Fault dynamic monitoring of intelligent power system telecontrol dispatching based on improved fault tree

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Abstract. The number of transmission messages is small when the traditional power system monitoring methods collect signals. Therefore, a fault dynamic monitoring method of intelligent power system telecontrol dispatching based on improved fault tree is proposed. The telecontrol communication model of intelligent power system is constructed. The communication signal of telecontrol dispatching channel is collected. The parameter of signal time-domain characteristic is measured. The time-domain waveform can pass through the zero period to get the carrier frequency range, judge whether the system telecontrol dispatching has fault, and analyze the fault mode by improving the graphical logic deduction of fault tree. A comparative experiment is carried out. Compared with the traditional methods, the results show that the design method can improve the number of packet transmission per unit time, increase the network traffic, and ensure that the communication network has very low load in the dynamic monitoring process.

1. Introduction
The power system can manage substations and power plants in a unified way. Telecontrol is the main technology of power dispatching. It can communicate with power equipment remotely, supervise and control the operation and fault conditions, and collect the real-time information of equipment status to the dispatching control center, so as to achieve the purpose of control and regulation of power equipment. Therefore, it is of great significance to study the fault dynamic monitoring technology of telecontrol dispatching [1]. There are two kinds of current dynamic monitoring technology. The first is to detect the carrier frequency of communication signal, so that the level of detection signal is combined with the frequency of display signal. If two regular frequencies are obtained, it is judged that the dispatching channel is normal. If the frequency components are disordered or only a fixed frequency is obtained, the fault is judged. The second is to measure the time-domain waveform of power telecontrol channel. The signal level is also combined with the display signal to observe the signal waveform and communication parameters, so as to judge the dispatching failure such as lost carrier frequency and channel interruption. The quality of telecontrol channel is evaluated [2]. On the basis of the above theory, a fault dynamic monitoring method of intelligent power system telecontrol dispatching based on improved fault tree is proposed.
2. Design of fault dynamic monitoring method of intelligent power system telecontrol dispatching based on improved fault tree

2.1. Construction of telecontrol communication model of intelligent power system

The dynamic monitoring of dispatching fault is distributed in the hierarchical structure of power system, and the telecontrol communication model of intelligent power system is constructed. The wide area Ethernet, MMS and IEC 61850 are used in communication to obtain the hierarchical and distributed network structure of power system, including substation and dynamic monitoring terminal, etc. The fault dynamic monitoring function is distributed in multiple levels to realize dynamic monitoring integration \[3\]. The details are shown in figure 1.

Fig. 1 network structure of intelligent power system

The process layer samples the analog quantity, completes the sending of control commands and the switching I/O functions. The bay layer uses the interval data to control the bay unit and power equipment. The substation layer sets up the monitoring interface to communicate with the telecontrol dispatching center to monitor the primary equipment of multiple intervals or the whole station. The dynamic monitoring terminal carries out remote communication for the equipment. In the substation, the IEC 61850 standard is followed, and the SCL of IEC 61850 is used to configure the power equipment remotely. The real-time communication protocol MMS is used inside the substation \[4\].

Intermittent monitoring of telecontrol dispatching fault identify a logical device, and use the way of copying logical device to map multiple physical devices to the gateway, establishing a complete logical device \[5\]. Then the information data that can represent the telecontrol dispatching is mined to obtain the logical nodes. The logical nodes that can meet the requirements of telecontrol dispatching are pruned. And the information data are standardized. For the information not defined in IEC 61850, the logical node of the information data is expanded and defined \[6\]. Finally, the server communication mode is used to associate the substation with the dynamic monitoring terminal and exchange the data sets used for telemetry and remote signaling. So far, the construction of intelligent power system telecontrol communication model has been completed.
2.2. Calculation of fault signal parameters of telecontrol dispatching channel

The composition and frequency domain characteristics of the telecontrol fault signal are analyzed, and the fault signal parameters are determined. Before accessing the dispatching channel, the MODEM modulator is used to convert the pulse signal of telecontrol signal into analog signal. For the telecontrol signal after channel transmission, demodulator is used to convert it into binary digital signal [7]. The demodulator selects frequency shift keying (FSK) modem and uses two carrier frequencies with different frequencies to represent the information bits of digital signals. It is divided into discontinuous phase modulation (DPM) and continuous phase modulation (CPM), so that the carrier frequency changes with the change of modulation signal. The time domain expression $S$ of binary telecontrol dispatching signal is as follows.

$$
S = \begin{cases} 
A \cos (a_1 t + \varphi_1), & \text{When sending signal 1} \\
A \cos (a_2 t + \varphi_2), & \text{When sending signal 0} 
\end{cases}
$$ (1)

In formula (1), $A$ is the signal level, $a_1$ is the modulation frequency offset corresponding to the modulation signal 1, $a_2$ is the modulation frequency offset corresponding to the modulation signal 0, $t$ is the acquisition period of the telecontrol dispatching signal, $\varphi_1$ is the initial phase of the carrier oscillation when sending code 1, $\varphi_2$ is the initial phase of the carrier oscillation when sending code 0 [8]. The time-domain waveform of $S$ is drawn to analyze the time-domain characteristics of the telecontrol dispatching signal, and then the parameters of the signal are measured. The telecontrol dispatching signal with continuous phase is selected. Assuming that the probability of transmitting code 1 and code 0 is equal, the calculation formula for frequency modulation index $m$ of acquisition signal is as follows.

$$
m = \frac{|f_2 - f_1|}{f} 
$$ (2)

In formula (2), $f_1$ is the carrier frequency corresponding to $a_1$, $f_2$ is the carrier frequency corresponding to $a_2$, $f$ is the carrier frequency in binary frequency shift keying [9]. Then the power spectrum $W$ calculation formula of telecontrol signal is as follows.

$$
W = \frac{\cos \left( \pi \cdot \cos 2\pi x \right)^2}{\left( 1 - 2 \cos \pi x + \cos^2 \pi m \right)}
$$ (3)

In formula (3), $x$ is the normalized frequency parameter. The power spectrum $W$ is taken as the time-domain characteristic of time-domain expression $S$. Two carrier frequencies are extracted from the power spectrum $W$. So far, the fault signal parameters of telecontrol dispatching channel have been determined.

