Online Monitoring of Transmission Line Operation Based on Power Internet of Things

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Abstract—Current monitoring methods of transmission line operation status cannot obtain real-time data of distributed distribution transmission line, which leads to a large error in monitoring results. Therefore, a multi-state on-line monitoring method based on power Internet of Things is proposed. Using the gateway of power Internet of Things to set up network control access mode, build edge computing model, and using AD chip of ADS8365W5300 to obtain the real-time data of massive distributed distribution network, then make a decision on the fault after processing and analyzing the data. This paper constructs an edge computing model which can complete the data processing and analysis in the edge node, and designs the deployment of the edge computing model. By evaluating the faults in the dynamic incremental fault set, the risk state of transmission line in the danger control area is obtained, and a multi-state on-line monitoring method is designed. The experimental results show that the proposed method can monitor the transmission line running state accurately.

1. Introduction
With the rapid development of power grid construction and the gradual expansion of power grid scale, transmission lines will face a variety of risks in the process of operation, affecting the safety and reliability of the power grid [1]. Therefore, it is necessary to warn the risk of transmission line operation. The danger control area of transmission line refers to some common fault areas which are divided by some power supply companies according to their experiences, which is convenient for management and maintenance. The risk early warning of transmission line danger control area can effectively avoid the occurrence of transmission line faults, and provide a strong guarantee for the safe operation of power system [2]. Because the quantity of risk-related information of power transmission line is small, it can not reflect the risk of power network very well, but also cause certain economic losses [3]. However, the existing early warning technology is vulnerable to natural disasters and manual intervention, resulting in poor early warning effect. So the paper [4] studies the model of early warning and assessment of transmission line fire prevention based on AHP, constructs the hierarchical structure by using risk factors, constructs the judgment matrix by combining the actual operation and maintenance data of transmission lines, and obtains the weights to realize the early warning of transmission line risk. Reference [5] Studies the intelligent monitoring method of transmission line hazard based on deep learning, and uses the intelligent identification algorithm of transmission line hazard to realize the risk early warning of transmission line. But the two methods have the problem of poor precision in the collection of risk information of transmission lines, which leads to the low
precision of early warning results and the poor timeliness of risk early warning. In order to realize the risk early warning of transmission line danger control area, the risk early warning technology of transmission line danger control area based on ubiquitous IOT is proposed. Ubiquitous power IOT technology is real-time, accurate and comprehensive, which can be widely used in the monitoring of power facilities and communication infrastructure, and can get the main information in different cases. Based on the overall information perception and overall configuration information of ubiquitous power IOT, the dynamic failure rate of components and the incremental dynamic failure set are calculated, and the precise risk warning results are obtained after the failure, and the risk status of all power grids is known according to the results, so as to realize the risk warning of transmission line danger control area.

2. Multi state online monitoring of transmission line operation based on power Internet of things

2.1. Set network control access mode based on power Internet of things gateway

In order to control the access mode of the device, we need to start with the sense network and communication network. Perceived input layer and perceived network interactive task data, and the number of accessible perceived network nodes, and the network has a fast transmission speed, long transmission distance, strong confidentiality, anti-jamming and other characteristics, so based on the basic characteristics of the perceived network to establish the perceived network routing control protocol [6-7], as shown in Figure 1 below.

![Fig. 1 Network-aware routing protocols](image)

In Figure 1, A1-A3 represents the control center node; a1-a3, b1-b2 are the branch control nodes. According to the above figure, the source node in the protocol transmits data to the branch nodes on both sides, which includes segmented transmission mode and phased transmission mode. Through different routing protocols, the Internet of Things gateway can identify the types of power tasks and improve the processing speed of task data according to the different transmission methods [8].

Network control access mode based on power IOT gateway through optimization and improvement of IOT awareness layer and communication layer [9-10].

2.2. Construction of edge computing model

Edge computing refers to an open platform that integrates network, computing, storage and application core capabilities and provides edge intelligent services nearby at the edge of the network close to objects or data sources, so as to meet the key needs of industry digitalization in such aspects as agile connection, real-time business, data optimization, application intelligence, security and privacy protection. Based on ADS8365W5300 high-speed AD acquisition chip, a mass of real-time data of distributed distribution network is obtained and transmitted to local Moss agent service center through 4G wireless channel. According to the current requirements of real-time and accuracy of fault detection, the network transmission channel is unable to deal with such a large scale of real-time data.
Therefore, an edge computing model that can complete the data processing and analysis of distribution network at edge nodes is established to alleviate network load and unreliability. The edge computation model is shown in Figure 2.

As shown in Figure 2, the distribution network data in the model is generated by multiple fault detectors at the top and multiple terminal devices at the bottom, and transmitted to the cloud computing center through the network. In particular, the terminal equipment at the lower end (i.e. the edge node) needs to make a request to the cloud computing center, and the client may feed back relevant grid data to the edge node only after it receives a response.

2.3. Design of multi state on-line monitoring method for transmission line

Based on the transmission characteristics of transmission line fault current, the catenary formula is used to calculate the sag and stress data of fault current. Most of the catenary formulas are hyperbolic functions, and the calculation process is complicated. When the transmission line is abnormal, the maximum length of fault current in stall distance is about 5 % larger than that in stall distance. Therefore, the calculation process can be simplified, and the distribution of fault current along the line direction of the hanging point can be regarded as uniform, so the parabolic formula is used to calculate the fault current data.

