networks, Radial Basis Functions $\phi()$ selected for the network performance impact is not significant. RBF network design and the training focus on determining the network structure. In which the number of the input and output modules are determined by samples of it, Pending the network parameters include the number of hidden units q, the center vector c, width parameter σ (Radial Basis Functions of this paper used Gaussian function), the network connecting value $w_{j,i}$, these parameters of the network to be determined is the key issue of RBF Network, needs to be completed through learning and training.

RBF NETWORK LOAD FORECASTING MODEL

Now load forecasting monthly as an example to establish RBF neural network model.

A. Load forecasting preparations

The preparatory work of Load forecasting, including two areas, first is the historical load data collection, should note that data integrity and non-repudiation, figures are accurate, reflect the normal state level, the separation of data has no abnormal items. Attention should also be paid to fill

data, and unreliable data to verify adjustment. Second, the load data preprocessing[6], make the abnormal data of historical information stable, as well as fill the missing data. In view of abnormal data, the method was used to deal with anomalies :

To set the historical data of load: $x_1, x_2, \ldots x_n$, if

$$x_i > \bar{x}(1 + 20\%), \text{then } x_i = \bar{x}(1 + 20\%), \quad \text{if}$$

$$x_i < \bar{x}(1 - 20\%), \text{then } x_i = \bar{x}(1 - 20\%)$$

B. Determination of RBF neural network model

To determine RBF neural network, first, it is necessary to determine the form of Radial Basis Functions, in this case, Radial Basis Function is Gaussian function, the form of RBF neural network is:

$$y_i = \sum_{j=1}^{q} w_{j,i} \exp(-\frac{\|x - c_j\|^2}{2\sigma^2}) \quad i = 1, 2, \ldots, m \quad (3)$$

Can be seen from the previous formula, the establishment of RBF neural network load forecasting lies in the selection of input and output variables, the determination of the number of hidden units, the selection of initial parameter and so on.

B.1 The selection of input and output variables

Load is a very complex system, there are many factors which will have an impact on the load changes. But too many factors to consider not only caused difficulties in modeling, but also brings problems such as computational complexity. Therefore, considering input variables should seize several factors that have the characteristics [7].

Load analysis based on historical data, we can see that, the changes of the electric load for a 12-month cycle. To reflect the characteristics, 12 different RBF network has been selected as the load forecasting model for the next year. In addition, the changes of load are often affected by the meteorological conditions, such as temperature, rain, humidity, etc, and the temperature factors also play a major role. Therefore, it has adopted the maximum temperature and minimum temperature as two neural network input. In short, the mathematical model can be used for load forecasting monthly could be expressed by

the following equation ,

$$x(t) = f(d_{T1}, d_{T2}, x(t-24), x(t-13),$$
$$x(t-12), x(t-3), x(t-2), x(t-1)) \quad (4)$$

In the formula, $x(t)$ as the output, the monthly load to forecast; d_{T1}, d_{T2} are the maximum and minimum temperature for the month; $x(t-i)$ is the load of the month i months before the month to forecast.

B.2 Determination of the number of hidden units

As in the use of neural network, we will find how to determine the number of hidden layer neurons. when the number of neurons is too little, it is unable to complete the task, when too many, it will increase computing time, make network generalization (Promotion) drop. At present, to select the number of hidden layers still has no fixed analytic or theoretical basis or theorem to determine. Based on several simulation experience we choose 8 as the number of neurons, 9 as the number of hidden layer neurons,1 as the number of the output layer neurons.

USING GENETIC ALGORITHM TO OPTIMIZE THE PARAMETERS OF THE NEURAL NETWORK

By the theory of pattern recognition, a linear separability problem in lower dimensional space can be mapping to high-dimensional space and it can be linear in the high-dimensional space. In a RBF network, the input of hidden layer is nonlinear (because the function of hidden layer is a nonlinear function) and the output of it is linear. And the output modules can be seen as part of a single-layer perception. So that as long as a reasonable choice of hidden units (the dimension of a higher dimension space) and its function ,we will be able to map the original problem to a linear separability question and solve it just as linear modules.

