Transmission Line Insulator Leakage Current Online Monitoring and Early Warning Algorithm

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***Abstract*—Existing research insulator leakage current monitoring method, mainly when the leakage current increases more than alarm threshold, the alarm information, do not have leak current trend prediction function and can't estimate moving along with the change of time. So this paper tries to build a forecasting model based on Elman neural network structure, and use genetic algorithm to Elman weights and threshold optimization algorithm, is used for fitting complex nonlinear relationship between leakage current and the meteorological factors, so as to improve the prediction accuracy. Through the analysis of survey data, using historical data training and validation repeatedly, finally get a meet the requirements of the error forecasting early warning model, and combined with examples verify its effectiveness.**

***Index Terms*—Insulator; on-line detection; predict; Elman neural network; genetic algorithm (GA)**

I. INTRODUCTION

The online monitoring system for transmission line in most parts of our country is not perfect, and it does not have the function of real-time online assessment and future trend forecast for the line and equipment. However, the on-line monitoring technology of transmission line monitoring system can provide powerful technical support for the development of transmission line condition based maintenance work. It is an important technical means to realize the management of the state operation and maintenance of transmission line, and to improve the lean production management. It is an important part of the intelligent transmission line system[1,2].

Trend prediction of on-line monitoring of transmission line is the guarantee for the better realization of the on-line monitoring of transmission line.The goal is to predict the production and operation of the line for a period of time, thus providing scientific advice for the operation and management of the Department. Trend prediction mainly include leakage current value prediction, tower tilt angle prediction, conductor temperature prediction, fatigue life prediction and ice growth forecast[3,4]. At present, the domestic and foreign scholars study more of the leakage current prediction, prediction and forecast the temperature of wire tower inclination.

On the research of the prediction method, prediction of surface leakage current of the rubber insulators exposed to salt spray chamber, the BP neural network is applied to the system, and the forecasting process has good convergence, but the prediction accuracy is not satisfactory in reference [5]; In order to determine the correlation between the meteorological factors and the maximum leakage current level, using the multiple regression method, the environmental parameters and the number of the periodic records as independent variables, and the correlation between the variables and the leakage current are judged. Multiple regression analysis method is introduced to predict the effect of the model variables, the introduction of different variables will produce different forecast values, and even the introduction of the relevant variables will be introduced to reduce the forecast accuracy in reference [6],[7].Reference [8] study on the trend of leakage current trend prediction and judging the degree of contamination, and the trend analysis method based on wavelet neural network method is used to make the trend prediction process have strong fault tolerance ability, and it seems that there is still a problem of poor convergence.

However, the prediction of contamination shift of insulators is influenced by meteorological factors, such as temperature, humidity, atmospheric pressure, sunshine and other factors. The prediction value and many factors are a multi variable, strong coupling and nonlinear relationship, and this relationship is dynamic, so the forecasting accuracy is not high. Because the neural network has the function of self organization, self-learning and the adaptive function, it can deal with the complex nonlinear object, so the neural network can be used to deal with the problem of on-line monitoring and forecast.Taking into account the characteristics of the contamination shift prediction of insulators, this paper tries to use the Elman network to predict and use genetic algorithm to optimize the network, and finally achieve the optimal or near optimal results and have good convergence.

II. THEORETICAL BASIS OF ELMAN ALGORITHM

Elman proposed the Elman neural network model in 1990, Elman neural network is a dynamic feedback network [9]. The network can directly reflect the dynamic process, and has the characteristics of adaptive time variant characteristics. As shown in Figure 1, the Elman neural network is divided into four layers: the input layer, the hidden layer, the following layer (context hidden layer unit), and the output layer.

The input layer plays a role in signal transmission through the neuron, and the output layer has a linear weighting function to the neuron. The receiving layer receives the feedback signal of the hidden layer, and can store the historical output value of the hidden layer neurons in the previous time, delay and store the output of the neurons, and then input the output results to the hidden layer. In this way, the Elman network has a strong sensitivity to the historical data, and the ability of the network to handle dynamic information is increased, so the effect of dynamic modeling is achieved[10].

