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Retraction

Retracted: On-Line Temperature Monitoring System of Electrical Equipment Based on Passive Wireless Sensor

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] J. Zhu, Y. Yang, F. Du, Z. Wen, and Y. Xiao, “On-Line Temperature Monitoring System of Electrical Equipment Based on Passive Wireless Sensor,” *Journal of Control Science and Engineering*, vol. 2022, Article ID 8118680, 8 pages, 2022.

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Research Article

On-Line Temperature Monitoring System of Electrical Equipment Based on Passive Wireless Sensor

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In order to solve the temperature measurement problem of fully enclosed equipment for power equipment operation inspection, the authors propose an online temperature monitoring system for electrical equipment based on passive wireless sensors. Aiming at the disadvantages of traditional temperature monitoring methods, the system adopts radio frequency technology. The scheme mainly expounds the key technologies and switchgear implementation in the monitoring system research and discusses the feasibility of the system scheme through experiments. Monitor all important components at different times, and establish a temperature monitoring network to complete monitoring and management. According to the test results, in the case of overheating, the temperature can rise to more than 75°C, and the temperature difference measured wirelessly is 0.5°C, which is sufficient to indicate the health of the change. Electrical equipment, the accuracy, and real-time performance of temperature monitoring are guaranteed.

1. Introduction

When the energy industry is developing in the direction of high efficiency, large capacity, and Internet, power is crucial to ensure the safety and stability of electrical equipment, which directly affects the reliable operation of electrical equipment [1]. During the operation of the electric power, the temperature of the electrical equipment can cause many errors, so it is necessary to increase the power to research, development, support, and implementation of electronic temperature measurement online.

Temperature is an important parameter that reflects the operating state of electrical equipment. Real-time collection of temperature changes at temperature monitoring points, real-time early warning function, and timely notification of relevant personnel can effectively improve the operational reliability and economy of distribution network equipment. In addition to infrared and optical fiber temperature sensors, various new wireless sensors emerge in an endless stream, such as self-powered infrared lattice temperature measurement, semiconductor temperature measurement, and wireless RF power semiconductor temperature measurement. At the same time, it was tested in small batches within the State Grid and China Southern Power Grid systems. At present, there are mainly three methods for measuring the temperature of electrical equipment at home and abroad: temperature sensor, optical fiber temperature measurement, and infrared temperature measurement, and relying on manual regular inspection, the efficiency is low, and there may be problems of missed detection and misrepresentation, it is also possible that some staff did not go to the site for inspection and directly filled out the report, resulting in failure to detect equipment failures in time, resulting in serious power accidents. Wireless sensor network (WSN) technology is a fast new technology in recent years, which is widely used in smart home, medical monitoring, industrial control, and other fields [2–4].

At present, many domestic power generation companies and power companies have experienced abnormal temperature changes due to insulation aging or poor contact of equipment such as substation switch rejection, closed busbar, isolation switch, and cable head to varying degrees, leading to accidents. Since these devices are high-voltage live devices and some of the device's hot spots are located inside, it is inconvenient to detect. In order to solve this problem, a thermal imager or a spot thermometer is mainly used to conduct regular inspections of the equipment, and the thermal imager can only detect the current situation, cannot realize online monitoring, and cannot preview the future situation and alarm in time. In addition, the sense of responsibility of the inspectors and the time interval of the inspection are also relatively prominent problems during the inspection process. As a result, many equipment defects cannot be discovered in time and are often found only when the defects expand and cause equipment damage. For the heating phenomenon inside the switch cabinet, the general method is to cut holes on the switch cabinet and then use a thermal imager to inspect. At present, there is no good method for the heating phenomenon inside the cable head [5]. At present, there is also a method of temperature monitoring through optical fiber conduction; since this method requires the temperature sensing element to be closely attached to the surface of the object to be measured, it belongs to contact measurement, and this will undoubtedly cause certain hidden dangers for the safe operation of high-voltage electrical equipment, especially outdoor high-voltage electrical equipment [6, 7].

