ISSN 2706-655X Vol.3, Issue 10: 14-26, DOI: 10.25236/IJFET.2021.031002

Distributed Mobile Cooperative Control of Complex Power System Based on Wireless Sensor Network

Jianxun Wang[1,a], Jia Li[1,b], Chi Zhang[2,c*]

[1]Beijing GD Power New Energy Technology Col, Ltd, ChaoYang 100101, Beijing, China
[2]Beijing ztxy Technology Co., Ltd, ChaoYang 100101 Beijing, China
[a]63199630@qq.com, [b]15040088825@139.com, [c]zhangc@cnztxy.com
**Corresponding author*

Abstract: *Stable power supply is the guarantee for social and economic development and people's normal life. Under the social background of pursuing sustainable development, the realization of energy diversity, resource optimization deployment, power storage and user demand response has become the new development direction of the power system. In order to promote the effective connection between complex power systems and smart grids, it is necessary to use wireless sensor networks to implement distributed mobile coordinated control of the system. In this paper, the application of wireless sensor networks in complex power systems has been studied, and many issues such as distributed control, distribution routes, fault identification, information monitoring and user services in smart grids have been discussed. To ensure that the data transmission rate in the sensor network is maintained at a high level, the number of sensor nodes can be controlled between 50 and 55. Experimental data shows that the data transmission rate of the number of nodes in this interval is 95.37%. If the number of nodes is low, the problem of insufficient alternative paths is likely to occur. If the number of nodes is too high, the data transmission rate will also decrease due to location distance and power consumption. In order to ensure that the power system can realize the comprehensive management of power transmission and distribution under various complicated conditions, distributed control has stronger competitiveness than traditional centralized control.*

Keywords: *Wireless Sensor Network, Complex Power System, Distributed Control, Topology Recognition Algorithm*

1. Introduction

The power system is a comprehensive system composed of multiple links such as power plants, power supply stations, distribution lines, and power usage. It is responsible for multiple responsibilities such as power generation, transformation, transmission, and distribution. The stable operation of the power system is a necessary condition for the normal development of society. The development of Internet science and technology has brought more opportunities and challenges to the traditional power industry, while the progress of social economy has made people pay more attention to the sustainable development of power. On the whole, smart grid has become an inevitable trend in the development of modern power systems. How to make good use of modern science and technology such as wireless sensor networks to achieve comprehensive control of complex power systems has become the main research direction in the power field of various countries.

In foreign countries, many scholars have carried out research on the application of modern technology and information technology in power systems. Bijami has carried out research on distributed control based on network wide-area systems. For complex systems such as power systems, if transmission delays or even data packet loss occurs in the communication network, it will directly affect the stability and control performance of the system. In order to solve this kind of problem, he proposed a distributed network sliding mode control framework, and designed a local sliding mode controller based on linear matrix inequality to control the wide area system. From the experimental data, the control framework is beneficial to reduce the random delay and packet loss probability in the communication network connection, but there is still room for improvement in the stability of the framework structure [1]. Jayawardene researches on the control of power system based on learning network. Renewable energy has a very important position in the current power system, and the integration of variable renewable energy into the transmission grid will bring no small challenge to the

ISSN 2706-655X Vol.3, Issue 10: 14-26, DOI: 10.25236/IJFET.2021.031002

real-time power system operation. To cope with this problem, he and his team used the predicted PV power as the input of the regional automatic power generation controller to implement dynamic contact power flow control. From the simulation experiment, this method can play a certain role in maintaining system power and frequency stability, but its calculation efficiency needs to be improved [2].

Domestic research on intelligent control of power systems started relatively late, but very good results have been achieved so far. Z Dong analyzed the transient stability of complex power systems. He and his team not only theoretically analyzed the impact of power control on the transient secondary pendulum stability of the power system in a centralized large-scale wind power base composed of double-fed asynchronous wind turbines (DFIG). Based on the static expansion equal area criterion, the voltage equation of the system network node integrated with DFIG was modified, and an infinite machine model suitable for wind power integrated multi-machine system was established. From the experimental process, the model can realize dynamic analysis of the DFIG system and provide the necessary and sufficient conditions for the transient instability of the secondary shimmy. But on the whole, the study did not carry out specific experimental explanations on the relationship between the first-order stability and the second-order stability in the wind power grid-connected system [3].

The research of this article mainly starts from the following parts. First, this article introduces various technologies and methods involved in complex power systems, including wireless sensor networks, smart grid technology, topology recognition algorithms, and energy adaptive time synchronization algorithms. Secondly, this article carried out simulation experiments on distributed control of power systems. The application of wireless sensor networks in complex power systems provides strong support for the system to achieve dynamic control in power distribution protection, fault location, and circuit monitoring. Finally, this article combines experimental data to explain in detail the distributed mobile cooperative control of complex power systems.

2. Power System Distributed Control Technology

2.1 Wireless Sensor Network

As a multi-hop self-organizing network, wireless sensor network has the characteristics of dynamic and self-organization, which can effectively realize data collection, processing and transmission [4]. The essence of wireless sensors is to combine various advanced communication technologies to organize a large number of sensor nodes in an orderly manner to realize the exchange and aggregation of data resources. In actual operation, a large number of sensor nodes will be deployed randomly by spreading, or will be deployed manually in the target area [5-6].

The sensor node in the wireless sensor network is similar to a simple embedded system. It not only can shoulder the task of a router, but also can play an effect similar to a traditional network terminal. In simple terms, the job of a sensor node is to obtain information and data in the target area, and send the information to the corresponding sink node after simple processing is completed [7]. Figure 1 is a schematic diagram of the wireless sensor node architecture.

