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INFORMATION MONITORING OF TRANSMISSION LINES BASED ON INTERNET OF THINGS TECHNOLOGY

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Abstract. To solve the problem of difficult real-time monitoring of current transmission lines, this article proposes an information-based monitoring system for transmission lines based on Internet of Things technology. The system utilizes the characteristics of strong scalability, good fault tolerance, low power consumption, and low cost of the Internet of Things. Taking the ultra-low power consumption MSP430 microcontroller and CC2430 radio frequency module as the core, a line monitoring system based on the Internet of Things is designed. The proposed design uses ZigBee wireless sensor network technology which is powered by solar energy. The collection, transmission, processing and judgment of various environmental parameters of the line are realized. The data information is transferred to the monitoring center of the upper computer through GPRS. When there is an abnormality, it can send a mobile phone short message to the person in charge to feedback the abnormal content in time. The distribution network's load symmetry allowed for the development of several locating procedures. For the three-phase symmetric scheme, the fault location approach based on line supply characteristics was employed, and for the three-phase asymmetric scheme, the fault location technique based on line impedance is proposed. One of the most vital uses for the Internet of Things is in the mitigation of power transmission line failures and disasters. Improved power transmission dependability, less financial loss, and fewer power outages are all possible thanks to the Internet of Things' cutting-edge sensing and communication technology. This research introduced the use of IoT in online monitoring system of electricity transmission line with a focus on the characteristics of the construction and development of smart grid. The results indicated that the system's highest temperature difference is 0.31°C, while the maximum humidity difference is 1.38%. The system increases the safety and manageability of electricity transmission while also fostering the widespread adoption and technical integration of the smart grid and the Internet of Things.

Key words: Internet of things; CC2430; Smart grid; GPRS/GSM; Data acquisition, Internet of Things (IOT)

1. Introduction. The Internet of Things technology is a technology that has emerged with the trend of technological development and people's expectations for high living standards, this technology can better ensure people's electricity safety and monitor the power grid at any time. To ensure people's requirements for a high standard of living. And the detection system under the Internet of Things technology can detect various problems at any time. Therefore, it is very necessary to use the Internet of Things technology to monitor the transmission line online. Also, due to the needs of the application, it is necessary to make a brief introduction to Internet technology. To better understand the meaning and role of the Internet of Things among users and beneficiaries. The economic development of the country is inextricably linked with the support of the electricity industry [1]. As technology advances in the world, the latest Internet technologies are gradually being introduced into electric transportation applications. Based on the Internet of Things technology, the online monitoring of the transmission line can detect the detailed problems of the transmission line anytime, anywhere, and reduce unnecessary losses to the maximum extent. Therefore, the online monitoring system of transmission lines using the Internet of Things technology is a necessary trend for national development and reform and world progress. Intelligent technology is the mainstream of technological development in the 21st century. Using various intelligent technologies to solve a series of problems in life and production can effectively reduce manual labor and save time. And in the overall inspection management, has a role that cannot be ignored.

The application of intelligent technology to transmission lines is a bold reform and innovation. The detection system can effectively prevent some problems that are easily overlooked [2]. The detection system of the Internet of Things can be updated at any time to check the transmission line and reduce the occurrence of accidents.

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Therefore, the application of the online monitoring system of the transmission line based on the Internet of Things technology is imperative. The Internet of Things, as the name suggests, is a network of connected objects. But in fact, it is not just the connection between objects and objects, but also the connection between people and objects. But no matter what kind of connection method, you need to intervene in the wireless network to play its due role. And connect the network in time for the relevant signs of the objects. Key features of the Internet of Things. The Internet of Things is a type of control and monitoring system that connects networks and provides intelligence to objects. This mode can identify various transmission problems more effectively and solve problems in time [3]. Smart grid is a hardware product because it is the new technological development of the new century. Therefore, understanding the importance and nature of the Internet of Things, that is, the nature of the information connection between things and people and things, can be useful in your work. Comprehensive state awareness, effective information processing, and practical and adaptable application are the traits of an IoT. It also contributes to the manufacture, consumption, operation, facility, and other features of energy in order to satisfy the strains of the supply network's multitype application. The fault segment location approach and the fault precise location method are currently the foremost themes of study on power system fault location. A D-PMU is the PMU application in the supply system and serves as an essential measurement expedient in the IoT. The voltage and current indications of the supply system can be calculated by a D-PMU in both steady state and abnormal circumstances. Numerous approaches for locating faults have been put forth, counting methods based on neural networks, upgraded line impedance methods, and methods based on travelling waves.