2. Literature Review

Temperature is an important parameter to characterize the operating state of electrical equipment [8]. Actual operating experience and theoretical analysis show that all kinds of faults at the busbars and cable joints are not a sudden process because the local temperature of the equipment continues to rise, the insulation gradually ages, the leakage current gradually increases, and then breakdown occurs after reaching a certain level, and it is a process from quantitative change to qualitative change. Therefore, by continuously monitoring the temperature change of the equipment, it is possible to grasp its operation status and conduct power outage maintenance in a timely manner according to the situation [9, 10].

A lot of research has been conducted on the temperature monitoring of electrical equipment at home and abroad, and a series of electrical equipment temperature monitoring systems have been developed, which are mainly used in small areas such as power plants and substations [11]. The monitoring modes mainly include regular manual inspection and online monitoring; the current online monitoring mainly uses contact temperature sensors for temperature conversion, and this method has certain safety hazards when the voltage level of electrical equipment is high. There are also temperature measuring fibers and gratings for temperature monitoring, and this mode has a large amount of on-site construction and high costs. These contact temperature monitoring methods all require power outages for high-voltage electrical equipment before construction and installation. Using manual inspection methods such as infrared spot thermometers and infrared thermal imagers, it is only suitable for specific analysis of special equipment.

Temperature is an important parameter for electrical equipment monitoring and control, and the temperature measurement difficulties of high-voltage fully enclosed equipment mainly include (1) fully enclosed equipment: the temperature of key points is not easy to measure; (2) the high temperature environment has requirements for the battery of the temperature measurement terminal, and the battery is not easy to replace, and the maintenance workload is large; (3) in the high-voltage environment, the wiring affects the insulation requirements, which is not conducive to equipment operation [12, 13].

The line temperature measurement technology has the advantages of large measurement range, high accuracy, no influence on equipment operation, and online real-time monitoring [14]. Based on the advantages of wireless temperature measurement and the difficulties in temperature measurement of fully enclosed equipment, the authors propose a passive wireless temperature monitoring system scheme based on radio frequency identification (RFID) technology. The system provides power to the wireless sensor nodes in the online monitoring system through wireless power supply, which has high security and anti-interference; noncontact information exchange and information collection through radio frequency signals realize automatic identification and remote real-time temperature monitoring and management. The authors introduce the principle and architecture of UHF RFID technology, the key technologies for realizing the temperature monitoring of radio frequency identification are pointed out, the implementation scheme of the system in the high-voltage switchgear is proposed, and the feasibility of the system scheme is discussed through experiments.

3. Methods

3.1. UHF RFID Technology. Most thermometers have three parts: thermometer, reader, and back-end server [15, 16]. The card reader has its own antenna from the feeder. The address of the antenna is connected to the address chip and a piece of paper, and the card reader can use RFID technology for wireless communication.

The basic operation of the system is shown in Figure 1 [17]. First, the reader generates a signal transmitted by its antenna. When the signal enters the signal box, the signal comes out of the reader, the signal is detected, and the information is transmitted electronically. Put it in the chip. First, the reader generates a carrier signal and transmits it through its antenna.When the sensing tag enters the effective coverage area of the electromagnetic wave emitted by the reader, the sensing tag is activated. The activated tag sends the identification information stored in the chip to the reader antenna through its built-in antenna. The high-frequency signal is transmitted to the reader by the antenna regulator for demodulation and decoding, and then sent to the host computer for data processing. Computers are very important for decision-making and information processing. The climbing computer determines the validity of the signal based on the performance of the work and follows the necessary procedures and controls for different areas, such as warning thermal report.

