FAULT PREDICTION AND SIMULATION ANALYSIS OF ULTRA-HIGH VOLTAGE TRANSMISSION-LINE BASED ON THERMAL ENERGY TRANSFORMATION

by

Shixi FU**, *Zhihui CHEN, Zongyue GAN, and Dena HAO

Power Grid EHV Transmission Company, CSG, Guangzhou, China

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In order to solve the traditional long-distance ultra-high voltage (UHV) transmission-line risk warning system in the design process, it neglects the classification step of early warning information, which leads to the poor effect of risk early warning, the authors propose fault prediction and simulation analysis of UHV transmission-line based on thermal energy transformation. In the hardware design part, the network video server is used to design the host control module, and the video decoding chip is used to convert the acquired analog signal into digital signal, then it is transmitted to the serial port server, and the risk warning circuit is designed based on it. In the software design, GA-BP algorithm is used to obtain the number of nodes in the middle layer, the constraint range is determined, and the warning information is classified to realize the risk warning of long-distance UHV transmission-lines. The experimental results show that the warning accuracy of the system under different conditions is high, and the highest warning effect can reach 95%. It is proved that the classification recall rate of early warning information is high, which can effectively resist interference and provide strong support for the safe operation of transmission-lines.

Key words*: GA-BP algorithm, remote monitoring, transmission-line, risk early warning, UHV transmission-lines, simulation analysis, thermal energy conversion*

Introduction

Heat is the energy source of life, it is also the main energy base of modern human society. With the development of modern technology, there is a growing desire for heat flow control. Especially in the military field, thermal stealth technology and thermal camouflage technology can be widely used to hide the military facilities and military personnel, or used to confuse and hinder the enemy's investigation and attack, which is the special requirements of modern military development technology and new technology for new materials. Using ordinary natural materials as basic structural units, artificial materials combined in a series of special ways have extraordinary physical properties that natural materials do not have and can be designed [1]. It has been found that a wide range of physical properties/quantities can be regulated by functional materials, including electromagnetic waves, light waves, acoustic waves and elastic waves, phonon-s, heat and so on [2].

* Corresponding author, e-mail: shixifu3@163.com

According to the characteristics of UHV transmission-line, this paper analyzes the research situation and important technology of UHV operation and technology, shows the existing work and maintenance, which is important to ensure the safe and reliable operation of UHV transmission-lines in the future, improve the performance of operation, maintenance and repair, and the modernization of operation and control mode. In the maintenance and repair of power transmission-lines, power supply companies need to invest more in better technology and new equipment to make the country's transmission-line smarter and not automatic. When the transmission-line is not working, they analyze to find the fault, and use the research such as segment analysis to work properly for the fault line, reduce the maintenance time, reduce the short time, and reduce business losses from power outages. Only in this way can we reduce the occurrence of line errors, reduce the burden of employees, thus improve the economic value of businesses and provide people with safety more and more reliable electricity [3].

Literature review

In the operation and maintenance of AC UHV line, it has its own characteristics in three aspects, such as environment, fault form and maintenance. Specifically, the AC UHV lines themselves carry over large distances and long lines, mostly running north-south or east-west, this makes the complex landscape, changeable climate and harsh meteorological conditions become the problems faced by every AC UHV line, these problems bring complicated operating conditions to some sections of UHV line. In terms of the characteristics of fault forms, in the operation and maintenance of AC UHV lines, five kinds of faults such as lightning strike, ice covering, pollution flashover, vibration and wind deflection are the most common fault forms of AC UHV lines, this is mainly due to the influence of the height of the pole and tower in the line, the heavy ice area, the haze weather and the line structure, in the face of these problems, we need to take targeted measures [4]. In recent years, with the rapid development of social economy, power grid investment and construction efforts are gradually increasing, a variety of line infrastructure overhaul technical upgrading projects are increasingly numerous, line production and construction safety monitoring facing more and more prominent problems, challenges are also more diversified. As an important means for line engineering supervisory units to grasp safety control, safety monitoring is also in urgent need of further improvement and strengthening to meet the development requirements under the new situation and environment.