1.1. Problem Statement and Motivation. The data information is transferred to the monitoring center of the upper computer through GPRS. When there is an abnormality, it can send a mobile phone short message to the person in charge to feedback the abnormal content in time. The distribution network's load symmetry allowed for the development of several locating procedures. Overhead high-voltage transmission lines are susceptible to wind vibration and wind deviation, which are the leading causes of transmission line failure. Strong winds can generate conductor galloping, which can occur for many hours and inflict significant damage to high-voltage transmission lines [4]. Possible threats to transmission line safety include ice due to rain and snow, tilting of the transmission tower due to unequal pulling forces, and power outages caused by these factors. The weather conditions along the transmission corridor are not reflected in the monitoring record supplied by the local meteorological station at any given moment. In addition, there are obstacles to fault diagnosis, prevention, and study of the power transmission line since there is essentially no historical weather data for the transmission corridor [5]. Internet of Things (IoT) technology used for online monitoring of power transmission lines provides the key to addressing the aforementioned issues.

1.2. Contribution and Organization. Transmission lines are an integral aspect of the electricity system, and their efficiency is a major factor in how smoothly the grid functions overall. The monitoring of the status information of power equipment based on the Internet of Things has significant research value because of the ongoing promotion of the application of the Internet of Things technology in the power industry. In this article, we combine theory and practise to examine the data information, tasks, and technical methods of power equipment status monitoring; we then conduct in-depth studies of both primary and secondary machines, and we conclude by outlining a strategy and method for monitoring power equipment status information via the Internet of Things [6]. The remaining article is structured as follows: a literature review is presented in Section 2 of the article, followed by a discussion of research methods, an overview of smart grid and IoT, the overall design scheme of the system, system hardware design, and system software design are explained in Section 3. Section 4 presents the results and discussion, followed by the conclusion section in Section 5.

2. Literature Review. In recent years, with the development of the economy, the country's electricity consumption has increased rapidly, and the construction and measurement of ultra-high voltage power system links have been rapidly expanding. Due to the characteristics of long distance, wide distribution, and difficult inspection and maintenance of high-voltage transmission lines, the transmission line network operating in remote areas with complex terrain and harsh environments, real-time remote monitoring of transmission lines and their environmental meteorological parameters has become an urgent task, by monitoring the operation status of transmission lines in real time and establishing a corresponding natural disaster early warning mechanism, the economic losses caused by power outages can be reduced, and the safety, stability, and efficiency of power grid operation can be improved [7]. Therefore, the establishment of online monitoring of transmission lines has played an important role in the stable operation of the power grid, and online monitoring of transmission lines is an important part of the smart grid. The traditional monitoring network is mainly wired, and there are problems such as complicated wiring, low reliability, low security, high cost, and difficulty in expansion and maintenance [8]. With the existing commonly used wireless communication technologies such as GPRS, and WiFi, there are problems such as high cost and high-power consumption.

With the goals of low power consumption, cheap cost, security, reliability, high network capacity, high performance, wireless, easy expansion, and electrical transmission in mind, Yang et al. [9] suggested a design based on wireless sensor network and ZigBee technology. Its ease of usage has led to its growing incorporation into the infrastructure controlling transmission lines. ZigBee networks may be integrated with preexisting communication infrastructure, and the usual 80-meter distance between network nodes can be increased to hundreds of metres or even kilometres with the use of power amplifiers [10]. In China, infection control systems are evolving quickly with advances in sensor, data transmission, and AI technology. The system uses Internet of Things technology to set up a multi-sensor cooperative wireless sensor network by attaching smart sensors to towers, transmission lines, and other crucial electronic equipment.