The temperature tag is installed in the distribution network equipment, as a radio frequency identification sensor, each tag stores its own identification information, including EPC code (electronic product code) and

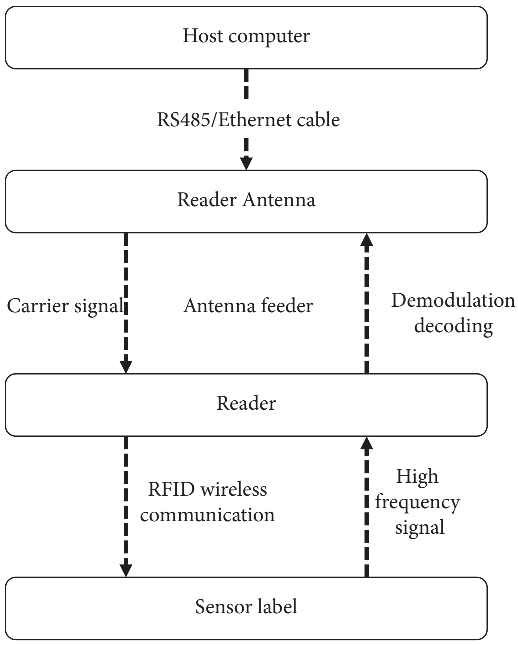

Figure 1: Basic working flow chart of the system.

temperature data, among which the label EPC code is unique and fixed at the factory. The identification information is read by the reader, and the installation address is set according to the EPC code of the label, and the user knows which specific sensors are sending key data on the server side, so as to know the address of the key temperature points and achieve the purpose of temperature monitoring at the key points.

3.2. Key Technology. In the process of system design, the research of 6 key technologies is mainly considered, including selection of temperature sensor tags and reader antennas, tag antimetal design, communication distance estimation, anticollision algorithm, equipment installation, and background software development [18]. From the principle and characteristics of the SAW sensor, it can be seen that there is no battery at the sensor end. On the one hand, it does not require frequent maintenance; on the other hand, even if the sensor is damaged, it will not cause damage to the equipment. Sensing Technology. However, in the current practical application, because the integrated design with the equipment is not fully considered, a series of problems occur in the process of installation, implementation, and maintenance. The integrated design sensor is an innovative design concept proposed to solve the abovementioned problems. The purpose is that the installation of the sensor cannot affect the original mechanical performance and electrical performance of the electrical equipment, but also needs to make the electrical equipment affect the wireless performance of the sensor and high-voltage reliability impact is minimized. The integrated design of the sensor will inevitably involve the following key technologies. ① Sensor installation structure design: it is necessary to fully consider the original structure of the primary electrical equipment and design a reasonable sensor installation structure, so that the sensor can be easily installed without affecting the mechanical and electrical performance of the electrical equipment. ② The antenna design of the sensor: on the basis of the structural design, the antenna of the sensor needs to be designed according to the specific equipment characteristics, so that the sensor has the highest wireless transmission performance under the specific installation structure. ③ High-voltage adaptive design: since the sensor works in a high-voltage environment for a long time, it is necessary to evaluate the impact of the sensor on the electrical performance of high-voltage equipment and the impact of high-voltage shock on the sensor at the same time. The high-voltage adaptability of the sensor is designed accordingly.

3.2.1. Label and Antenna Selection. The parameter specifications of the temperature label selected by the authors are shown in Table 1. The reader antenna is S8658 produced by LAIRD Company, and its parameter specifications are shown in Table 2.

3.2.2. Antimetal Design of Sensor Tags. Since the label is used in the distribution equipment, the influence of metal on the label must be considered [19].

The main functions of the ABS button are the following: (1) measure the RF temperature through the wire sensor near the focus. The ABS package cover plays the role of protecting the insulator. (2) The packaging shell adopts AMC design and improves the reading speed of the label; second, since the metal layer is located at the bottom of the layer, it has good thermal conductivity at the temperature of the thermistor. (3) The button returns to the simplicity of setting [20].

3.2.3. Communication Distance Estimation. Measuring the distance, that is, detecting the maximum r of the RFID reader disconnection signal, is an important task [21]. The power received from the source at the distance reader R is calculated using the Friis equation.

$$P_{\mathrm{th}} = P_t G_r \frac{A_{eT}}{4\pi r^2} = P_t G_r G_t \left(\frac{\lambda}{4\pi r}\right)^2 \left(1-|s|^2\right). \qquad (1)$$

In the formula, G_r and G_t are the gains of the reader and the tag antenna, respectively; P_t is the transmission power of the reader; and s is the reflection coefficient of the complex power wave.