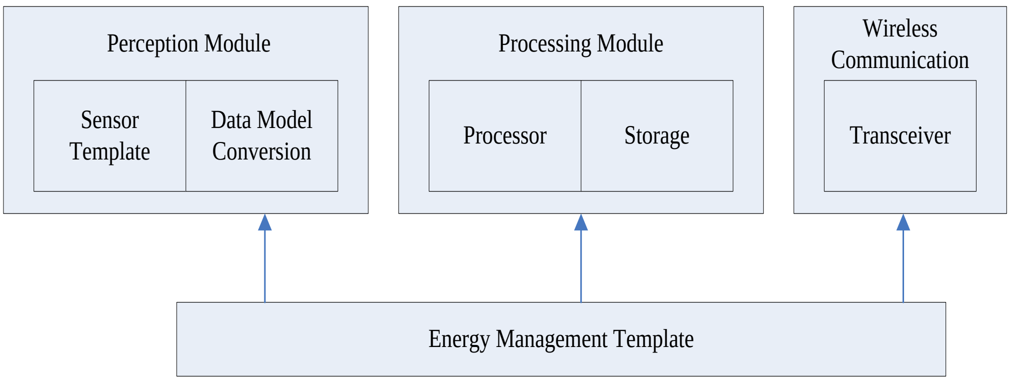

Figure 1: Schematic Diagram of Wireless Sensor Node Architecture

It can be seen from Figure 1 that wireless sensor nodes are usually divided into four modules by people: energy management module, perception module, processing module and wireless communication module. Among them, the main task of the perception module is to obtain the data in the target area, and conduct appropriate induction and conversion; the processing module not only needs to process the data transmission and reception, but also undertakes various operations and storage tasks in the wireless sensor node; wireless communication module It is responsible for realizing effective communication with external nodes and issuing control commands; the energy management module is responsible for ensuring the energy required for the stable operation of all wireless sensor nodes [8].

Wireless sensor networks can exert very good effects in the application research of complex power system automation, such as real-time monitoring of the working status and operating efficiency of the power system, and timely feedback on the occurrence of faults [9]. The key technologies for applying wireless sensor network technology to power systems mainly involve the deployment of wireless sensor nodes, communication and networking, routing protocol design, node positioning technology, service quality description for different application targets, and power system integration and other related aspects [10].

2.2 Smart Grid Technology

With the progress of modern science, people are committed to using automatic control and modern communication technology, combined with renewable energy and alternative energy sources, to build a safer and more efficient modern power grid [11]. In the smart grid, intelligent sensing and measurement technology, communication technology, power grid information platform, power electronics technology, simulation analysis and control decision-making technology, and a variety of complex intelligent devices need to be comprehensively applied [12].

The data information involved in the power system has the characteristics of large quantity, variety, and dynamics. In order to achieve comprehensive control, a large number of sensors must be used to intelligently monitor the power grid. For example, smart energy meters used to realize user-side intelligent management; various smart sensors used for device status detection; smart sensors based on different communication technologies for various applications, such as optical fiber sensors and wireless radio frequency sensors [13-14].

Modern communication technology is the key to the construction of a smart grid. The establishment of an open system and highly integrated communication system covering the power generation side to the user side enables real-time monitoring and information exchange of the entire grid [15]. The communication network usually includes three levels: indoor communication network, local area communication network and wide area communication network. The power grid information platform can provide service support for the informatization of various professional branches, and realize the dynamic sharing of data, large-capacity high-speed access, information integration and exchange, and information display [16].

2.3 Topology Recognition Algorithm

The grid topology is one of the important information of the grid model. When monitoring the state of the power system, the network topology information can play a very important role. With the increase in the scale of the power grid, the traditional data acquisition and monitoring control system SCADA has been difficult to complete the real-time update of the wide area power grid topology information. In modern power grids, too many distributed energy grids will cause frequent changes in the grid topology, increasing the difficulty of smart grids to achieve large-scale topologies [17]. In order to improve this problem, this paper proposes a topology recognition method based on impulse adaptive observer. From the experimental data, this can play a good effect on improving the speed and accuracy of smart grid topology recognition.

Set $f(t^+)$ to represent the right limit of the function, and $f(t^-)$ to represent the left limit of the function, then the derivative of function $v(t)$ satisfies the formula:

$$D^+v(t) = \lim_{h \to 0^+} \sup \frac{v(t+h)-v(t)}{h} \tag{1}$$

Set x_i to represent the state vector of the node, when $t \to \infty$ satisfies the formula:

$$x_i = A_i x_i + f_i(t_i x_i) + \in \sum_{i=1}^{N} c_{ij} B_{ij} g_{ij}(t, x_j), i = 1, \cdots, N \tag{2}$$

ISSN 2706-655X Vol.3, Issue 10: 14-26, DOI: 10.25236/IJFET.2021.031002

Assuming that there is a constant for any vector $x_i, y_i \in R^n$, L represents a positive scalar, then the inequality is satisfied:

$$\| f_i(x_i) - f_i(y_i) \| \le F \| x_i - y_i \| \tag{3}$$

$$\| g_{ij}(t, x_j) - g_{ij}(t, y_j) \| \le G \| x_i - y_j \| \tag{4}$$

$$\lambda_{\max}(A_i + A_i^T) \le L \tag{5}$$

Impulse-based adaptive observer is a topology recognition method for studying complex dynamic networks [18]. Based on the original complex dynamic network, the following form of impulse adaptive observer response network is first established:

$$\hat{x}_i(t) = A_i\hat{x}_i(t) + f_i(t, \hat{x}_i(t)) + \sum_{i=1}^{N} \hat{d}_{ij}(t) B g_{ij}(t, \hat{x}_j(t)) + U_i \tag{6}$$

$$x_i(t_k) = \hat{x}_i + K(\hat{x}_i(t_k^-) - x_i(t_k^-)) \tag{7}$$

$$x_{i0}(t_0) = \hat{x}_{i0} \tag{8}$$

Among them, $\hat{x}_i(t) = (\hat{x}_{i1}(t), \hat{x}_{i2}(t), \ldots, \hat{x}_{in}(t))^T$ is the corresponding state of the i-th node, and $\hat{d}_{ij}$ is the estimated value of the coupling parameter c_{ij}. The adaptive law of the coupling parameter is determined by the following formula:

$$\hat{d}_{ij}(t) = -B g_{ij}(t, \hat{x}_j(t))(\hat{x}_i(t) - x_i(t)) \tag{9}$$

Control U_i has the following form:

$$U_i = -k_i(t)(\hat{x}_i(t) - x_i(t)), k_i = \| \hat{x}_i(t) - x_i(t) \|^2 \tag{10}$$