Parameters such as wire temperature, humidity, sag, line icing, breeze vibration, wire wind deflection, tower inclination, insulator contamination, etc. are collected through sensors, the data is transmitted to the upper computer monitoring center by the combination of optical fiber communication and wireless communication.When the parameters are abnormal, it will automatically alarm, reminding the duty personnel and management personnel to take relevant measures in time to avoid accidents [11]. Considering the requirements of the working environment and conditions of high-voltage transmission line monitoring equipment, the author designed a wireless transmission line online monitoring system based on ZigBee technology [12]. Combined with the inductive method, it easily solves the problem of high-voltage insulation, and at the same time, it has the advantages of a large capacity network, small size, lightweight, low energy consumption, and easy installation. good. the ideal solution for controlling high-voltage transmission.A fault location approach based on online impedance was published in [13], and it was applicable for both multi-source and single-source power distribution systems because it required less data. The approaches put forth by [14] and [15] have great accuracy, but they failed to take grid operation symmetry into account when determining fault location accuracy. The use of synchronized voltage and current phasors obtained from phasor measuring units or clever electronic devices as a novel fault-finding technique for multi-terminal nonhomogeneous transmission lines was reported in [16]. The Internet of Things (IoT) is an extensive network of interconnected computing and sensing nodes that collect and interchange data using technologies such as radio-frequency identification (RFID) tags, infrared sensors, GPS, laser scanners, and the Internet itself to collect data. The IoT collects data and verifies identities using a variety of sensors and smart devices that are interconnected. In order to analyze data and unearth concealed insights, it relies on the worldwide web and other communication networks and employs numerous computer systems and applications [17]. Through the exchange of data between humans and objects, as well as between objects themselves, IoT technology enables real-time control, precise administration, and scientific decision-making of the physical world. In the smart grid, Power IoT (PIoT) represents the Internet of Things. With the assistance of a wired or wireless communication network and intelligent data processing in the power grid system, PIoT can achieve its objective of dependable information transfer [18, 19]. Power generation, transmission, transformation, distribution, and consumption are only a few of the numerous use cases for the Internet of Things in a smart grid. When high-voltage transmission lines are exposed to the elements, transmission line damage, interference with the secure operation of transmission facilities, the inability to provide power to a large region, and a substantial loss to the national economy are all possible outcomes.

3. Research methods.

3.1. Overview of Smart Grid and IoT. The smart grid consists of integrated, high-speed two-way communication, and is a new modern energy technology developed by integrating advanced measurement technology, information communication technology, analysis and decision-making technology, and automatic control. technology and energy and energy technology [20]. The purpose of the smart grid is to ensure security, safety, economy, efficiency, environmental performance, and safety, and its main characteristics are robustness, self-healing, socialization, financial efficiency, integration, and optimization.Compared with the existing energy grid, the smart grid integrates energy flow, information flow, and business flow very effectively, and its advantages are generally as follows:

1. It integrates and improves the power of the power grid, which is resilient to various external influences and attacks, adaptable to the use of clean energy and renewable energy, and has a strong infrastructure for power generation and support.
2. Information technology, sensor technology, automatic control technology, integration of electronic plans, collection and reception of electrical work characteristics, timely detection and prediction of faults. In the event of a fault, the power grid can quickly isolate the fault, restore itself, and avoid massive power outages [21].
3. Through the use of modern technology of communication, information, and management, it can improve the efficiency of the use of energy resources, reduce energy loss, and make the operation of the electric grid energy-saving and efficient.
4. Provide clear, complete, and state-of-the-art operational plans for advanced data integration, sharing, use, and performance management, including support decisions, management plans, and response plans.
5. Create a two-way interactive service model, users can understand information about energy capacity, energy quality, energy cost, and energy efficiency in timely, and effective energy management; Energy companies can obtain detailed information on consumers energy consumption and provide value-added services [22].