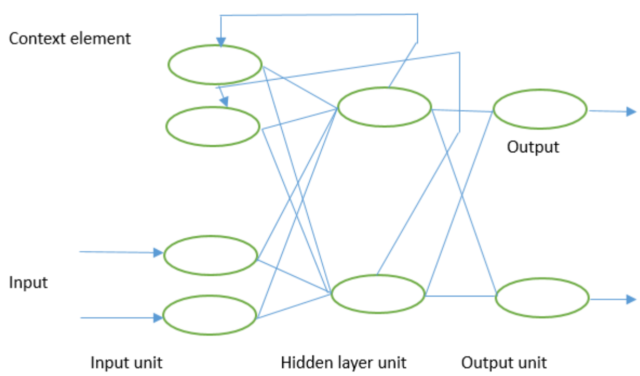

Figure1. Elman network structure

The mathematical model of Elman network is：

$$Y(k) = g(w^3 X(k))$$
$$X(k) = f(wX_c(k) + w^2(U(k-1)))$$
$$X_c(k) = X(k-1) \quad (1)$$

Where Y represents the output node vector of m dimensional; represents Intermediate layer node unit vector of n dimensional; U represents output vector of r dimensional; Xc represents feedback state vector of n dimensional; w represents the connection weights of the intermediate layer to the output layer; w^2 represents the connection weights between the input layer and the middle layer;w^3 represents the connection weights between the following layers to the middle layer; g(•) is the transfer function of output neurons; f(•) is the transfer function for intermediate layer neurons. At the same time, the Elman neural network uses the BP algorithm to modify the weights, and uses the error square and the function to study the index function. By the error function to measure whether the algorithm is over, the error function is shown in the formula (2)：

$$E = \sum_{k=1}^{n} [Y(k) - D(k)]^2 \quad (2)$$

Where *Y(k)*, *D(k)* represent real output vector and expected output vector respectively.

III. THEORETICAL BASIS OF GENETIC ALGORITHM

Genetic algorithm is established by Holland and other scholars. The genetic algorithm does not depend on the specific domain of the problem, it can provide a general algorithm framework for the optimization of complex system problems. Therefore, genetic algorithm is widely used[11].

Genetic algorithms (Genetic Algorithms, GA) only use three basic genetic operators: selection operator, crossover operator and mutation operator. The main elements of the basic genetic algorithm are: chromosome encoding, fitness evaluation, genetic operators (selection operator, crossover operator, mutation operator) and genetic parameters setting[12].

Genetic algorithm simulates the occurrence of genetic, cross, and natural selection, and so on, genetic operations such as selection, crossover and mutation are carried out from any initial population, resulting in a group of individuals that are more adaptive to the environment, making the population evolve into the search space which are better and better, such a generation of the continuous propagation of evolution, and finally converge to a group of individuals in the most adaptive environment, obtain the optimal solution or approximate optimal solution, the detailed genetic algorithm flow chart is also found in the reference [13].

IV. ELMAN NEURAL NETWORK OPTIMIZATION MODEL BASED ON GENETIC ALGORITHM

At present, the Elman algorithm is widely used to decrease the initial weights of the network, and the initial weights of the network are more sensitive to different sensitivity, different initial weights will lead to different prediction results. The selection of parameters in the training process is lack of theoretical guidance. Only personal experience can be determined. The value of the weights will not converge, and the network is easy to fall into local extremum, which can not get the best weights, and the generalization ability of the network will be affected directly [14]. In this paper, genetic algorithm is used to optimize the connection weights of Elman network to solve the problem. The weights and threshold values of the neural network based on GA are as follows：

(1)Input and output sample set of Elman network；

(2)The weights of Elman network are represented by real numbers, so the number of hidden layer neurons and the individual string length are selected directly by using real encoding;

(3)According to the length of chromosome number of initial population, and randomly generated initial population;

(4)The network weights and threshold values were obtained by decoding each position in the population;

(5)The network output of the network weights and threshold values are obtained by the input sample set;