When $\bar{x}_i = \hat{x}_i - x_i$, the system error satisfies the way:

$$U_i = -k_i(t)(\tilde{x}_i(t)), k_i = \| \tilde{x}_i \|^2 \tag{11}$$

$$\tilde{d}_{ij}(t) = -g_{ij}(t, \hat{x}_j(t)) \tilde{x}_i(t) \tag{12}$$

Based on the above-designed pulse adaptive tumbler, the response network is synchronized with the drive network, and the balance relationship between nodes in the original network is obtained according to the steady state state, which can further realize the recognition of network topology [19-20].

2.4 Energy Adaptive Time Synchronization Algorithm

Time synchronization plays a very important role in the establishment of the basic framework of distributed systems, and it is also the core supporting technology of wireless sensor networks [21]. This paper proposes an energy-adaptive time synchronization algorithm, assuming that the root node executes the following adaptive energy algorithm in its child node table to calculate the equivalent energy of the child nodes:

$$E_i^{eq} = \begin{cases} a \times E_i & (N_i^c > 0) \\ E_i & (N_i^c = 0) \end{cases} \tag{13}$$

Among them, E_i is the remaining energy of the node, E_i^{eq} is the equivalent energy of the node, N_i^c is the number of child nodes of the node, and the node when it is zero is a leaf node. It is preferentially selected as the reference child node to perform comparison and synchronization with the parent node, which is beneficial to balance the energy consumption of the node and prolong the life of the network [22]. Suppose the time deviation between child nodes is δ and the round-trip delay is d, then they satisfy the calculation formula:

$$\delta = \frac{(T_{B2} - T_1) - (T_4 - T_3)}{2} \tag{14}$$

$$d = \frac{(T_{B2} - T_1) + (T_4 - T_3)}{2} \tag{15}$$

$$T = \begin{cases} T_5 - \delta \\ T_6 - (T_{B2} - T_{C2}) - \delta \end{cases} \tag{16}$$

Wireless sensor network is an application-dependent network. Different applications have different requirements for the accuracy of time synchronization. At the same time, the frequency drift of different nodes will change with environmental changes [23]. In view of this situation, this article adjusts the synchronization time period according to the latest time offset and the expected time offset, the adjustment range is 1%, the specific algorithm is as follows:

$$T = \begin{cases} T \times (101/100) & (\delta_{cur} < \delta_{\exp}) \\ T \times (99/100) & (\delta_{cur} > \delta_{\exp}) \end{cases} \tag{17}$$

Where T is the current synchronization period, δ_{cur} is the current time offset, and $\delta_{\exp}$ is the expected time offset. According to formula (18), the corresponding node with the smallest equivalent level L can be used as its parent node, and then immediately send a synchronization request packet to perform two-way comparison and synchronization with this parent node [24]. Set as the initial energy of E and E_i as the remaining energy, they satisfy the formula:

$$L = \frac{E}{E_i} \times L_i \tag{18}$$

The node that fails to synchronize will send a synchronization request to the parent node after the timer expires. If the number of synchronization reaches a certain requirement, the parent node will be determined to be dead, and the broadcast level will re-search for the parent node and issue the request [25].

3. Power System Distributed Control Experiment

3.1 Experimental Background

The power system is a complex and comprehensive system, which contains multiple components such as power generation, transmission, and distribution. With the advent of the era of intelligence, artificial intelligence has gradually penetrated into all aspects of our lives, but for now, in most areas of my country, there is still room for improvement in the level of intelligent applications in the power system. In our country, the construction of power infrastructure is very complete, even in remote and poor mountainous areas, the power grid can be covered. But on the other hand, this also makes the branch of the power grid more complicated, and the traditional manual line inspection has been difficult to meet the requirements of modern power grids for timeliness and safety.

Traditional power system monitoring is mostly carried out by means of wired communication, so installation and maintenance difficulties are inevitable. In contrast, the complex power system based on wireless sensor network not only has lower cost, but also can exert excellent effects in wireless monitoring. The intelligent power system can supervise and protect the safety of power stations, transmission lines, and electricity use 24 hours a day, and give timely response decisions to realize distributed coordinated control.

3.2 Experimental System Design

In order to explore the dynamic integrated control in the complex power system, this paper constructs a power system model based on the wireless sensor network. Starting from the network communication demand analysis, intelligent power distribution control and power system fault location, it explores the modern science and power system. How does the system combine to realize distributed mobile coordinated control of the system.

The intelligent power distribution communication wireless sensor network designed in this paper adopts a system structure compatible with the hierarchical structure of the distribution automation system. The system consists of three equipment layers and two communication layers: the equipment layers are the power distribution main station layer, the distribution electronics station layer, and the power distribution feeder terminal equipment layer. The communication layer is the main station optical fiber communication layer and the feeder equipment wireless sensor.

The wireless sensor network router in this article is composed of a power supply module, a microprocessor module, a wireless radio frequency module, and a serial communication module. The intelligent distribution network communication wireless sensor network protocol stack with QoS routing protocol is embedded in the microprocessor to provide a communication that conforms to power distribution Good real-time and reliable QoS transmission support for data requirements.