3.2. Overall design scheme of the system. The system is mainly composed of two parts: line monitoring system (lower computer) and a monitoring center (upper computer). The line monitoring system is mainly composed of various sensor nodes (terminal nodes), cameras, main processing units (coordinator nodes), and solar power supply units. Among them, the sensor nodes can be configured as required, usually including tension sensors, wind speed sensors, wind direction sensors, temperature and humidity sensors, inclination sensors, leakage current sensors, and wire temperature sensors. The main processing unit and the solar power supply unit are generally installed on the line tower, and the sensor node is installed at the position that needs to be monitored, the sensor node has its wireless module, which can wirelessly send the collected data to the main processing unit, after processing and analysis, the relevant data and images are transmitted to the upper computer monitoring center through the power line or GPRS network [23]. The host computer stores the current image data and related sensor data in the database or hard disk, and the user of the power monitoring network accesses the receiving center through the monitoring software, and reads various parameter information of the current tower and line from the database or hard disk, provide a basis for early warning of transmission line disasters. The system mainly includes the functions of icing state monitoring, meteorological parameter monitoring, image monitoring, electrical parameter monitoring, mechanical parameter monitoring, and wire temperature monitoring. Ice-covering state monitoring: Measure the wire weight, insulator declination, wind speed, wind direction, temperature, and other parameters through relevant online monitoring equipment, the analysis software synthesizes the above data and wire parameters using relevant mathematical models, the equivalent ice thickness of the wire is calculated [24]. Meteorological parameter monitoring: Micro-meteorological monitoring online monitoring of parameters such as line ambient temperature, humidity, wind speed, wind direction, rainfall, atmospheric pressure, etc., comprehensively analyze meteorological data and display all data to users through various reports, statistical charts, curves, etc.

The coordinator processing unit and the solar power supply system are installed on the tower, and the terminal sensor unit is installed on the line, in which the coordinator node is the core part, of the system, it is responsible for establishing a network and communicating with each sensor node joining the network, receiving data, issuing control commands, and transmitting the collected data to the monitoring center through GPRS or power line; The terminal sensor is configured as required, and is mainly responsible for the collection and transmission of on-site environmental parameters. It consists of sensors, alarms, and ZigBee modules. Due to its small size, low power consumption, and strong function, it can be fixed on high-voltage transmission lines, and the built-in solar power supply device can meet the power demand. The sensor node collects various environmental and state parameters of the transmission line, then the process and volume of the data are stored and sent wirelessly to the partner. When transmitted to the control center of GPRS, the control center

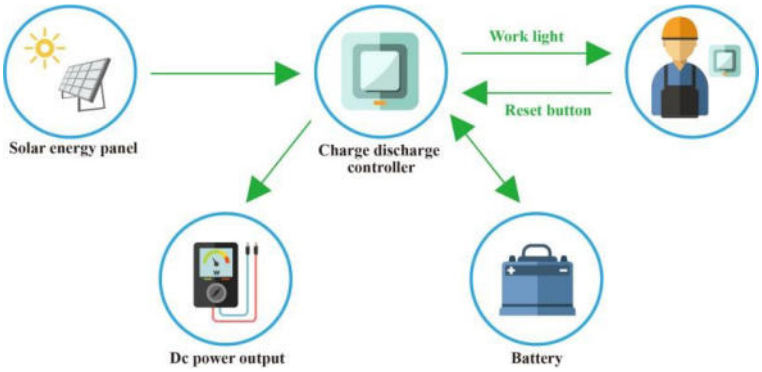

Fig. 3.1: Structure diagram of solar power supply

processes and collects data and reports it in real-time, so that when the transmission is abnormal, control of the timing of transmission lines can be used. will automatically alert lines, send reports to the control center and responders, and take timely measures to prevent power outages and other incidents layer [25].

