Application of Smart Expert System for Icing on Transmission Line

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ABSTRACT: Single in early 2008, extreme ice rain destroyed struck the power system infrastructures in Southern China, which has triggered lots of reflection on modeling of icing on overhead transmission lines. Due to complexity of physical process of icing on overhead transmission lines and it was difficult to predict icing accurately by mathematical and physical model, combined with on-line monitoring, neural network and expert system, a new idea to establish a smart expert system of icing on transmission lines have been proposed. Firstly, base on remote data acquisition and pretreatment, combined with the specific design of the thickness of ice on transmission lines, the condition assessment of icing on transmission lines was run. Second, base on historical data of icing on transmission, a combined gray neural network model was constructed to predict the trend of icing. Then, data of the trend analysis and expert knowledge in knowledge base were used for early warning to the state. Application shows that the results of the condition and assessment of icing is effective and reasonable.

KEY WORDS: smart overhead transmission line; icing; neural network; expert system; on-line monitoring

0 **Introduction**

Smart power grid is the world's latest trends in the development of power system. European and America are competing to carry out the research of Smart Power Grid.

Smart transmission grid is a core component of smart power grid, and monitoring and evaluation of substation and transmission equipment is the basis of smart transmission grid [1-2]. The goals of the construction of smart transmission grid are the state visualization, virtual control, platforms intensive and interactive information to establish equipment operating status can be observed, the whole production process can be monitored and the risk can be early warning smart information systems.

In early 2008, southern China suffered a rare snow and sleet storms, which resulted in a total outage of 36740 10kV & above t transmission lines and 1743 substations and is a serious threat to the security and stability of power grid [3]. Due to icing transmission line located in sparsely populated areas, it is difficult to get real-time data of ice. The stations were generally established to observe the ice at home and abroad. However, the stations need large investment and operating expenses, long construction period, extremely limited and can not achieve real-time monitoring of the entire grid. In this case, the research, on-line monitoring and early warning expert system, should be strengthened to guide operating personnel to take measures, which is important for security and stability of the grid.

The on-line monitoring system for icing on transmission lines has been built in Guangdong, Guangxi, Yunnan and Guizhou provincial grid of the china southern power grid [4-7], and Shanxi, Hunan and Fujian and other areas grid of the national grid.

In this paper, based on remote on-line monitoring technology and historical data of icing thickness, trend analysis and early warning is initially realized by the combination of expert knowledge and gray neural network.

1 On-line monitoring system

Remote data acquisition system consists of data collection terminal and transmission channels [8-10]. The structure of the system is shown in Figure 1.

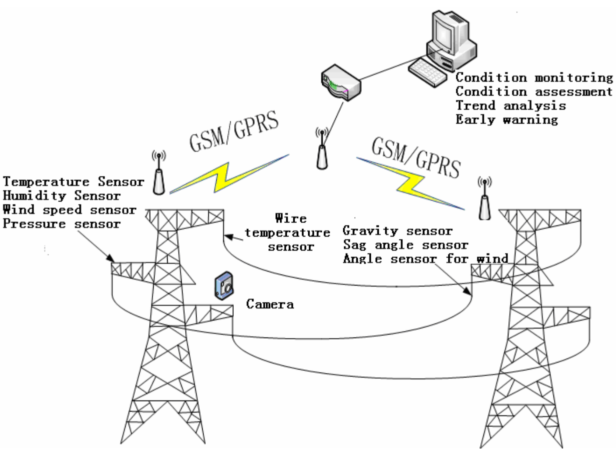

Fig.1 Remote data acquisition system on overhead transmission lines of china southern power grid

2 The structure of expert system

The expert system is a core component of icing thickness monitoring and evaluation and the status visualization, virtual control, platforms intensive, interactive information of the monitoring system are achieved. The composition of expert system is shown in Figure 2.