Using the radar ranging equation:

$$P_r = \sigma \frac{G_r G_t}{4\pi} \left[\frac{\lambda}{4\pi R^2}\right] P_t, \qquad (2)$$

where σ is the radar cross section of the tag.

Only when the energy P_r received by the antenna is not less than P_{th} and $P_{\min}$, can it be sensed. From formula (2), we get the following:

Table 1: Selected temperature label parameter specifications.

Frequency (MHz)	Temperature measurement range (°C)	Precision(°C)	Communication distance (m)	Upload speed (kb/s)	Return rate (kb/s)	EPC encoding (bit)	Size (mm)	Temperature measuring element
860 ~ 960	−25 ~ 105	± 0.5	2	26.7 ~ 128	40 ~ 640	96	134.8 × 38.4 × 3	Thermistor

Table 2: S8658 antenna parameters.

Frequency (MHz)	Gain (dB)	Standing wave ratio	Lobe width (°)	Front to back ratio (dB)	Polarization	Maximum output (W)	Size (cm)
865 ~ 960	8.5	1.4 : 1	65	20	Circular polarization	3	$10.2 \times 10 \times 1.32$

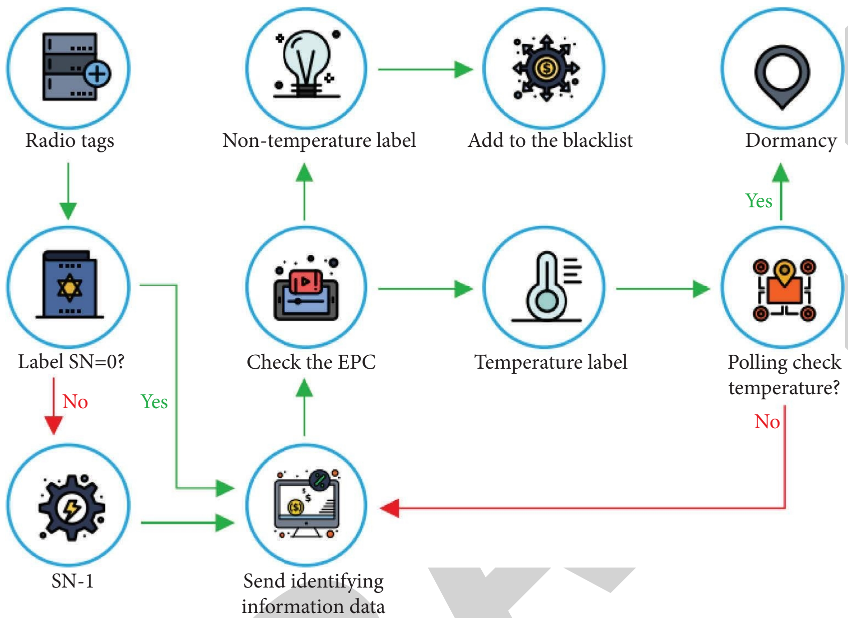

Figure 2: ALOHA polling mechanism based on dynamic frame time slot (high end).

$$R_1 = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_r G_t\left(1-|s|^2\right)}{P_{\text{th}}}}, \tag{3}$$

$$R_2 = \sqrt{\frac{\lambda}{4\pi}\left(\sigma \frac{P_t G_r G_t}{4\pi P_{\min}}\right)^{1/2}}. \tag{4}$$

Substitute the selected equipment parameters into equations (3) and (4), and the estimated communication distance of the system theoretical communication is 4.13 m [22].