3.3. System Hardware Design.

3.3.1. Power supply unit hardware. Due to the lack of an easily accessible AC power source for the high-voltage gearbox line in the wild, a battery-powered line monitoring device is impractical. There are now two major ways of power supply for high-voltage transmission line monitoring systems, thus it is important to design an independent power supply device with the aid of energy harvesting technology. The energy of the rotating electromagnetic field around the high-voltage AC wire may be harvested via the concept of electromagnetic induction, and then the alternating voltage produced can be transformed into direct current and either used immediately or stored in a battery. The second option is to use the solar energy system to provide power. Electromagnetic induction is challenging to regulate precisely because of its high initial current. As a result, solar panels and charge and discharge controllers make up the system's solar power source, as seen in Figure 3.1. The charge and discharge controller takes the solar panel's output voltage and converts it to the stable DC voltage needed by the monitoring system during peak sunlight hours; it then uses any leftover solar power to charge the battery, ensuring that the system has enough juice to run through the night and on cloudy, rainy days. Since the system nodes are all mill watt-level power consumers, a 30W solar panel can be charged for more than 10 days in a single day, so the use of solar power can meet the system's power supply requirements [26].

The actual power used by the solar panel. The battery adopts a lithium iron phosphate battery with a small size, long life, good environmental compatibility, high-temperature resistance, suitable for fast charging, and high safety factor, the battery capacity calculation formula:

$$B_c = APN_LT_0/C(Ah) \tag{3.1}$$

In the formula, A is the safety factor; P is the average power consumption, which is the working current multiplied by the daily working hours; N_L is the longest continuous rainy day; T_0 is the temperature correction coefficient; C is the depth of discharge of the battery.

3.3.2. Sensor Node Hardware. Figure 3.2 depicts the sensor node's physical design. The ZigBee module may be expanded with the addition of sensors, cameras, solar power, LED indicators, and buttons because of its CC2430 chip and straightforward peripheral circuit [27]. The CC2430 is an improved ZigBee system-on-a-chip (SOC), incorporating a CC2420RF receiver with high sensitivity and strong anti-interference, as well as a high-performance low-power controller, a direct memory access (DMA) controller, a programmable watchdog timer, an AES-128 security coprocessor, and a 14-bit analog-to-digital converter (ADC). The sensor node is solar-powered, which is a key technical indicator for both small solar panel area and low power consumption.

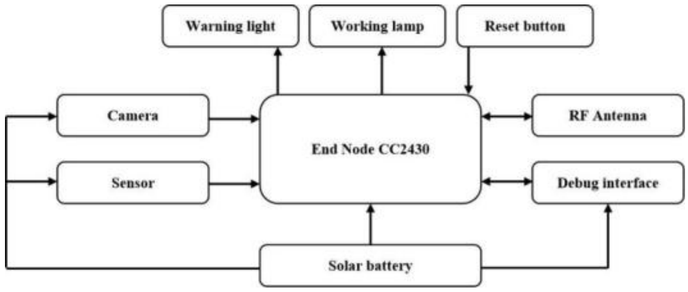

Fig. 3.2: Terminal node structure diagram

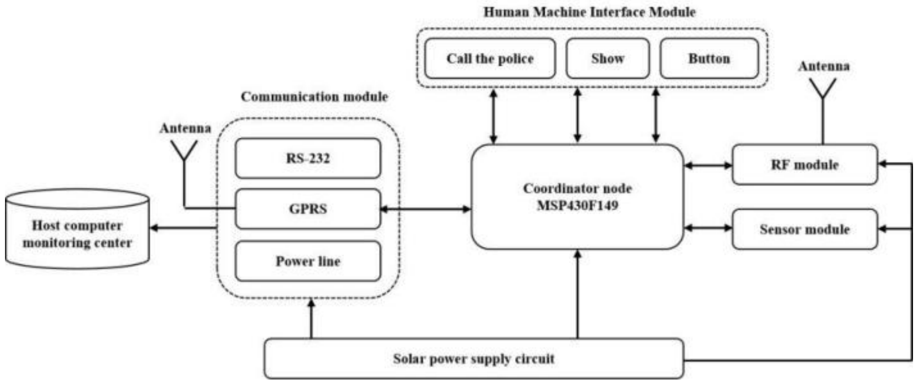

Fig. 3.3: Coordinator node structure diagram

To further reduce power consumption and maximize solar energy harvesting, the node implements a sleep/wake mode, allowing for user-defined data collection intervals and an automatic transition to a low-power state once data transmission is complete [28, 29].