(6)The fitness function selects the error sum of squares and the reciprocal of the error between the forward output value and the expectation value, and calculates the fitness value of each chromosome, and the larger the error, the smaller the fitness;

(7)According to the degree of selection and genetic manipulation space, uniform selection sorting method, cross selection of multi point method, the current generation group was treated with genetic manipulation, resulting in a group;

(8)Repeat (4) - (7) steps , the new generation of the new generation of a new round of iteration, the termination function using maximum genetic algebra, when the genetic algebra to achieve a certain number of training termination, that is, a set of optimal weights;

(9)At last, the connection weights and thresholds of the neural network are applied to the Elman network. The algorithm flow chart is shown in Figure 2:

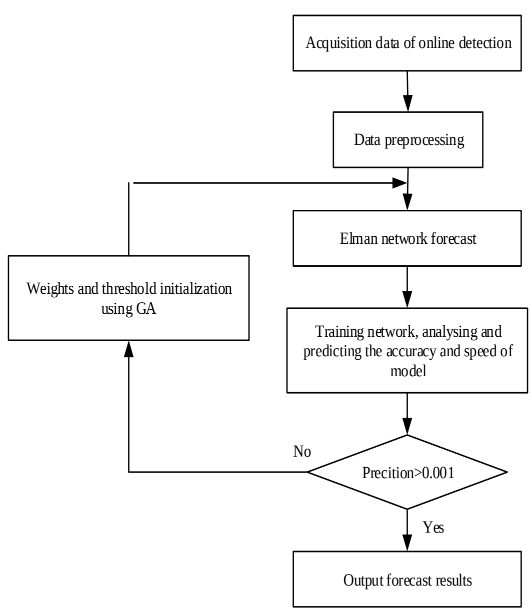

Figure2. The flow chart of genetic algorithm to optimize Elman prediction model.

V. PREDICTION MODEL AND SIMULATION ANALYSIS OF LEAKAGE CURRENT FOR TRANSMISSION LINE INSULATOR

A provincial network of online monitoring of the transmission line insulator contamination monitoring system, by measuring the leakage current changes in the size of insulator contamination monitoring. Leakage current is a dynamic parameter, which is the result of the operation voltage, climate (atmospheric pressure, temperature, humidity, and so on), and contamination, it is the comprehensive effect of the three factors. The relationship between them is a typical nonlinear multivariable function relation, so the single variable forecasting and early warning model is not scientific, in this paper, a multi input alarm model is used.

Some references show that the leakage current of insulators increases with the increase of the ambient humidity, and the variation trend is basically the same. The highest peak of the leakage current occurs in the morning of the day, which is the lowest temperature and humidity in a day. Therefore, this paper uses the prediction algorithm based on genetic algorithm optimization Elman, through leakage current and surrounding temperature, humidity, contamination shift degree as the input variables, using historical data to system modeling, for insulator leakage current make forecast for the next few hours to 24 hours estimated contamination changes with time, namely the surface of the insulator product contamination, to determine the contamination shift time to reach dangerous values, in power demand of the development of the maintenance under, more accurately the online evaluation of the degree of insulator surface contamination shift, so as to solve the problems of insulator is to clean, for power system safe and reliable operation to provide a scientific basis.

A. Sample selection

Choose December 8, 2011 to December 29th until 12 a.m. provincial grid 500kV factory Qing II lines prone to insulator flashover time period for the prediction of the sample, the sample data can be seen in appendix. Taking one day monitoring information as a set of samples, selecting the 20 groups of data as the prediction sample of the insulator contamination degree. The monitoring information is selected: the 25 discharge current, the maximum temperature and the minimum humidity, the maximum humidity and the minimum value, and the contamination degree of the insulator. Contamination degree (observation value) into the normal, the general contamination, serious contamination, serious contamination, the corresponding values of MATLAB are 0, 0.25, 0.5, 0.75.

B. Simulation results of MATLAB

Through the MATLAB of the sample data normalization, the simulation is repeated to the network to test, until the network to achieve the expected network accuracy leakage current forecast map. The network training results show that the network in the fourth step is to achieve the optimal state, the accuracy of the network reached 10-15, and finally, the optimal network forecast results are obtained by genetic algorithm. MATLAB simulation results are shown in Figure 3.