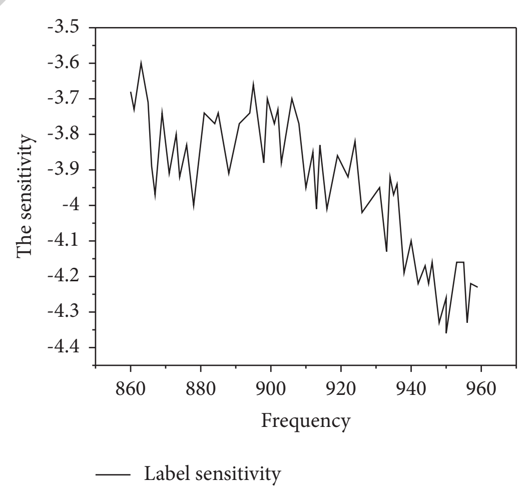

Figure 3: Label sensitivity curve.

3.2.4. Anticollision Mechanism. During the operation of the RFID system, communication conflicts such as collisions occur when more than one document is in the range of the reader at the same time [12]. On this online thermometer,-There are two types of collisions in this online temperature monitoring system:One is collision caused by multiple tags responding to the reader at the same time. The other is the interference of nontemperature tags in the reader range to the RFID system. Since the number of thermometers is limited to online monitoring thermometers, the authors first introduced a voting package to change the input time of ALOHA reading algorithm to improve the working experience [23].

The reader analyzes the data sent to the address, classifies the characters into hot, nonhot, full hot, and cold sleep according to the EPC, and does not search for these frames; do not add nontemp posts to the blacklist and query them later. The reader repeats the above process continuously until no tag signal is received in a certain frame, and then all temperature tags are considered to be recognized. Its algorithm flow is shown in Figure 2.

3.2.5. Equipment Installation. The details of the temperature of the electrical equipment are divided into bus connection, cable connection, and electrical connection; temperature

Table 3: Tag read rate.

Tag distance from the antenna (m)	Read rate (times/s)					
	No metal partitions			With metal partition		
	1st	2nd	Average (times/s)	1st	2nd	Average (times/s)
0.5	20	22	21	22	20	21
1	23	20	21.5	6	4	5
1.5	20	20	20	23	20	21.5
2	20	22	21	0	0	0

Table 4: Comparison of temperature labels and mercury thermometers.

Label number	Wireless temperature measurement (°C)	Mercury thermometry (°C)	Difference (°C)
	15.7	15.5	+0.2
0597	20.1	19.8	+0.3
	25.3	24.5	+0.5

sensor of the system is installed on the hot points above, and the labels are placed in the bus connection [24]. The antenna is drilled into the door to provide an antenna opening for reading and writing. The reader can see the wires receiving power from the outside of the switch cabinet. Additional technologies of fixed antennas are used to extend communication, such as signal interference wiring and thermal shielding.

3.2.6. Background Software Development. The temperature monitoring software developed in this paper is based on C# programming language of Microsoft.NET platform. The system software has the functions of connecting readers to online real-time temperature measurement and temperature data storage and real-time alarm temperature curve analysis. The main information displayed on the link is the IP address of the card reader, the EPC or EPC in the multiantenna, the number of card readers, the time and temperature, and the document configuration as the EPC tag. The temperature data is plotted as a dichotomous curve, and the curve integral changes with time; hot data is stored in the History. Log file every 30 seconds (configurable), which allows operators to monitor queries and print historical hot data information. The above functions are useful in real-time monitoring of the main content of online operations, and human-computer interaction is essential for monitoring and integrated management.

3.3. Experiment and Feasibility Analysis

3.3.1. Sensory Label Sensitivity Test. For a specific frequency band, most chip manufacturers only give priority to sensitive chips without specifying the frequency change. The sensitivity curve of the paper is shown in Figure 3.

The test tag sensitivity should be stable in the frequency range of 860 MHz~960 MHz and kept at −4 dBm, with the tag sensitivity of 950 MHz. A comparable RFID frequency band measure is −4.1 dBm.

3.3.2. Label Reading Speed Evaluation. Considering the effect of changing the connection wire at a total distance of 2 m from the standard connection, the reader antenna is placed at a distance of 0~2 m from the paper and attached paper with the size of 20 cm × 20 cm. To ensure the best RF connection to the balance of the reader antenna, the direction of the metal plate, the label, and the metal plate are the same. Table 3 shows the comparison of tag reading speed and metal resistance.