3.3 Experimental Data

In order to ensure the smooth progress of the research, this paper conducted various performance tests on the experimental system, such as networking mode, terminal command packets, and data transmission delay. Table 1 is the sampling test data result of the wireless sensor network terminal command packet.

Table 1: Terminal Command Packet Sampling Test Data

Node number	Access status	Send command packet	Receive command packet	Success rate
054	No access	50163	50077	99.83%
069	Access	51356	50950	99.21%
052	Access	36348	35650	98.08%
031	No access	28829	28782	99.84%
107	No access	13265	13177	99.34%
043	Access	36415	35056	96.27%
088	No access	52324	51439	98.31%
027	Access	18563	18561	99.99%
093	No access	35985	34981	97.21%
073	Access	25536	25117	98.36%

It can be seen from Table 1 that among the 10 data service nodes randomly checked, the wireless sensor network terminal has the highest success rate in the 027 variable node, with a success rate of 99.99%; the 043 variable node with the lowest success rate has a probability of 96.27; each business The average success rate of nodes is 98.644%. In the terminal data transmission delay test, the maximum delay is 846 milliseconds, the minimum delay is 461 milliseconds, and the average delay is 768 milliseconds. Judging from the sampling test results of the reliability of the wireless sensor network and the information system, the highest qualified rate of the call data is 100%, the lowest qualified rate is 99.028%, and the average success rate is 99.471%.

4. Distributed Mobile Cooperative Control of Complex Power System

4.1 Wireless Sensor Network Communication Requirements for Complex Power Systems

The two-way flow integration system of power energy and communication information is an important technical support for complex power systems, and the flexible and reconfigurable smart grid communication system structure is the basis for its realization. To apply wireless sensor networks to smart power distribution communications and build wireless sensor networks that adapt to the characteristics of smart grids, it is necessary to combine the structural characteristics of the distribution automation system to characterize the wireless sensor network system architecture; combine the distribution characteristics of power distribution terminal equipment to characterize wireless Sensor network topology; use power distribution communication specifications to characterize wireless sensor network communication performance indicators. Table 2 is a statistical table of basic communication information types and lengths of terminal equipment.

Table 2: Type and Length of Terminal Equipment Communication Information

	Transmission data type	Update cycle	Information unit length
State quantity	Switch position	Burst transmission or 1-5 second cyclic polling	1-3
	Switch pressure signal	Burst transmission or 1-5 second cyclic polling	1-3
	Terminal status	Burst transmission or 1-5 second cyclic polling	1-3
	Fault signal	Burst transmission or 1-5 second cyclic polling	1-3
Analog	voltage	Burst transmission or 1-5 second cyclic polling	2-6
	Power Factor	Burst transmission or 1-5 second cyclic polling	2-6
	Temperature	Burst transmission or 1-5 second cyclic polling	2-6
	Electric energy	15 minutes cyclic polling	4-24
other	Total call	10 minutes or reinitialize	36
	Time information	30 Minutes	8
	Power quality	Burst transmission or 15 minutes cyclic polling	2-6 X harmonic number
	Time record	Burst transmission	10

It can be seen from Table 2 that in the smart grid power distribution system, in the smart grid, in addition to the data of the FTU of the distribution switch, the terminal TTU of the distribution transformer, and the terminal DTU of the switching station, the terminal communication of a 10kV distribution line is also possible. Including remote collection, user demand response, distributed power generation and power storage and other information. In the area under the jurisdiction of an intelligent power distribution system, there may be as many as hundreds of power distribution lines, and there may be thousands of smart communication terminals. Each node has various information and the amount of transmission information is very large. Figure 2 and Figure 3 are the statistics of energy consumption and energy proportion of each module of the wireless sensor node.

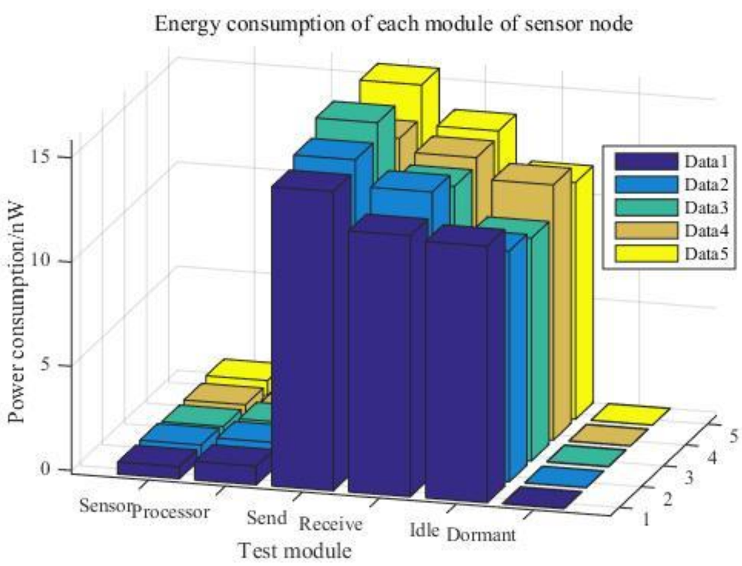

Figure 2: Energy Consumption Statistics of Each Module of Sensor Node

It can be seen from Figure 2 and Figure 3 that in the energy consumption of wireless sensors, the communication template consumes most of the node energy. Among them, the sensor sending nodes accounted for the highest proportion of consumption, accounting for 36.02%, while the dormant state with the lowest proportion of consumption only accounted for 0.06%. Sink nodes can not only complete data processing better, but also perform well in wireless communication and information storage. People can think of it as a wireless sensor node with super computing power, or a special network management device capable of wireless communication interface. With the help of convergent nodes, the complex power system can effectively establish the connection between the wireless sensor network and the terminal, and better realize user management.