3.3.3. Coordinator node hardware. Figure 3.3 depicts the coordinator node, which employs a 16-bit RISC mixed-signal processor, the MSP430F149 microcontroller. This microcontroller is capable of receiving data, processing it, storing it, displaying it, and transmitting it thanks to its powerful functions, ultra-low power consumption, and abundant peripheral resources. Receive data from other wireless sensor nodes via the radio frequency module, process the data according to a certain algorithm, and send the data to the upper computer data centre via GPRS at the set frequency; when the collected data exceeds the set threshold, it can automatically alarm and send alarm information to relevant personnel via GSM short messages. When the amount of information sent is relatively large, it can also transmit the data via GSM short messages.Finally, when the amount of information sent is relatively large, it can also transmit the data via the machine keeps its original RS-232 serial port for use in file downloads and debugging. If the data collected by a terminal node exceeds the set value or is not in the network, it will alarm and display the relevant information on the LCD screen, and the coordinator node receives the wireless signal sent by the terminal node through the CC2430 module, stores the data in the RAM of the microcontroller, and sends the data to the upper computer regularly.

3.4. System software design.

3.4.1. Software design of lower computer. The software design of the lower computer adopts the cross compiler and debugger of IAR Embedded Workbench7.30B to develop, debug and realize the wireless communication of data, both the coordinator node and the sensor node need to load the TI protocol stack,

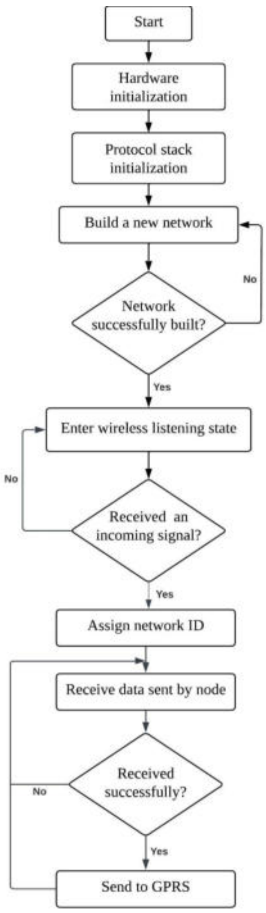

Fig. 3.4: System software flow chart 1

and write application programs at the application layer according to different functions, the coordinator node is responsible for network establishment, automatic networking, GPRS communication, interruption response, etc. From a structural perspective, the terminal node primarily realises the acquisition of sensor data and the wireless transmission of data, and their software architecture is identical, with the primary difference lying in the interaction of the protocol stack, application programme, and operating system. Figure 3.4 depicts the coordinator node's flowchart. First, the coordinator node's MSP430F149 microprocessor, radio frequency module, and liquid crystal are initialized; next, the ZigBee protocol stack is initialized, the interrupt is opened, and the process of establishing a new network begins; finally, the coordinator's physical address, the new network ID number, the channel number, etc. are displayed via the serial port if the network has been successfully established. If the join is successful, the coordinator will begin to receive data from the terminal node. Otherwise, it will attempt to rejoin until it is successful. Afterward, the microcontroller analyses the data that has been wirelessly transmitted to the lab for testing through GPRS or to the appropriate individuals via SMS. The procedure at a sensor node is depicted in Figure 3.5: Like the coordinator, each sensor must first power on and initialize CC2430 before sending an application signal to join the coordinator's network and waiting for a response before receiving an address from the coordinator [30].