2.3. Fault dynamic monitoring of telecontrol dispatching based on improved fault tree

By changing the signal parameters of operation state and combining with the improved fault tree technology, the fault dynamic monitoring of telecontrol dispatching is realized. In order to reduce the influence of noise on the signal, the time domain waveform of the telecontrol signal passes through the zero period by using the signal time domain characteristics $W$. During the counter counting, a higher level value is used to ensure the continuous change of the signal amplitude. The signal is converted into an approximate rectangular wave. A significant jump signal amplitude value is obtained near the zero point, and then the carrier frequency of the denoised signal is obtained. The number of pulses is measured in the zero period, the transition period and zero period of the signal are filtered, and the average value of the effective zero crossing period is calculated, so as to obtain the filtered signal carrier frequency [10]. The telecontrol channel is equivalent to the band-pass channel, and the carrier
frequency range of the telecontrol dispatching signal of the power system is counted. If the carrier frequency range of the signal collected by the monitoring end exceeds the set threshold, it indicates that the telecontrol dispatching channel is faulty. Otherwise, it is judged that its operation state is normal.

If there is a fault in the telecontrol channel, the improved fault tree analysis method is used to deduce the fault signal. The process is as follows, in-depth analysis of the direct influencing factors of the fault as the intermediate event of the fault tree. The basic cause of the fault is determined as the bottom event of the fault tree. Finally, the detected telecontrol dispatching fault is taken as the fault tree top event. Through the above reasoning, the fault mode of telecontrol dispatching fault is defined, and the fault signal is continuously tracked to realize the fault dynamic monitoring of telecontrol dispatching based on improved fault tree. So far, the design of fault dynamic monitoring method of intelligent power system telecontrol dispatching based on improved fault tree has been completed.

3. Experimental demonstration and analysis
A comparative experiment is carried out. The design method is recorded as the experimental group, and the traditional dispatching fault dynamic monitoring method is recorded as the control group. The intelligent power system based on C/S mode is selected, configuring the communication structure and substation in the power system to generate the SCL configuration description file. In the description of the document, there are two voltage levels in the substation. The voltage levels are distinguished by the number of voltage transformers and transformers. The line spacing is changed to make the current transformer realize electrical connection at the connection node. In the communication structure, the communication rate is set to 15Mbps, and the power telecontrol gateway includes two elements, access point and service. The actual communication test is carried out for the substation. The process is shown in figure 2.

Before TCP connection is established, it listens for telecontrol dispatching fault, sends connection request to power equipment and waits for the connection request from communication gateway. After receiving the request, the connection is established and the running state is continuously monitored. When the TCP connection is closed, it enters the listening state again. The monitoring command is transmitted to the power equipment and identified, and then the single point remote signaling frame is sent with the type identification of 1. After the emergency of dispatching failure of the equipment, the single point remote signal displacement frame is sent to the communication gateway, and the change data of the dispatching fault is sent to the monitoring terminal. During the test, the timing calling cycle of monitoring message is changed. The protocol analyzer is used to capture the message. The number
of messages transmitted by two monitoring methods in the same calling period is compared. The experimental results are as Table 1.

| Call cycle / S | Number of experimental groups | Traffic / Mbps | Number of control group / piece | Traffic / Mbps |
|---------------|-------------------------------|----------------|---------------------------------|----------------|
| 5             | 573                           | 0.012          | 325                             | 0.009          |
| 10            | 735                           | 0.025          | 582                             | 0.016          |
| 15            | 903                           | 0.034          | 794                             | 0.027          |
| 20            | 1193                          | 0.046          | 902                             | 0.036          |
| 25            | 1426                          | 0.052          | 1273                            | 0.048          |
| 30            | 1638                          | 0.062          | 1462                            | 0.052          |
| 35            | 1784                          | 0.078          | 1582                            | 0.069          |
| 40            | 1802                          | 0.084          | 1694                            | 0.074          |
| 45            | 1893                          | 0.089          | 1702                            | 0.083          |
| 50            | 1986                          | 0.097          | 1826                            | 0.091          |

The regular calling cycle is the time interval for calling all monitoring data. According to the table above, the average number of messages transmitted in the experimental group is 1393, while that in the control group is 827. Compared with the control group, the number of messages transmitted in the experimental group is increased by 566. To sum up, compared with the traditional monitoring method, this design method improves the number of packet transmission per unit time, and then the network traffic is increased. In the dynamic monitoring process of dispatching fault, it can ensure that the communication network has very low load.

4. Conclusion
This design method gives full play to the technical advantages of the improved fault tree and effectively increases the number of packets transmitted per unit time. However, there are still some deficiencies in this research. The research on the operation status of telecontrol channel is not deep enough, and the measurement standard of signal-to-noise ratio is ignored. In the future research, real-time monitoring of signal-to-noise ratio will be carried out to further improve the engineering reference value of the monitoring method.

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