RBF network has two adjustable parameters, the central position c_j and variance, σ_j^2 (or the width parameter of function, σ_j), this time, The entire network has three adjustable parameters: the basic center position, variance and the right to export unit value.

The traditional method used in the training

programs are:1) the global parameters optimization is achieved by gradient descent algorithm;2)the center position is achieved by K-means clustering algorithm and the weight cost is achieved by Least square method, thus the whole neural network optimization is acquired.

The traditional training plan, either gradient descent algorithm or Least Square Method, not only had a slow convergence rate, but also was very likely to fall into local minimum points. Therefore a series of training plan appeared, such as Genetic Algorithms, immunity algorithm, etc. In all these methods, GA gained a lot of attention because of its unique biological background. Therefore, in this paper, a genetic algorithm was used to optimize the design of neural networks RBF[8].

A. Basic Genetic Algorithm

Genetic Algorithm comes from the natural law of survival of the fittest genetics and biotechnology, is a group operation. The operation targeted to individual groups of all, through choice, crossover and mutation operators produce a new generation of groups, Until the results are satisfactory. It is based on natural selection and natural genetics adaptive probability based on the iterative search algorithm. In the solution space, the genetic algorithm has more random search of solutions, and to identify the optimal solution. Due to the random genetic algorithm, a search of all solutions is possible, so they can find the global optimum.
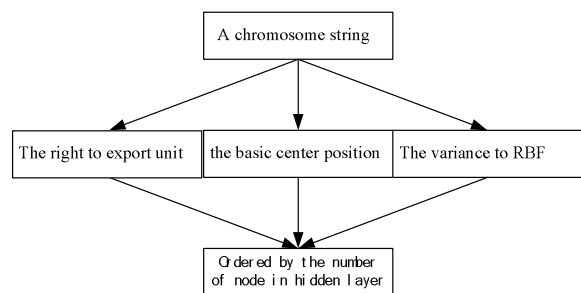

Fig.2 sketch map of real coding

B. Defined Coding Scheme

It is a complex multi-parameter optimization that Genetic Algorithm is applied to optimize the parameters (such as the right to export unit, radial basis function center and the variance to RBF) of the neural network [9]. If using binary coding, the coding

string is too long and the string should be translated to the real and Calculate the fitness, then the accuracy of the net is affected. So in this paper, the real coding is used. The right to export unit, radial basis function center and the variance to RBF is arranged by some order. The structure of the real coding is shown as Fig2.

C. Defined Fitness Function

The right to export unit value , the basic center position, the variance to RBF of chromosome were all assigned to the Network Structure. And the training samples were seen as the input and output of the net.

Therefore, the fitness function can be defined as ,

$$F(x) = \sum_{i}^{m} \frac{1}{\dfrac{\sum_{i}^{m}[y(k) - \hat{y}(k)]^2}{m}} \qquad (5)$$