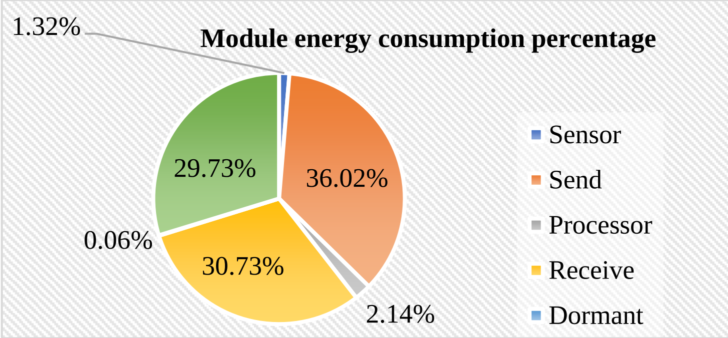

Figure 3: Statistics of the Energy Consumption of Each Module of the Sensor Node

4.2 Intelligent Distribution Control of Complex Power System

The network topology and networking methods of wireless sensor nodes are the key to real-time monitoring of data communication systems in smart distribution networks. The distribution network is an important part of the power system. It directly faces the power infrastructure and directly undertakes the task of supplying power to users. The distribution network has a wide distribution range and complex wiring structure, which greatly affects the reliability of power supply to users. According to the load density, geographical environment, power distribution station protection methods, and distribution network grounding methods in different distribution areas, the network structure of the distribution network has many forms, and the main wiring methods include radiation structure and ring network structure.

In order to verify the effectiveness and applicability of the shortest path algorithm after the establishment of the wireless sensor network topology of the distribution network, this paper uses network simulation tools to test the performance of the proposed algorithm and model, and analyze the results. It provides a theoretical basis for constructing the wireless sensor network topology and data transmission path of the distribution network in practical applications. Table 3 shows the trace record format description.

Table 3: Trace Record Format Description

Event	The cause of the incident
Time	Time of event
From node	The starting point of the incident
To node	The end of the event
PKT type	Packet type
PKT size	Packet size
flags	Packet label
Not detected	Packet data flow

It can be seen from Table 3 that the reason, time, location, type and data flow of the packet time will be recorded in detail in the record. If the record description is "r" means that the packet is received by a node, "d" means that the packet is discarded by the queue, and "+" and "-" mean entering the queue and leaving the queue respectively. Use the awk language in the simulation tool to analyze the trace record information. Figure 4 shows the end-to-end delay scatter plot.

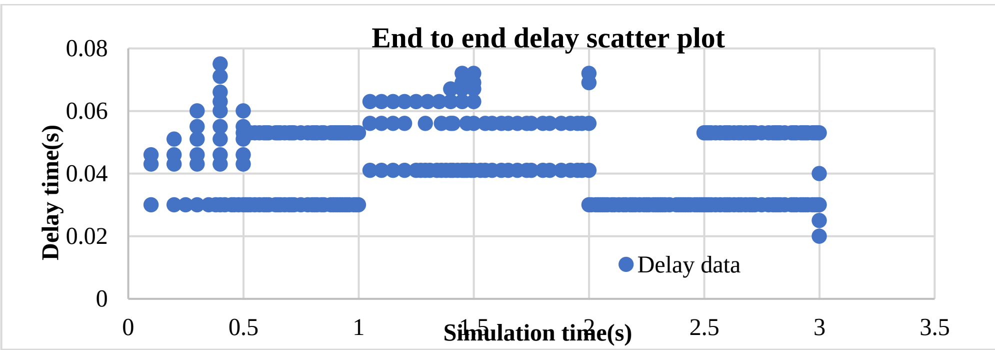

Figure 4: End-to-End Delay Analysis Scatter Plot

ISSN 2706-655X Vol.3, Issue 10: 14-26, DOI: 10.25236/IJFET.2021.031002

It can be seen from Figure 4 that when the transmission delay between adjacent nodes in the network is 10ms, the maximum end-to-end delay of the data packet does not exceed 0.08s. Using simulation tools to analyze the packet loss rate of the trace record file, we can see that a total of 488 packets were sent. Because a link suddenly failed at 1.0s, 5 packets were lost, and the final transmission reliability was 98.97%. Figure 5 shows the average throughput statistics of packets.

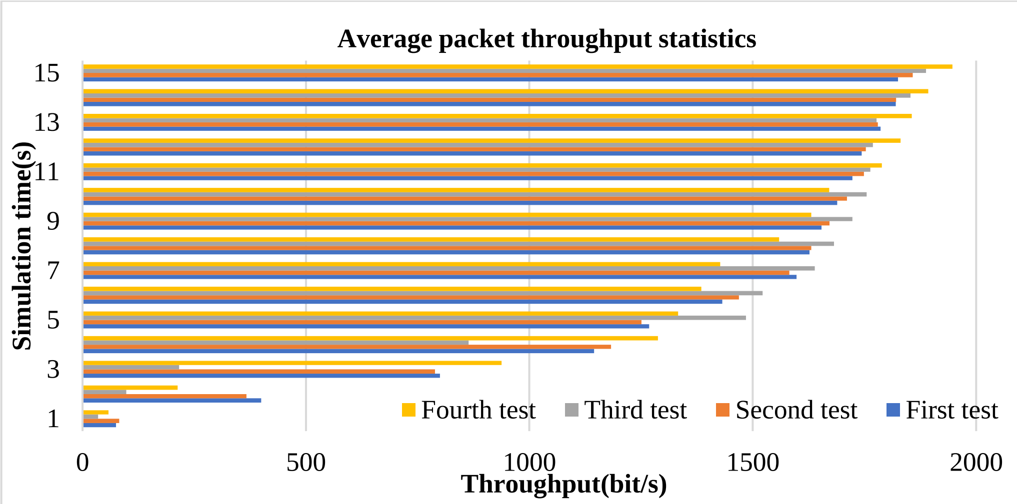

Figure 5: Average Packet Throughput Statistics

For throughput analysis, it is necessary to remove the 1.0s link failure simulation environment setting, and to truly reflect the network throughput, the simulation time is extended to 15s. The results from Figure 5 show that as the network running time increases, the average throughput approaches the threshold of 2M bandwidth, which means that the network communication is in good condition and there is no obvious congestion. Figure 6 shows the number of nodes and the data transfer rate.