Therefore, it is necessary to warn the risk of long-distance UHV transmission-lines. The existing early warning system is easily affected by natural disasters and human intervention, resulting in poor early warning effect. Jiang *et al*. [5] summarized the key technologies related to the power cable robot, and studied the key technical indicators such as operation reliability, operation efficiency and operation quality in the actual application process of the robot. Ma *et al*. [6] proposed and established equivalent variable damping and equivalent variable stiffness models of hydraulic torque converter. On this basis, a torsional vibration simulation model of loader with variable damping and stiffness is established, and the frequency and amplitude of torsional vibration mode of transmission system varying with engine speed and hydraulic torque converter speed ratio are obtained. Baales *et al*. [7] proposed a time series clustering method for smart meters. Based on two-stage *k*-medroid clustering, the method divides the standardized load shape time series in a day into 48 time points.

Methods

System design

The system collects field images by camera, and can conduct module conversion after video acquisition, once the transmission-line is abnormal, the video monitoring extension will send the field situation the background monitoring center through optical fiber network. The overall structure design of the system is shown in fig. 1.

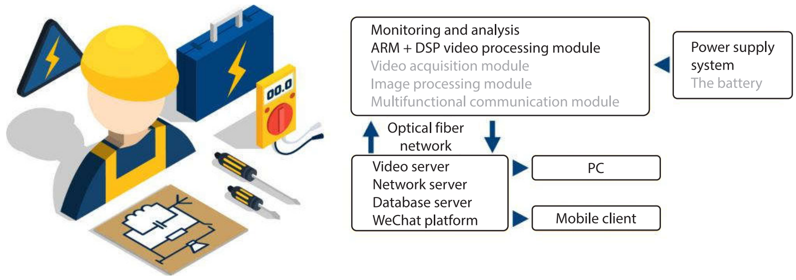

Figure 1. Overall structure design of risk early warning system

In fig. 1, the main control board composed of ARM + DSP extension takes ARM microprocessor as the main control chip, communication through the SIP session initiation protocol. The collected video image is transmitted to the microprocessor, and then the video difference in DSP digital signal processing is debugged to analyze the field operation status. At the same time, the on-site warning information received by the background monitoring center is sent in real time through the wechat platform, and the network server synchronizes the information the host, users can check it again by logging in to the mobile phone server [8].

Hardware structure design

Adopting modular design concept, the hardware structure of the system is designed. The overall hardware structure of the system includes video acquisition, host control, risk warning circuit and other modules. The acquired analog video signal is converted into digital signal and uploaded to the video processing module. According to the relevant differentiation principle, the early warning information can be sent to the background through the optical fiber network to judge whether there is danger on the transmission-line site.

Host control module

The control host is the main equipment for monitoring the damage caused by external forces on long-distance UHV transmission-lines, SN-RDR900 network video server is adopted, internal real-time digital hard disk monitoring system, can be Windows XP, the system for remote operation, support HTTP communication protocol [9].

Video collection module

The TVP5147 video decoding chip is used to convert the analog signal to digital signal, which is then transmitted to the front end of the video for processing. In order to collect the weak load voltage, it is necessary to use the high precision voltage sensor through the AD amplifier to amplify the signal processing, constantly adjust the resistance, so that the digital processor to meet the high standard requirements of the input signal. After AD conversion, multiple channels of data can be collected at the same time, and all the collected data can be transferred to the serial port server through serial port connection, providing data support for risk warning [10].

Risk warning circuit

The risk warning circuit uses LM386 as alarm operating power amplifier, with audio integration function. The SCM at the input end of LM386 has P3.4 pin and can connect the loudspeaker at the output end. Once the actual risk threshold exceeds the set minimum threshold, the SCM pin will output frequency signal, after audio amplification processing, the system will alarm.