If the work light of the terminal node is lit if the join is successful, and the work light of the join fails is off, the node will reapply for joining. After successfully joining the network, the terminal node enters the sleep state, and the terminal node collects sensor data at regular intervals. If the data is normal, the data is packaged and sent to the coordinator by cyclically calling the SendData() function, and the successfully sent

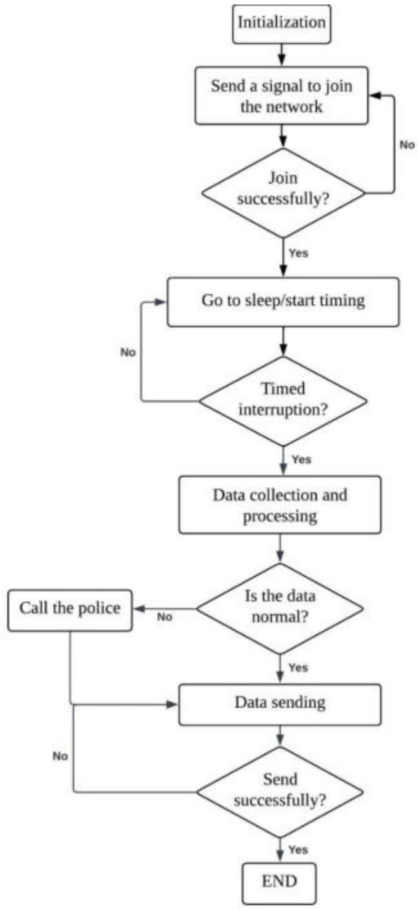

Fig. 3.5: System software flow chart 2

node will re-enter the sleep state; When the data is abnormal, the alarm light will start flashing and the sensor will collect data again and send the data to the coordinator twice. If the transmission is unsuccessful, the sensor immediately re-collects the data again and sends it to the coordinator.

3.4.2. PC software design. The host computer is programmed with Visual Basic 6.0; the prototype system only uses temperature and humidity sensors for data acquisition, and the data received by radio frequency is transmitted to the host computer monitoring center database. Mainly realize the following functions:

1. Real-time data display, the data collected by the terminal sensor is displayed in the form of a real-time curve, and the specific value and time are displayed in the table column on the upper left side, which is refreshed every 3s.
2. Historical record query, the system can query historical records according to different nodes and different periods, and display them in a certain order.
3. System security, when the system is abnormal or faulty, it can automatically save relevant data and can set thresholds for sensors, and automatically alarm when the limit is exceeded.
4. Remote monitoring, the monitoring system can realize remote login through a GPRS connection to Ethernet, and realize remote query and control.

4. Results and Discussion. The prototype undergoes in-depth, objective laboratory testing to evaluate the system's performance metrics. The real temperature and humidity are measured to within 0.1 degrees Celsius (using a conventional thermometer) and within 2% (using a relative hygrometer). Table 4.1 displays

Table 4.1: Test data

RSSI	Measure temperature / ° C	Actual temperature / ° C	Measure humidity %	Actual humidity %
0×85	19.2	18.89	41.23	41.60
0×73	18.8	18.86	42.54	42.98
0×6A	20.1	20.16	43.24	44.62
0×56	19.5	19.42	42.72	43.16
0×48	19.8	19.84	46.36	48.02
0×32	20.4	20.38	45.84	46.24

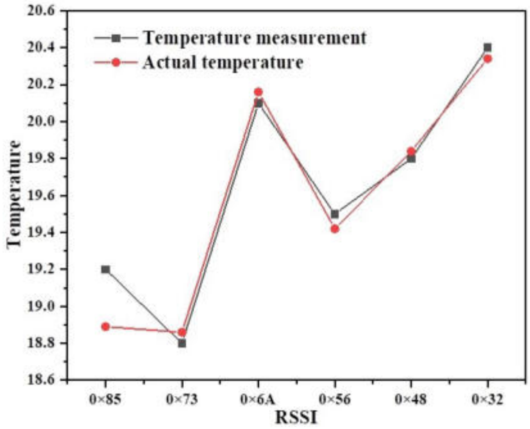

Fig. 4.1: Temperature comparison analysis diagram

the wireless communication distance, the temperature and humidity values collected and sent by the sensor nodes, and the signal strength indicator value received by the coordinator node.