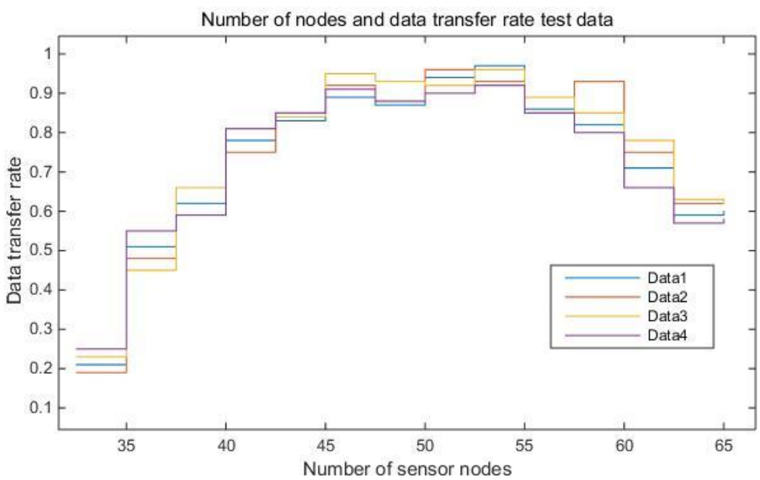

Figure 6: Number of Nodes and Data Transfer Rate Test Data

It can be seen from Figure 6 that when the number of sensor nodes is 50-55, the data transmission rate can be stably maintained at a relatively high level. If the number of nodes is less than 35, the transmission efficiency will be low due to lack of alternative paths; if the number of nodes is higher than 65, the data transmission rate will change due to the impression of location distance, channel parameters, power loss and other factors. Getting lower and lower.

Based on the theoretical basis of the simulation results, this paper completes the reasonable deployment of wireless sensor network nodes in the distribution network, and achieves the networking effect of the intelligent distribution communication wireless sensor network topology and the distribution line structure, making the wireless sensor network communication mode The data transmission efficiency of the topological structure is the highest, which provides a theoretical basis for practical applications. That is, on the basis of the topology of the wireless sensor network for smart distribution network communication, establish a real-time and reliable routing mechanism that meets

ISSN 2706-655X Vol.3, Issue 10: 14-26, DOI: 10.25236/IJFET.2021.031002

the requirements of smart distribution network communication reliability.

4.3 Fault Location of Power System Based on Wireless Sensor Network

The distribution network fault monitoring system based on wireless sensor network is composed of wireless sensor nodes, monitoring gateway and monitoring center. Normally, fault location needs to go through four processes: networking, data collection, data processing, and final fault location. After the network is established with the coordinator node in the wireless sensor network, the network parameters need to be initialized, and the networking process is realized through the sensor node and the coordination node.

If there is a power failure, the system will transmit the fault information and zero sequence current to the monitoring center, where the collected zero sequence current values are analyzed, processed and compared. When a single-phase ground fault occurs in the system, the monitoring center will receive zero sequence current from the coordination node. After the fault occurs, the compensation degree will be adjusted due to the function of the arc suppression coil. At this time, the command to collect the current will be sent to the coordination node again. By repeating the above working process, the monitoring center will compare the changes of the zero sequence current under the same voltage to determine the location of the fault. Figure 7 shows the current value when the fault occurs.

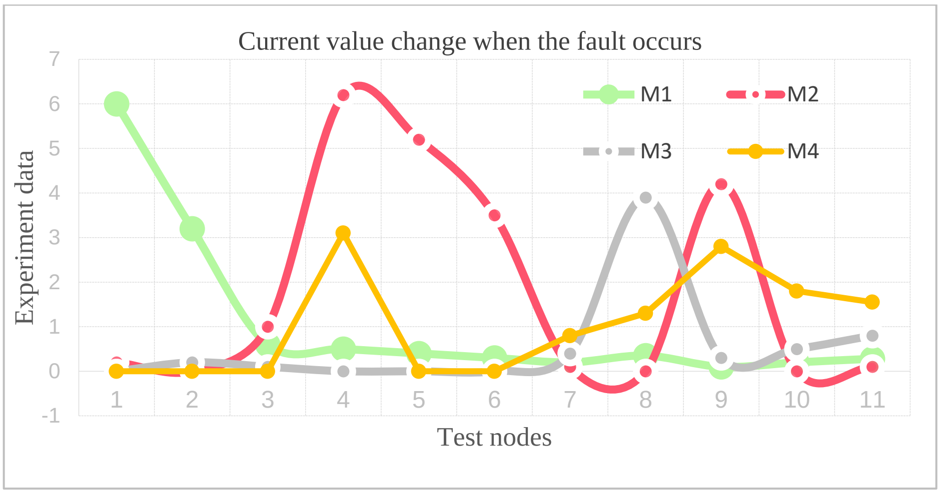

Figure 7: Statistical Graph of Current Value when a Fault Occurs

In the simulation model, it is assumed that the node has a node failure, and the measurement device is used to measure the node data. It can be seen from Figure 7 that there is a very significant difference in values between nodes 1, 2, and 3. Therefore, the values measured at M2 can be used to estimate the faults at nodes 4, 5, 6, and 9, and M3 can be used to measure nodes 7, 8 , 10, and 11. When a fault occurs on a different line connecting two nodes, wavelet energy entropy and Clark component can also be used to distinguish the same fault. Table 4 and Figure 8 are the current amplitude difference data before and after the fault.