(1) Calculation of sag of fault current

As shown in Figure 1, in a transmission line with different height of suspension points, the shift \( l \) between points A and B is higher than that of point \( h \). Based on the sag formula of oblique parabola, the maximum sag of fault current in the transmission line is:

\[
f = \frac{f^2 \cdot G}{F \cos \phi}\]  

(1)

In the formula, \( F \) represents the horizontal tension at the lowest point of the fault current, and \( N \), \( G \) represents the gravity force per unit length of the fault current.
The formula for calculating the inclination angle of fault current at hanging points A and B is as follows:

\[
\theta_A = \arctan \left( \frac{l \cdot G - h}{F \cos \phi - l} \right) \quad (2)
\]

\[
\theta_B = \arctan \left( \frac{l \cdot G + h}{F \cos \phi + l} \right) \quad (3)
\]

By substituting the \( \frac{G}{F} \) in the formulas (2) and (3) into the formula (1), the relationship between the fault current sag and dip angle can be obtained as follows:

\[
f = \frac{(\tan \theta_A + \frac{h}{l})}{8} \quad (4)
\]

\[
f = \frac{(\tan \theta_B - \frac{h}{l})}{8} \quad (5)
\]

By measuring the relationship between the fault current sag and the inclination angle, the maximum sag in the fault current stall is calculated.

(2) Load calculation of transmission lines

The change of temperature will cause the expansion or contraction of transmission line, and the change of load will make the value of fault current rebalance, and the result will change the value of fault current. Under different working conditions, the relationship between transmission line and current can be expressed by state equation, that is:

\[
\begin{align*}
H_n &= \frac{l^2 w_m^2 ES}{12 F_m^2} \\
H_m &= \frac{l^2 w_n^2 ES}{12 F_n^2} + \alpha ES (t_n - t_m)
\end{align*}
\]  

(6)

In the formula, \( H_m \) and \( H_n \) respectively represent the magnitude of fault current under \( m \) and \( n \) working conditions, \( w_m \) and \( w_n \) respectively represent the magnitude of fault current under \( m \) and \( n \) and unit length of fault current under \( m \) and \( n \) working conditions, \( t_m \) and \( t_n \) respectively represent the conductor temperature of fault current section under \( m \) and \( n \) working conditions, \( E \) represents the elastic coefficient of conductor of fault current section, \( \alpha \) represents the coefficient of temperature expansion, and \( S \) represents the cross-section area of conductor of fault current section. The energy consumption of abnormal data during the fusion process is:

\[
E_{DA} (\cdot) = E_\eta \quad (7)
\]

In formula (7), \( E_{DA} \) represents the energy consumed by fusing 1 bit abnormal data, and \( \eta \) represents the fusion coefficient. Next, the multi state on-line monitoring of transmission line is realized through the transmission line condition monitoring process.
3. Experimental comparative analysis

3.1. Setting experimental parameters
In order to analyze the performance of the proposed monitoring method based on fault current propagation, reference [4] method and reference [5] method, three monitoring methods are modeled in MATLAB environment. Three transmission line towers shall be installed within the monitoring area of 60 meters * 1100 meters. The communication master station is located on the first tower pole, and the distance between the three towers is 500 meters. 20 sensor collection nodes are deployed near each tower pole. Two of the nodes use induction to power the monitoring process with unlimited energy and all the remaining nodes use batteries to power the monitoring process. The initial energy is set at 1 joule. The main communication station is located at (30, 30), and all nodes cannot be moved once installed.

3.2. Comparative test of transmission line condition monitoring error
The multi-state on-line monitoring method, reference [4] method and reference [5] method based on the Internet of Things are adopted to monitor the state of transmission lines, and the comparison result of the monitoring error is shown in figure 4.

![Comparison results of transmission line condition monitoring errors](image_url)

Fig. 4 Comparison results of transmission line condition monitoring errors

It can be seen from the experimental results in Fig. 4 that the monitoring method in reference [4] does not calculate the transmission line fault current data, so that the transmission line condition monitoring results affected by the sag of the fault current are lower than the real value of the transmission line condition data, and the monitoring error becomes larger; The monitoring method in reference [5] is affected by the transmission line load, which makes some values of the transmission line condition monitoring results close to the real value, but the final monitoring error is still very large; The transmission line condition monitoring method based on the propagation characteristics of fault current calculates the sag of fault current and the load of transmission line respectively, which makes the data value of transmission line fault current more accurate, so as to reduce the transmission line condition monitoring error.

4. Conclusion
In order to solve the problem of large errors in the monitoring results of current transmission line operation status monitoring methods, a multi-state online monitoring method for transmission line operation based on power Internet of Things is proposed. Build edge computing model, obtain massive real-time data of distributed distribution network, and design the deployment of edge computing model. The risk state of transmission line risk control area is obtained, and the multi-state online monitoring method of transmission line is designed. Experimental results show that the multi-state monitoring results of the proposed method are consistent with the real situation and meet the
application requirements in this field. In this paper, the analysis and processing of the operation status of the distribution line is not in-depth enough. In the follow-up research process, we can consider the elimination and correction of erroneous data.

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