Figure 4.1 shows that the system's greatest temperature difference is 0.31°C and that its maximum humidity difference is 1.38%. Both temperature and humidity thresholds may be configured, with a text message delivered to a mobile device when the measured value rises above the threshold. For instance, the maximum allowable temperature is 30.0 °C and the maximum allowable humidity is 60%. Data is captured every 10s and transferred via GPRS to the monitoring centre; when the threshold is surpassed, a text message reading "Warning! the value is: Temperature: 31.6 °C; Humidity: 41.5%" is delivered.

Two state-of-the-art methodologies were used to evaluate the efficiency of fault location using power IoT in the power system. The superiority of the proposed approach for fault finding is made abundantly clear in Figure 4.2. The suggested method's error increased with increasing fault resistance because it was more affected by fault reactance than the hybrid fault location technique. Even though the location inaccuracy was large when employing the hybrid fault location approach, the issue of high-resistance grounding was ultimately handled. The fully adaptive fault location approach offers fast calculation speeds but poor location performance. However, the method proposed in this study takes into consideration a number of characteristics that improve fault localization. These variables include the node, connecting line, fault type, fault length, and fault resistance. To ensure the safe and dependable operation of power transmission facilities, the operational staff can make choices and issue orders based on the analytical findings of the information management system.

5. Conclusion. In this paper, an Internet of Things-based system is presented for the informatization of transmission line monitoring. The purpose of this effort is to improve upon the weaknesses of the existing power monitoring setup. The system is based around a 16-bit microcontroller that uses very little power and

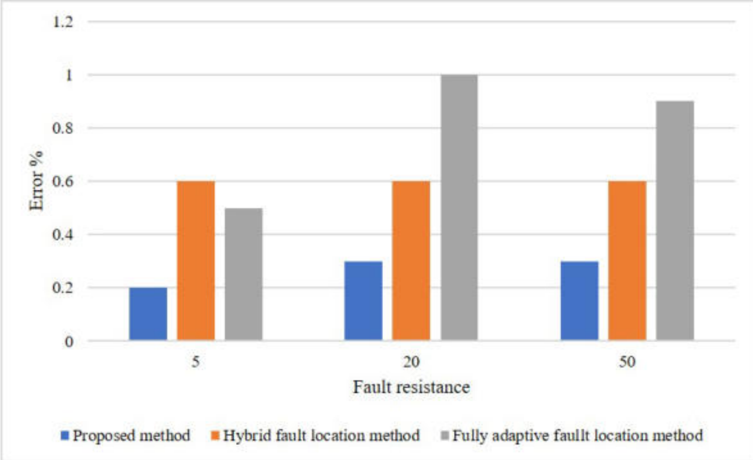

Fig. 4.2: Fault resistance comparison of proposed method with existing methods

can monitor a wireless sensor network. The suggested architecture realizes the collection, transmission, and monitoring of high-voltage transmission line characteristics while also integrating monitoring, display, alarm, communication, and other services into a single package. Accuracy of the method depends on the precision of both the smart control platform system and the measurement data. Future study will investigate how the method proposed in this paper, which is based on IoT data, may be used to distribution network fault finding technology that relies on a smart algorithm to trust the supply generation. Data collected by the prototype shows that the designed system has low measurement error, with most of the error stemming from the sensor itself and almost none coming from the network transmission process. Additionally, the system operates smoothly and reliably, allowing it to fulfill its intended purposes. With this kind of real-time monitoring and early warning of disaster in place, the power system will be better able to withstand or at least mitigate the effects of large natural disasters. Our future work will focus on lowering the price of our power transmission line monitoring technology and increasing its dependability.

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