Hardware structure design

Combined with the characteristics of long-distance UHV transmission-line security monitoring, the scattered graphic and text information in the process of security monitoring are organically integrated through the program system established on the wechat instant messaging platform, it plays the role of full coverage of monitoring, identification and pre-control of danger points, performance of safety monitoring and information feedback [11].

Wechat platform extension program

Wechat platform extension program design, mainly including ARM microprocessor and DSP digital processor, through the microprocessor to configure and control the device. The video front-end module composed of controller, engine and white balance module can directly store the acquired video signal in the existing video signal library. The back-end module composed of engine and video coding can superimpose two videos on one video window to realize the picture-in-picture function. The video decoding chip is transmitted to the ARM microprocessor, and the GA-BP algorithm in the digital processor is invoked to conduct real-time analysis of the video retrieved from the scene, and the results will be transmitted to the microprocessor, through optical fiber communication can be sent to the background server, and then synchronized to wechat, in the form of information set the mobile device of the staff [12].

Classification of early warning information based on GA-BP algorithm

The BP neural network simulates the real working mechanism of human brain neural network to complete the bidirectional flow before and after the signal. The BP neural network model includes input layer, hidden layer and output layer, and each layer is connected with neurons. The transmission-line data of the access system is called the input data, and the output data can be obtained by the propagation information of the neural network. The weighted value of network neurons can be changed according to the size of the error to ensure that the network output can reach the target value [13].

To overcome the blind value problem, set it as the input layer, b as the hidden layer, and c as the number of neurons in the output layer. Based on the detail application of WeChat platform, using a, b, and c to calculate the number of nodes in the middle layer to get the approximate maximum number of nodes, and using GA to get the optimal results of network results. Specific descriptions are as follows.

- Initialize the network, design the network topology according to the warning type, determine the algorithm parameters, and generate the initial genetic population with the help of coding optimization object. Genetic manipulation is performed using binary coding and the total number of initial weights and thresholds is determined.
- Input the training samples, obtain the mean square error of BP neural network, thus obtain the sum of squared errors:

$$T = \frac{1}{\sum_{i=1}^{f}\left(E_i - S_i\right)^2} \tag{1}$$

where E_i is the expected value of network output, S_i – the indicates the actual network value, and f – the number of neurons.

– The proportion method is used to select the encoded threshold for replication, and the new threshold P is obtained:

$$P = \frac{1}{\sum_{i=1}^{n} TS_i} \tag{2}$$

where n indicates the maximum number of network links i. The selected threshold is crossed among individuals and self-variation is carried out to generate a new population, and the fitness d is calculated, the fitness interval is [0, 1], judge the state Z of long-distance UHV transmission-line information according to the fitness:

$$Z = \begin{cases} E_i, 0 < d \le P \\ \beta E_i, d = 0 \end{cases} \tag{3}$$

where β is represents the risk factor. According to eq. (3), when the fitness of the new population is 0, the long-distance UHV transmission-line information is the risk warning information.

– Judge whether the long-distance UHV transmission-line is dangerous according to the output data, and repeat Step 4 until the error fully meets the target requirements to obtain the classification result [14].

Based on the aforementioned analysis results, the classification process of risk early warning information for long-distance UHV transmission-lines can be obtained, as shown in fig. 2.