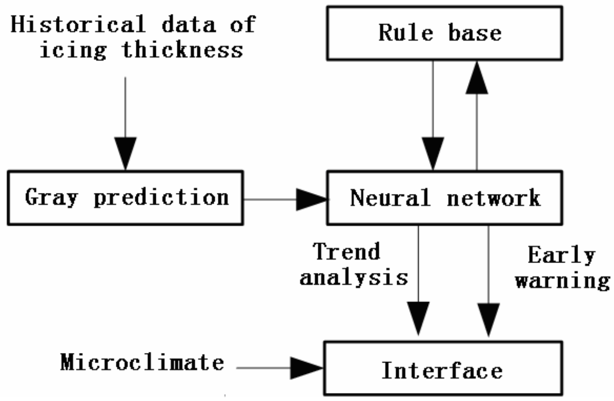

Fig.2 The structure of expert system

2.1 Condition assessment of ice thickness

Icing thickness on transmission line is calculated by using improved mechanical model of south china university of technology [11], taking into account the influence of wind, to get a more accurate icing thickness.

The angle of the insulator was formed by icing, due to the different of the level of tension of the wires on both sides of the main tower.

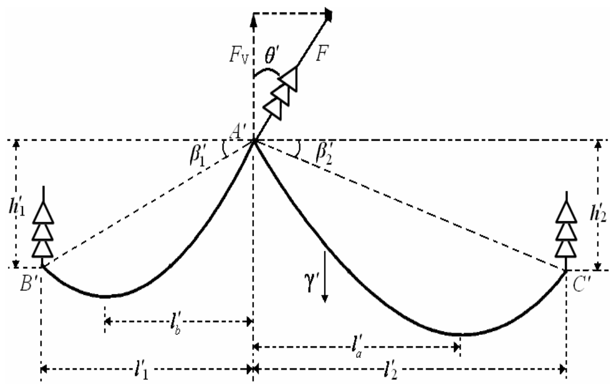

Fig.3 Transmission line model in deviation plane for wind

The force was a load, which is gravity of wire and insulator strings in the deviation plane resulting from the effects of wind. After icing on the on transmission line, the load was increased. After icing, the vertical pulling force $F_V=F\cos\theta'$. According to the force balance in the vertical direction, the following expression:

$$F\cos\theta' = \frac{G}{\cos\eta} + \frac{q_{ice}(S'_a + S'_b)n}{\cos\eta} \tag{1}$$

In the equation (1), S'_a is the length of wire from the larger point of the large number side of the wire to the main tower; S'_b is the length of wire from the lower point of the large number side of the wire to the main tower; θ' is the angle in the vertical between axial tension of insulator string and the deviation plane for wind; q_{ice} is the icing load degree of transmission line.

θ' has the following relationship with the tilt angle and wind drift angle:

$$\cos\theta' = \frac{1}{\cos\eta\sqrt{1+\mathrm{tg}^2\eta+\mathrm{tg}^2\theta}} \tag{2}$$

ρ is the density of icing; D is the diameter of the conductor; the shape of icing is equivalent to a uniform cylinder, so the equivalent icing thickness as follows:

$$b = \frac{1}{2}\left(\sqrt{\frac{4q_{ice}}{9.8\pi\rho} + D^2} - D\right) \tag{3}$$

According to the above formula, the icing thickness on transmission can be calculated more accurately.

2.2 Trend analysis of ice thickness

Gray system theory is widely used as a prediction method in recent years, which use less data and weaken its volatility, by accumulating, to establish a unified differential equation model to predict.

At first, the trend of icing was predicted by GM (1, 1) model [12], Verhulst model [13]and DGM (1, 1) model[14]. GM (1, 1) model is that the original data is accumulated to establish differential equation and get the fitting curve. Verhulst model is applicable to data sequence with strong exponential and more suitable for saturated growth. The trend of icing is likely to be saturated "S-type" growth [15]. DGM (1, 1) is a single sequence model of second-order linear, can be fitted by differential equation.

Any one of the three models is difficult to comprehensively reflect the variation of ice thickness.

As artificial neural with good nonlinear characteristics, it should be used to synthesize the trend of each of three models to reduce the randomness and improve the accuracy.

RBF (radial basis function) neural network is a 3-layer feedforward network, and its structure is shown in Figure 4. Input layer nodes pass the input signal to the hidden layer, and the function of nodes in hidden layer has local response to the input signal. The output layer get output of the network by synthesizing linearly the output of nonlinear function in hidden nodes. The most common form of RBF is Gaussian function.