Table 4: Current Amplitude Difference Data Before and After the Fault

Grounding mode	Current amplitude difference	Fault impedance0.01	Fault impedance1	Fault impedance10
Neutral point ungrounded	ΔIm(A)	131.21	130.86	128.1
	ΔIm(B)	0.01	0	0.01
	ΔIm(C)	0.018	0.018	0.018
Arc suppression coil grounded	ΔIn(A)	179.65	180.98	178.23
	ΔIn(B)	0.01	0.01	0.01
	ΔIn(C)	0.018	0.018	0.018

It can be seen from Fig. 8 that the A-phase current before the fault location is significantly greater than the B-phase and C-phase currents, and the voltage of A relative to the ground changes from large to small, while the three-phase current after the fault remains symmetrical with little change. The above

ISSN 2706-655X Vol.3, Issue 10: 14-26, DOI: 10.25236/IJFET.2021.031002

results are in line with the characteristics of single-phase grounding. After a single-phase grounding fault occurs in two different grounding methods, the current amplitude change between adjacent nodes in the fault location is greater than the current amplitude change between adjacent nodes of the non-faulty phase. After the fault location, the current amplitude between adjacent nodes of each phase line The current amplitude is the same.

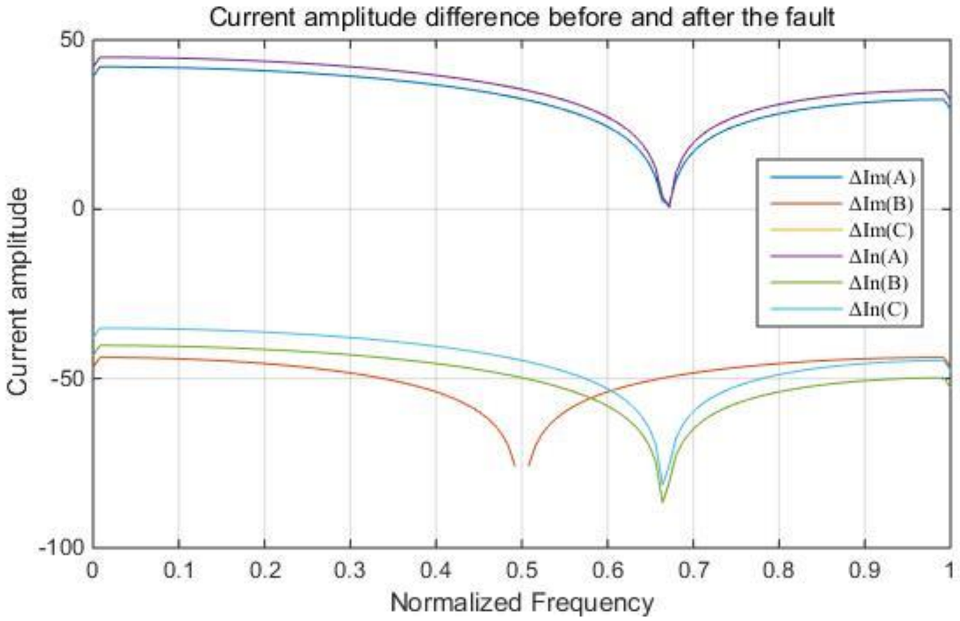

Figure 8: Data Diagram of Current Amplitude Difference before and After Fault

On the whole, each fault location method used for distribution lines has its own advantages and disadvantages, and the results obtained by using only one method for fault location are not ideal. If the advantages of multiple methods can be comprehensively used and compared with the results of various fault location methods, the fault range can be reduced to improve the reliability and accuracy of location, and better play the distributed cooperative control in the power system.

5. Conclusions

This article analyzes the communication requirements of wireless sensor networks in complex power systems. To realize the intelligent work of the power system, it is necessary to form an adaptive connection between the wireless sensor network and the power distribution system and terminal equipment, and to ensure the real-time nature of data transmission. In this paper, the application of wireless sensor network in intelligent distribution network communication system is studied. After analyzing the architecture mode of the intelligent distribution network, a related structural model was established. This article simulates the sending and receiving process of data packets using the shortest path algorithm, and analyzes the simulation results. The reasonable deployment of wireless sensor nodes can make the data transmission efficiency of wireless sensor network communication mode and topology structure the highest. On the whole, the use of wireless sensor networks to realize intelligent monitoring of the distribution network is applicable, which can meet the indicator requirements of the communication function of the intelligent distribution network monitoring communication system, and improve the reliability and flexibility of the communication system.

This paper focuses on the research of power system fault location based on wireless sensor network. Firstly, it introduces the overall steps of the distribution network fault location, discusses the information processing and judgment results in detail, and introduces the wavelet energy entropy to judge the fault type, the fault phase line and the fault section. This paper analyzes the characteristics of single-phase ground faults in the distribution network, and finds that the current amplitude changes between adjacent nodes in the fault location are greater than the current amplitude changes between adjacent nodes in the non-fault phase, and the current amplitude changes after the fault are the same. This variation feature can be used to detect single-phase ground faults. But for the problem that the capacitance current to ground is small when the line has high resistance, low resistance, and intermittent faults, it is difficult to accurately detect the problem. This paper uses the zero sequence current increment method combined with the zero sequence instantaneous power direction method as the criterion to determine the monitoring Whether the line at the point is the line through which the fault passes, experiments show that the combined method has high power supply reliability and is less affected by the fault grounding resistance and the line-to-ground distributed capacitance.

This dissertation has carried out research on distributed mobile cooperative control of complex power system based on wireless sensor network. With the continuous advancement of the power marketization process, higher requirements have been placed on the intelligence and comprehensive control of the power system. In order to adapt to the new demands of the traditional power management model in the current society, it is necessary to give full play to the advantages of wireless sensor networks. In the future, power research based on wireless sensor networks still has a lot of space waiting for people to explore. Restricted by various conditions, the research work of this article has some shortcomings. The subsequent exploration will mainly focus on the following points: (1) The reasonable development and utilization of network resources at each layer in the wireless sensor network; (2) Comprehensive consideration of wireless The feasibility of applying smart substations to sensor networks; (3) Establishing a cross-layer collaborative quality control protocol stack model for smart distribution networks.