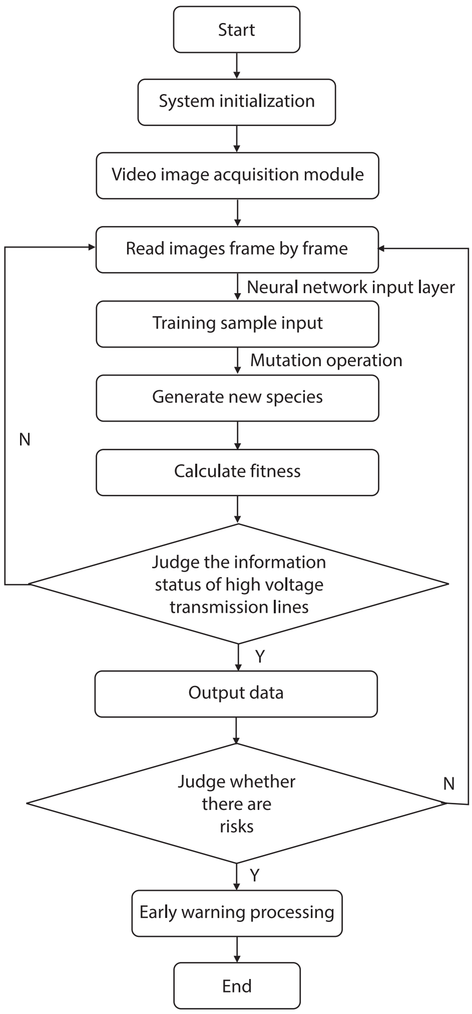

Figure 2. Operation flow of the warning system

Simulation experiment analysis

The total length of the position-line is 756 km, and the whole line adopts the same tower double circuit structure. The total length of the line is 750 km, which is divided into three parts: 350km, 230 km, and 170 km. In the experiment, 1200 long-distance UHV transmission-line data were collected and divided into 12 groups with 100 data in each group, among them, two groups were used as training samples for neural network model construction and the other eight groups were used as test samples for experimental analysis.

The resolution of the video image is 1600 × 1200, the pixel size is 3.2 μm × 2.2 μm, and the output color is black and white or color, the number of data bits in the neural network model is 10 in RGB and 8 in RGBA, the SNR of data is greater than 42 dB, and the number of hidden layer nodes is 10 [15].

Results and discussion

In order to verify the effectiveness of the system proposed by the author, in the event of natural disasters and human impacts, the system that the author has compared with the traditional system was designed.

Natural disasters

Under the influence of six different climates, the effectiveness of risk early warning for long-distance UHV transmission-lines of the two systems is compared and analyzed, and the warning accuracy (risk early warning information/information of all transmission-lines) of the two systems is calculated, the calculation results are shown in tab. 1. Where A represents the traditional system and B represents the early warning system based on GA-BP algorithm.

Table 1. Warning accuracy % of the two systems

System	Climate	Number of experiments				
		1	2	3	4	5
A	Wind	62.8	69.8	65.4	63.2	65.7
	Fog	60.5	59.2	58.3	64.2	64.1
	Heavy snow	59.8	55.9	56.7	58.3	58.4
	Heavy rain	54.5	54.3	52.6	52.7	55.1
	Cold	58.2	54.6	54.3	51.2	51.3
	Heat	54.2	54.8	53.1	50.6	52.4
B	Wind	92.0	91.5	93.2	91.9	92.3
	Fog	95.6	96.3	96.2	95.1	95.8
	Heavy snow	91.9	91.8	91.3	91.0	92.0
	Heavy rain	95.7	96.8	95.9	94.9	95.8
	Cold	93.2	90.5	93.5	93.4	93.5
	Heat	96.8	97.2	96.9	95.8	96.3

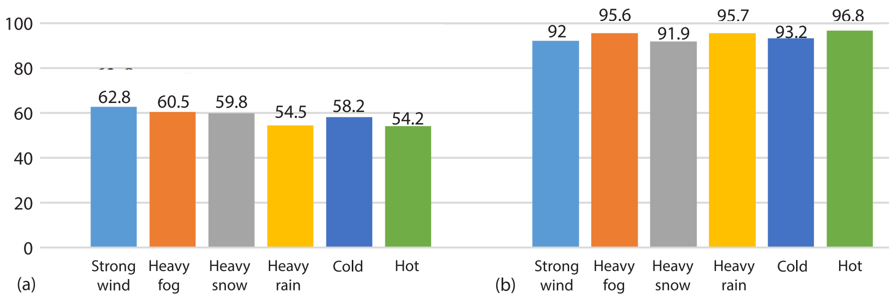

Figure 3. Analysis and comparison of the early warning accuracy of the two systems

It can be seen from tab. 1 and fig. 3 that in different disaster situations, the early warning based on GA-BP algorithm is always more accurate than the traditional early warning system. It can be seen that the error of early warning system of the author's system and the measure precision is small, and the early warning system based on GA-BP algorithm is better than the traditional system [16].