$$\delta = \frac{\sum_{i}^{m}[y(k) - \hat{y}(k)]^2}{m} \qquad (6)$$

Where $y(k)$ is the Actual output and $\hat{y}(k)$ is the forecasting output. m is the number of input and output sample. and x is the chromosome. The optimal output is achieved based on the fitness function and δ which is the prediction error function.
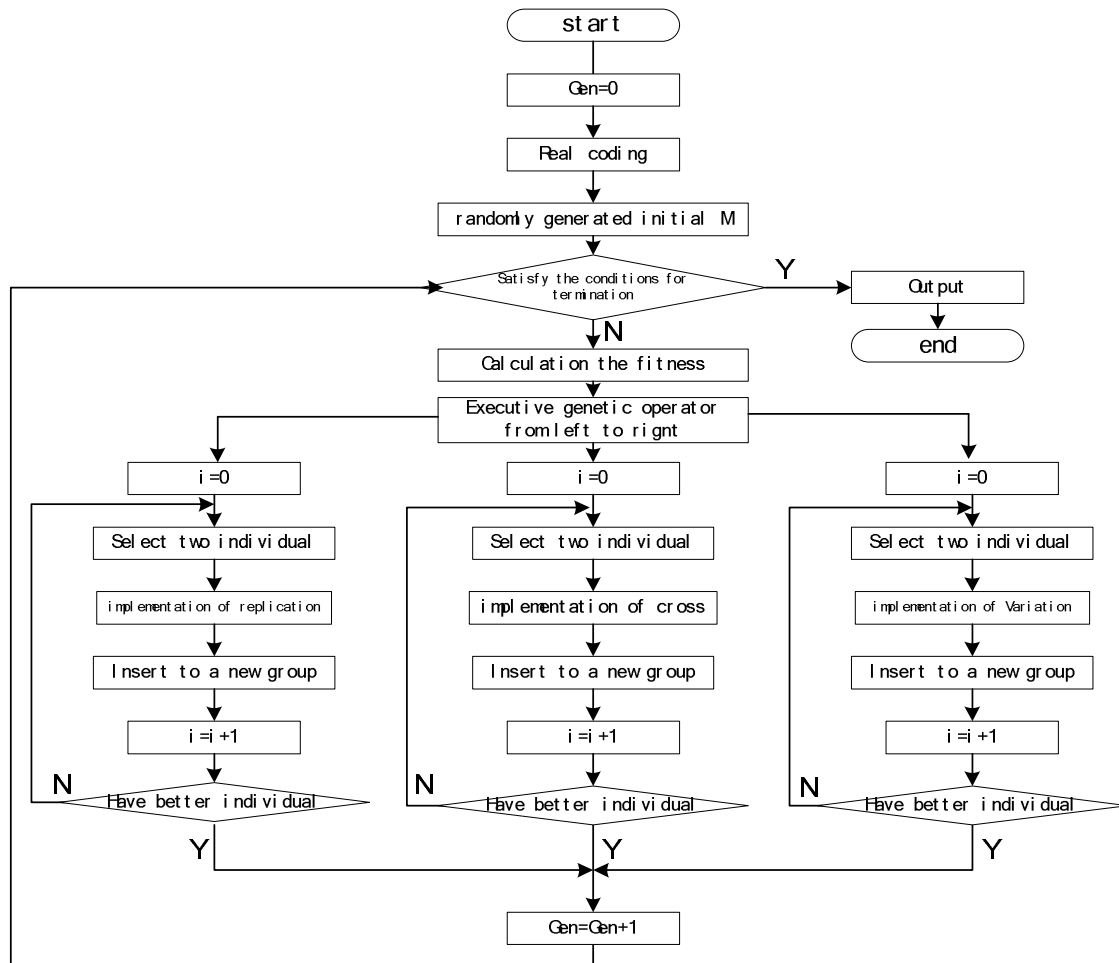

Fig.3 The Flowchart of Genetic Algorithms

D. Set Parameters of Genetic Algorithm

The genetic algorithm is affected by the crossover p_m and mutation rate p_c. If p_c is bigger, the speed of the new entity is faster. On the other hand, it is a greater possibility that the genetic model is damaged. If p_m is bigger, the genetic algorithm will become random search algorithm. On the other hand, p_m is too small to generate a new Individual. Therefore, the following way is used to adjust the crossover and mutation rate.