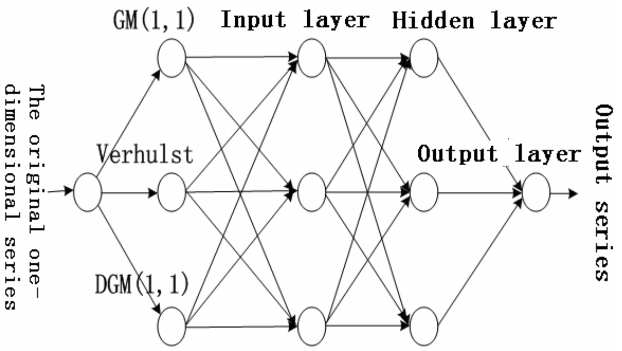

Fig.4 Structure of 3G-ANN neural network

2.3 Early warning of ice thickness

After obtaining the trend of icing by the expert system, combined with the design of each icing thickness on transmission line, the trend value T is divided into four subsets: Z (no icing or thin icing), PS(medium icing)、PM(severe icing) and PB(Alarm). The relationship between T and icing thickness is shown in Tab.1:

Tab.1 Relationship of Ice thickness and the design

The subset of the trend of icing thickness	Z	PS	PM	PB
Icing thickness	<1/3 design value	<1/2 design value	<2/3 design value	> design value

Considering icing thickness in the next 12 hours, the next 24 hours and the designed value, the early-warning result of icing are classified into 4 parts: safety(S), attention(P), dangerous(D) and alarm (A). Its rule base is shown in Tab.2:

Tab.2 rule base 2

N \ T	the next 12 hours	the next 24 hours
S	Z	Z/PS
P	PS	Z/PS
D	PM	Z/PS/PM
	Z/PS	PM
A	PB	Z/PS/PM
	Z/PS/PM	PB
	PB	PB

3 Application

Tower NO.143 is located at N27.8740°, E103.9210°, and its altitude is 811m. It is in the valley between two mountains, nearby river and has a complex meteorological environment. So, this is an area prone to icing on transmission line In winter. Its terrain is shown in Figure 5.

Fig.5 Terrain of an 110kv transmission line tower No. 143 of Yunnan power grid

Icing occurred on the transmission Line in the February 14, 2010.Then, icing thickness was assessed as severe by condition assessment and trend analysis of the next 24 hours was started at 15:47 on February 15. The curve of trend analysis and the actual icing curve are shown in Figure 6.

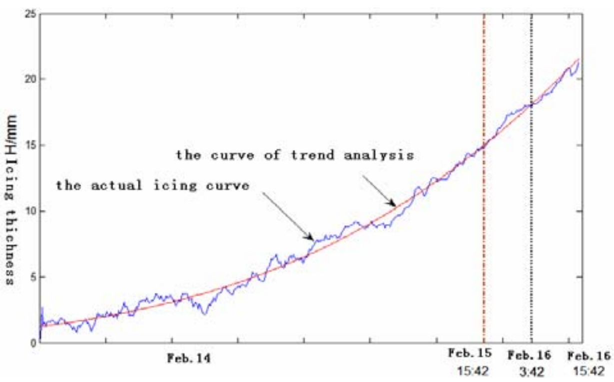

Fig.6 Transmission Line thickness trend analysis

Seen from Figure 6, Trend Analysis of icing curve is very close to actual curve, which meet the general requirements of trend analysis. After 12 hours and 24 hours, the differences between trend analysis and the actual icing thickness are shown in Tab.3.

Tab.3 the results comparison of trend analysis and the actual thickness

	after 12 hours	after 24 hours
Actual thickness	17.94mm	21.14mm
Trend analysis	18.11mm	21.60mm

Based on icing thickness from the trend analysis after 12 hours and 24 hours, combined with rule base 2, the assessment results are shown in Tab.4.

Tab.4 Results of condition assessment

Assessment items		Assessment Results	Comprehensive Assessment Results
Icing thickness	Present	PS (medium)	D (severe)
	After 12h	PS (medium)	
	After 24h	PM (severe)	

Application example shows that Using historical icing data and the specific design of icing thickness, combined with expert knowledge and gray neural network, Expert system can be established to effectively analyze icing trend and get early warning. The assessment is Reasonable and accurate, and provide a strong support for power companies to make scientific decisions as soon as possible.

4 Conclusion

In this paper, smart expert system for icing on Transmission Line is established to achieve condition monitoring and assessment, trend analysis and early warning. The application shows that results are reasonable and accurate.

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