Human intervention

Under the influence of human intervention, the risk warning of long-distance UHV transmission-lines of the two systems is compared and analyzed, and the results are shown in fig. 4.

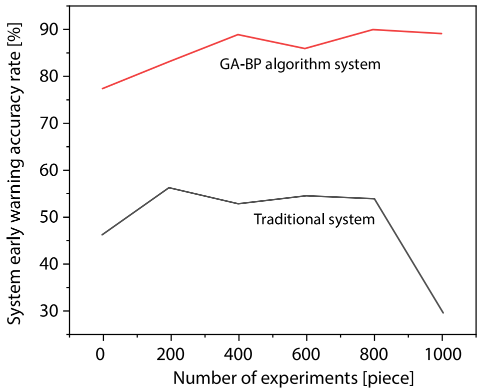

Figure 4. Comparative analysis of the early-warning accuracy of the two systems

It can be seen from fig. 4 that although the pre-warning capability of the two systems is changed to some extent with the increase of the test value in the process of manual interaction, the pre-warning capability of the system based on GA-BP algorithm is always higher than that of the traditional system, percent that can reach 95%. In conclusion, the risk early warning based on the GA-BP algorithm can prevent impact of external events through hardware and software functions, and has the best early warning results. In the process of software development, the author uses the GA-BP algorithm to obtain the number of middle layer nodes, determine the limit, and classify the early warning information. Based on this, the early warning system was developed and the accuracy of the system was improved [17].

In order to further verify the effectiveness of the authoring system, the authors analyzed the recoveries of early warning data as compared with the traditional systems in 5, 10, 15, and 20 pilot sequences.The comparison results are shown in fig. 5.

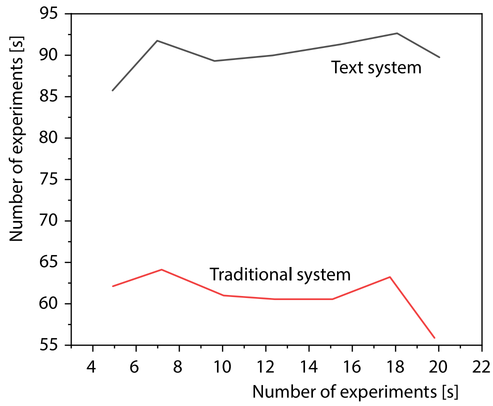

Figure 5. Comparison result of recall rate of warning information classification

As can be seen from fig. 5, the classification recall rate of the transmission-line early warning information of the author's system is as high as 93.5%, while the highest classification recall rate of the traditional system is only 63.2%, it can be clearly seen that the performance of the author's system is superior [10, 18, 19].

Conclusion

A method of fault prediction and simulation analysis for UHV transmission-lines is presented. A risk warning system based on GA-BP algorithm is designed. Based on the overall structure of UHV remote transmission-line risk warning system, the hardware structure and software function of the whole system are designed. It improves the early warning effect and reduces the influence of construction safety guarantee. The development of power system can-not be separated from the installation of power cables. With the development of economic power, large and small power grids have conquered every inch of China's territory. They have made great contributions to economic development and the improvement of people's living standards. At the same time, in the face of all over the country, and the maze of responsible lines, it is very important to do a good job in the operation and maintenance inspection of distribution-lines. This is responsible for the people's electricity safety, and it is of extraordinary significance to the power construction. As an important channel for the development of power industry in recent years, transmission-line engineering is still a brand new field in construction safety risk warning.

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