$$p_{c1} = 0.99 \times (1 - gen/G)$$
$$p_{c2} = 0.4 \times (1 - gen/G) \tag{7}$$

$$p_{m1} = 0.3 \times (1 - gen/G)$$
$$p_{m2} = 0.01 \times (1 - gen/G) \tag{8}$$

$$p_c = \begin{cases} p_{c1} - \dfrac{(p_{c1} - p_{c2})(f' - f_{avg})}{f_{max} - f_{avg}} & f' \geq f_{avg} \\ p_{c1} & f' < f_{avg} \end{cases} \tag{9}$$

$$p_m = \begin{cases} p_{m1} - \dfrac{(p_{m1} - p_{m2})(f_{max} - f)}{f_{max} - f_{avg}} & f \geq f_{avg} \\ p_{m1} & f < f_{avg} \end{cases} \tag{10}$$

where, g_{en} is the present multiply generation and G is a constant($G \geq gen$). f_{max} is the max fitness of the group and f_{avg} is the average fitness of the group. f' is the bigger fitness of the two crossover individual and f is the fitness of the variation Individual.

Through adaptive adjustments, there is a bigger crossover and mutation rate for the poor performance of the individual, on the other hand, the crossover and mutation rate of the good performance individual is determined by the fitness. With the increasing of the multiply generation, crossover and mutation rate will drop to facilitate the convergence.

By this analysis, the flowchart of the Genetic Algorithms applied to optimize the RBF can be designed as,

1) Set Evolution generation, Gen=0 and Give the initialization groups.
2) Estimates each value of P(Gen)
3) Select two individuals from P(Gen). After crossover and mutation of these two individuals , a new generation ,P(Gen+1) is achieved. And set Gen=Gen+1.
4) If the termination conditions (prediction accuracy conditions) are satisfied, then the algorithm is end. Otherwise it will transfer to 2)

The Flowchart of Genetic Algorithms is shown if Fig.3.

EXAMPLE ANALYSIS

Next a new load forecasting system basing on one city's month load was built, and the forecasting result of it was used to compare with the result of traditional grey model.

Table1 The Comparison of Load Forecasting Result

month	Actual value	RBF net		Grey model	
		Forecast	Relative error	Forecast	Relative error
1	139.60	141.23	1.17%	142.87	2.34%
2	104.14	107.32	3.05%	108.86	4.53%
3	162.26	158.96	-2.03%	167.55	3.26%
4	169.67	170.35	0.4%	166.70	-1.75%
5	185.75	187.26	0.81%	182.02	-2.01%
6	189.79	192.58	1.47%	195.45	2.98%
7	241.21	239.02	-0.91%	232.89	-3.45%
8	226.23	227.72	0.66%	229.08	1.26%
9	212.36	210.58	-0.84%	207.35	-2.36%
10	197.25	198.14	-0.45%	189.68	-3.84%
11	185.19	188.47	1.77%	193.19	4.32%
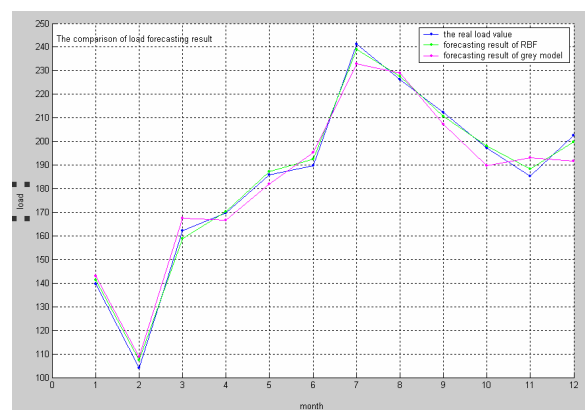
Fig.4 The comparison of load forecasting result

It can be seen from Figure 4 that the RBF network model based on genetic algorithms can be more accurate in load forecast. What's more, the prediction curve and the actual load curve were better curve fitting. Compared with the traditional gray model,

there is a great degree of improvement in the forecast accuracy, 3.05% to 5.38%.

CONCLUSION

In this paper, a new load forecasting system basing on RBF neural network was proposed, and genetic algorithm was applied to optimize the parameters of the neural network. The simulation results show that the forecasting accuracy and convergence speed of this model has been improved greatly. And it can meet the needs of load forecasting.

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