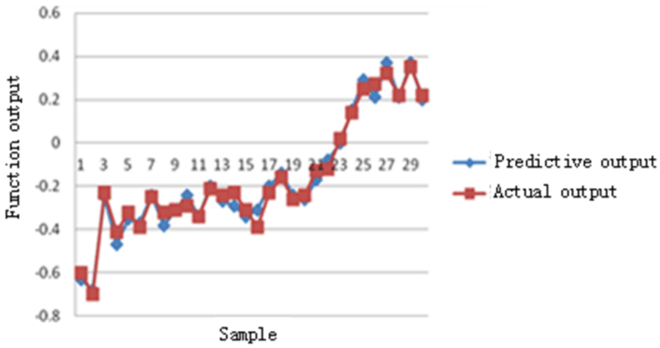

Figure3. Prediction of insulator leakage current.

CONCLUSION

Elman neural network is constructed to predict the leakage current of insulators, and genetic algorithm is used to optimize the weight and threshold of Elman algorithm. The complex nonlinear relationship between the leakage current and the meteorological factors is fitted in the optimization process, and the prediction accuracy is improved. The results of numerical examples show that the proposed algorithm is close to the real value.

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APPDIX . PREDICTION SAMPLE DATA OF INSULATOR CONTAMINATION DEGREE

Sample date	Time (h)	Dec. 8th	Dec. 9th	Dec. 10th	Dec. 11th	Dec. 12th	Dec. 13th	Dec. 14th	Dec. 15th	Dec. 16th	Dec. 17th	Dec. 18th	Dec. 19th	Dec. 20th	Dec. 21th	Dec. 22th	Dec. 23th	Dec. 24th	Dec. 25th	Dec. 26th	Dec. 27th	Dec. 28th
Leakage current	0:00	0.52	0.48	0.31	0.19	0.14	0.31	0.18	0.59	0.23	0.12	0.21	0.33	0.19	0.16	0.13	0.22	0.15	0.25	0.24	0.13	0.63
	0:30	0.56	0.45	0.49	0.24	0.27	0.11	0.16	0.6	0.49	0.24	0.27	0.46	0.46	0.38	0.28	0.18	0.16	0.3	0.5	0.38	0.16
	1:00	0.54	0.49	0.21	0.25	0.25	0.11	0.22	0.54	0.21	0.21	0.25	0.37	0.62	0.62	0.39	0.25	0.21	0.25	0.57	0.62	0.22
	1:30	0.51	0.62	0.23	0.57	0.28	0.12	0.21	0.48	0.23	0.57	0.28	0.49	0.62	0.62	0.39	0.25	0.21	0.25	0.57	0.21	0.48
	2:00	0.46	0.46	0.38	0.28	0.18	0.16	0.3	0.5	0.38	0.28	0.18	0.21	0.31	0.19	0.14	0.31	0.18	0.59	0.23	0.3	0.5
	2:30	0.37	0.62	0.62	0.39	0.25	0.21	0.25	0.57	0.62	0.39	0.25	0.23	0.21	0.63	0.24	0.2	0.34	0.62	0.22	0.25	0.57
	3:00	0.49	0.59	0.48	0.45	0.15	0.25	0.43	0.14	0.48	0.45	0.15	0.38	0.21	0.22	0.54	0.21	0.21	0.25	0.37	0.43	0.14
	3:30	0.4	0.53	0.53	0.29	0.25	0.25	0.53	0.14	0.53	0.29	0.25	0.62	0.52	0.21	0.48	0.23	0.57	0.28	0.49	0.53	0.14
	4:00	0.56	0.43	0.48	0.25	0.16	0.27	0.47	0.14	0.48	0.25	0.16	0.48	0.51	0.3	0.5	0.38	0.28	0.18	0.21	0.47	0.14
	4:30	0.5	0.64	0.78	0.25	0.21	0.25	0.78	0.18	0.78	0.25	0.21	0.53	0.54	0.25	0.57	0.62	0.39	0.25	0.23	0.78	0.18