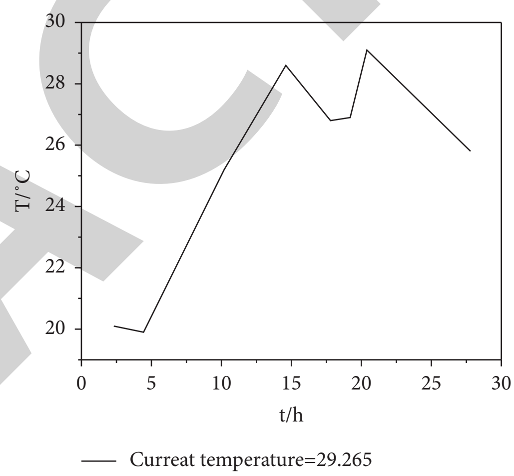

Figure 4: 24 h temperature of phase A contact.

According to the test data, the metal separation indicates and blocks the area of the reader of 1 m, which reduces the reading speed of the label, but it cannot be read completely. 2 m test data shows that when metal is insulated, the metal absorbs the radio frequency energy and converts it into electrical energy, which increases the total power of the radio. The power frequency and the tag are not working properly. The 1.5 m read and write distance is sufficient for the installation and temperature of the product.

4. Results and Analysis

Table 4 is the comparison result of temperature difference and mercury thermometer.

According to the daily use, maintenance, and cleaning of the cabinet, the temperature of the electrical connection is 30°C~60°C, the temperature is above 75°C, and the temperature is weak. A temperature difference of 0.5°C indicates the health of the transformer.

The test was carried out in the 10 kV high-voltage switch cabinet of the university's high-voltage laboratory, and the contact paper was installed on the A-phase connection of the circuit breaker of the cabinet change location. In this paper, the 24 h temperature record data is selected to reflect the temperature change of the switch cabinet throughout the day. As shown in Figure 4, the temperature data of the switching device is daily. With 24-hour temperature recording and analysis, the RFID online temperature measurement system is always active and uninterrupted.

The distribution network switchgear is developing in the direction of comprehensive monitoring without power failure. Compared with the online monitoring and local online monitoring of the circuit breaker mechanism, the temperature online monitoring technology is more mature and reliable. On the one hand, online temperature monitoring can early detect the increased contact resistance of the connection parts caused by long-term operation and the excessively high temperature caused by factors such as overload. The head is checked, especially in the case of poor contact, and the unbalanced three-phase temperature value can directly indicate the detailed situation. The wireless temperature sensor installed after the transformation is usually installed on the busbar. Since there is a certain distance from the real heating point of the contact point of the moving and static contacts, this installation method can generally reflect the size of the load, and the temperature rise value can represent sudden failures, but the measured absolute value of the temperature is lower than the temperature of the real hot spot. Although the real contact temperature can be measured in the insulating box of the moving and static contacts, the raised sensor occupies the insulating space. How to avoid partial discharge and solve the problem that the sensor will not be damaged under repeated operation and large vibration amplitude and strengthening the firmness of its installation is an important construction process. Therefore, the package and size of the sensor should be the starting point of installation, and the reliability of the device in the sensor should be studied and analyzed under the condition of high pressure and complex construction, so that the manufacturer can optimize the integrated design and manufacturing technology. When the sensor is installed in these two ways, it must be ensured that the entire busbar is in a power-off state.

5. Conclusion

The authors propose online temperature monitoring of electronic devices based on passive wireless sensors. Temperature monitoring of network equipment is very important for device security and stability, and the concept of using passive wireless sensors for online RFID temperature measurement is proposed. The temperature is off and the sensor node does not require power. Through wireless data transmission, the temperature of multiple nodes is monitored online. This system has the following advantages in the control process: (1) the equipment is small in size and easy to install; (2) low cost and no maintenance costs; (3) class functions are not affected or easily affected from the environment; (4) track online schedules; and (5) computers provide an easy-to-use and effective human-machine interface.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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