References

[1] Bijami E , Farsangi M M , Lee K Y . Distributed Control of Networked Wide-Area Systems: A Power System Application [J]. IEEE Transactions on Smart Grid, 2020, 11(4):3334-3345.

[2] Jayawardene I , Venayagamoorthy G K . Reservoir based learning network for control of two-area power system with variable renewable generation [J]. Neurocomputing, 2015, 170(dec.25):428-438.

[3] Z. Dong, M. Zhou, G. Li, et al. Influence Mechanism of Active Power Control of Wind Turbine Generators on Power System Transient Second Swing Stability[J]. Proceedings of the Csee, 2017, 37(16):4680-4690.

[4] Zhang Y, Liu W, Lou W , et al. Location-based compromise-tolerant security mechanisms for wireless sensor networks [J]. IEEE Journal on Selected Areas in Communications, 2015, 24(2):247-260.

[5] Lin, Shan, Miao, Fei, Zhang, Jingbin, et al. ATPC: Adaptive Transmission Power Control for Wireless Sensor Networks [J]. Acm Transactions on Sensor Networks, 2016, 12(1):1-31.

[6] Hong Y W, Scaglione A . Energy-efficient broadcasting with cooperative transmissions in wireless sensor networks [J]. IEEE Transactions on Wireless Communications, 2016, 5(10):2844-2855.

[7] Mahmood M A , Seah W K G , Welch I . Reliability in wireless sensor networks: A survey and challenges ahead[J]. Computer Networks, 2015, 79(mar.14):166-187.

[8] Luo J , Hu J , Wu D , et al. Opportunistic Routing Algorithm for Relay Node Selection in Wireless Sensor Networks[J]. IEEE Transactions on Industrial Informatics, 2017, 11(1):112-121.

[9] Shu L , Wang L , Niu J , et al. Releasing Network Isolation Problem in Group-Based Industrial Wireless Sensor Networks[J]. IEEE Systems Journal, 2015, 11(99):1340-1350.

[10] Han G , Dong Y , Guo H , et al. Cross‐layer optimized routing in wireless sensor networks with duty cycle and energy harvesting[J]. Wireless Communications & Mobile Computing, 2015, 15(16):1957-1981.

[11] Fadel E , Gungor V C , Nassef L , et al. A survey on wireless sensor networks for smart grid[J]. Computer Communications, 2015, 71(NOV.1):22-33.

[12] Ejaz W , Naeem M , Shahid A , et al. Efficient Energy Management for the Internet of Things in Smart Cities[J]. IEEE Communications Magazine, 2017, 55(1):84-91.

[13] Jia Y , Xu Z , Lai L L , et al. Risk-Based Power System Security Analysis Considering Cascading Outages[J]. IEEE Transactions on Industrial Informatics, 2016, 12(2):872-882.

[14] Yimin G , Shundong L , Jiawei D , et al. Deterministic cloned tag detection protocol for anonymous radio-frequency identification systems[J]. Iet Information Security, 2015, 10(1):28-32.

[15] Zhu Y , Li L , Song Y , et al. Storage and Parallel Processing of Big Data of Power Equipment Condition Monitoring on ODPS Platform[J]. Diangong Jishu Xuebao/Transactions of China Electrotechnical Society, 2017, 32(9):199-210.

[16] Hamon C , Perninge M , Soeder L . A computational framework for risk-based power system operations under uncertainty. Part II: Case studies[J]. Electric Power Systems Research, 2015, 119(feb.):66-75.

[17] Weng Y , Liao Y , Rajagopal R . Distributed Energy Resources Topology Identification via Graphical Modeling[J]. IEEE Transactions on Power Systems, 2017, 32(4):2682-2694.

ISSN 2706-655X Vol.3, Issue 10: 14-26, DOI: 10.25236/IJFET.2021.031002

[18] Hu H M , Fang W , Zeng G , et al. A person re-identification algorithm based on pyramid color topology feature[J]. Multimedia Tools and Applications, 2017, 76(24):26633-26646.
[19] Farajollahi M , Shahsavari A , Mohsenian-Rad H . Topology Identification in Distribution Systems Using Line Current Sensors: An MILP Approach[J]. IEEE Transactions on Smart Grid, 2020, 11(2):1159-1170.
[20] Weng Y , Ilic M D , Li Q , et al. Distributed algorithms for convexified bad data and topology error detection and identification problems[J]. International Journal of Electrical Power & Energy Systems, 2016, 83(dec.):241-250.
[21] Han W , Shen X , Hou E , et al. Precision time synchronization control method for smart grid based on wolf colony algorithm[J]. International Journal of Electrical Power & Energy Systems, 2016, 78(jun.):816-822.
[22] Shahzad K , Shiwu X , Ping W , et al. Analysis of Research Development on Time Synchronization Algorithm for Wireless Sensor Networks[J]. Microcontrollers & Embedded Systems, 2016, 113(4):942-945.
[23] Yildirim K S. Gradient Descent Algorithm Inspired Adaptive Time Synchronization in Wireless Sensor Networks[J]. IEEE Sensors Journal, 2016, 16(13):5463-5470.
[24] Chen M Y, Zhu C A . Research on Time Synchronization Algorithm of High Precision and Low Power Consumption Based on IRBRS WSNs[J]. Wireless Personal Communications, 2017, 95(4):1-16.
[25] Pei Z , Wei C . Improved algorithm of time synchronization based on control perspective of wireless sensor network[J]. Le Lait, 2015, 70(2):89-106.