	5:00	0.52	0.57	0.55	0.18	0.19	0.28	0.55	0.21	0.59	0.21	0.63	0.48	0.37	0.19	0.25	0.47	0.2	0.53	0.51	0.24	0.2
	5:30	0.59	0.21	0.63	0.24	0.2	0.34	0.62	0.22	0.5	0.52	0.6	0.78	0.2	0.2	0.23	0.59	0.21	0.52	0.54	0.22	0.19
	6:00	0.5	0.52	0.6	0.22	0.19	0.25	0.47	0.2	0.53	0.51	0.59	0.59	0.3	0.18	0.25	0.56	0.15	0.56	0.37	0.59	0.2
	6:30	0.53	0.51	0.59	0.59	0.2	0.23	0.59	0.21	0.52	0.54	0.61	0.5	0.21	0.19	0.3	0.53	0.14	0.58	0.2	0.25	0.18
	7:00	0.52	0.54	0.61	0.25	0.18	0.25	0.56	0.15	0.56	0.37	0.6	0.59	0.34	0.18	0.29	0.59	0.21	0.47	0.3	0.25	0.19
	7:30	0.56	0.37	0.6	0.25	0.19	0.3	0.53	0.14	0.58	0.2	0.62	0.61	0.24	0.16	0.3	0.45	0.59	0.52	0.21	0.15	0.18
	8:00	0.58	0.2	0.62	0.15	0.18	0.29	0.59	0.21	0.47	0.3	0.62	0.6	0.59	0.21	0.47	0.3	0.62	0.6	0.52	0.16	0.16
	8:30	0.47	0.3	0.62	0.16	0.16	0.3	0.45	0.59	0.52	0.21	0.58	0.62	0.47	0.2	0.53	0.51	0.59	0.2	0.59	0.34	0.19
	9:00	0.52	0.21	0.58	0.34	0.19	0.29	0.67	0.43	0.42	0.34	0.18	0.62	0.21	0.52	0.54	0.61	0.5	0.21	0.5	0.53	0.16
	9:30	0.42	0.34	0.18	0.53	0.16	0.22	0.76	0.55	0.2	0.23	0.59	0.58	0.24	0.2	0.2	0.23	0.59	0.21	0.53	0.3	0.25
	10:00	0.24	0.2	0.34	0.62	0.22	0.5	0.52	0.6	0.78	0.2	0.2	0.23	0.21	0.59	0.25	0.19	0.3	0.53	0.36	0.27	0.21
	10:30	0.22	0.19	0.25	0.47	0.2	0.53	0.51	0.59	0.59	0.3	0.18	0.25	0.21	0.62	0.6	0.59	0.34	0.18	0.29	0.59	0.21
	11:00	0.59	0.2	0.23	0.59	0.21	0.52	0.54	0.61	0.5	0.21	0.19	0.3	0.52	0.59	0.18	0.25	0.19	0.3	0.53	0.62	0.52
	11:30	0.25	0.18	0.25	0.56	0.15	0.56	0.37	0.6	0.59	0.34	0.18	0.29	0.51	0.5	0.52	0.21	0.15	0.18	0.17	0.59	0.51
	12:00	0.6	0.59	0.34	0.18	0.29	0.52	0.21	0.15	0.18	0.6	0.59	0.34	0.54	0.24	0.6	0.59	0.34	0.18	0.29	0.5	0.54
Contamination	Contamin	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0.2	0	0	0	0	0	0

	atd Degree								5							5						
Meteorological characteristics	Minimum temperature	-3	3	-2	1	-2	-6	-5	-8	-8	-7	-5	-4	-3	-1	-5	-3	-3	-5	-3	-3	-3
	Maximum temperature	3	7	6	8	6	4	3	4	5	3	2	6	6	6	7	6	9	2	4	1	1
	Minimum humidity	24	39	25	36	55	30	17	12	31	29	35	31	31	17	17	16	19	19	45	43	58
	Maximum humidity	59	54	41	59	89	92	56	52	71	66	60	62	62	73	16	61	42	48	62	64	69