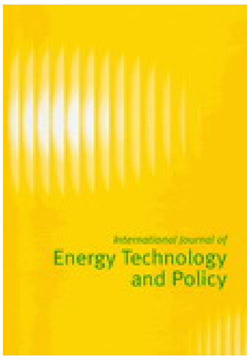


International Journal of Energy Technology and Policy

ISSN online: 1741-508X - ISSN print: 1472-8923
https://www.inderscience.com/ijetp

Application of an infrared sensor based on edge computing in power electronics technology

Shanshan Li, Yu Shen

DOI: 10.1504/IJETP.2025.10073267

Article History:

Received:	31 January 2025
Last revised:	11 July 2025
Accepted:	14 July 2025
Published online:	31 October 2025

Application of an infrared sensor based on edge computing in power electronics technology

Shanshan Li* and Yu Shen

College of Mechanical and Electrical Engineering,
Henan Quality Institute,
Pingdingshan 467000, Henan, China
Email: lishanshan0375@126.com
Email: shenyu_118@163.com
*Corresponding author

Abstract: This paper examines the application of infrared sensors based on edge computing in power electronics technology to improve the fault detection efficiency of power equipment. An infrared sensor is a type of sensor that uses the outside of the red line for data processing. It has high sensitivity and can control the operation of the driver. The communication network between the edge and the power server detection is established by applying edge operation, which realises the intelligent scheduling of power equipment, reduces the detection delay, and enhances the security of power electronics. This work lays a foundation for the development of intelligent power electronics. This study provides support for the application of infrared sensors in the detection of power electronic equipment. In the future, the development of intelligent power systems can be promoted by improving the response speed and accuracy and combining artificial intelligence and edge computing.

Keywords: edge computing; infrared sensor; power electronic technology; power fault detection; power equipment.

Reference to this paper should be made as follows: Li, S. and Shen, Y. (2025) 'Application of an infrared sensor based on edge computing in power electronics technology', *Int. J. Energy Technology and Policy*, Vol. 20, No. 6, pp.33–50.

Biographical notes: Shanshan Li graduated from Nanjing University of Science and Technology and received her Master's degree. Her research interests include electronic technology, computational intelligence and automatic control.

Yu Shen holds a Master's degree and the professional title of Associate Professor. She graduated from Nanjing University of Science and Technology in 2012. Her working unit is Office of Scientific Research, Henan Quality Institute. Her research direction is in the field of digital design and manufacturing.

1 Introduction

Against the backdrop of rapid global industrial development, the safe and stable operation of the power system, as the core infrastructure for the operation of modern society, is not only related to the steady development of the national economy but also an important guarantee for social livelihood. In recent years, with the continuous advancement of China's industrialisation and urbanisation, electricity demand has continued to grow rapidly, which has posed unprecedented challenges to the reliability and stability of power systems. Moreover, the constraints on traditional energy resources are becoming increasingly tight, and environmental protection requirements are constantly increasing, thus the power industry faces an urgent need for transformation and upgrading. In this context, ensuring the safe and stable operation of the power system and improving the quality and efficiency of the power supply has become a key issue in the current development of the power industry.

As an important means to ensure the safe operation of a power system, the development level of power equipment monitoring technology directly affects the reliability of the entire power system. Traditional power equipment monitoring methods rely mainly on regular power outages and manual inspections, which are not only inefficient but also have difficulty achieving real-time and accurate fault diagnosis. With the in-depth advancement of smart grid construction and the rapid development of next-generation information technologies such as the Internet of Things and big data, power equipment monitoring technology is undergoing a profound transformation from traditional manual methods to intelligent and automated methods. In particular, the innovative combination of edge computing technology and infrared sensing technology provides a new technical path to solve the many challenges currently faced by power equipment monitoring, showing broad application prospects.

Based on the actual needs of the power industry, this study proposes a set of innovative intelligent monitoring system solutions based on edge computing and infrared sensing technology. The system realises real-time monitoring and intelligent diagnosis of the status of power equipment by building a distributed monitoring network architecture. At the hardware level, the system adopts a high-performance infrared sensor array, which can accurately capture the temperature distribution characteristics of the equipment surface; at the software level, the system integrates advanced machine learning algorithms, which can perform in-depth analysis and intelligent judgement on the collected data. Notably, the system adopts a hybrid architecture that combines edge computing and cloud computing, which not only ensures real-time monitoring but also ensures the accuracy of data analysis and provides reliable technical support for fault warning and status evaluation of power equipment.

In terms of the actual application effect, the intelligent monitoring system has been successfully deployed in multiple substations and transmission lines, and its excellent performance has been highly recognised by users. The system can not only promptly detect abnormal conditions in equipment operation but also accurately warn of potential faults, providing an important basis for preventive maintenance of power equipment. Compared with traditional monitoring methods, this system has obvious advantages in monitoring accuracy, response speed, reliability, etc. More importantly, the system adopts a modular design concept, has good scalability and adaptability, and can be flexibly configured according to the needs of different application scenarios, which lays a solid foundation for its promotion and application in a wider range of fields.

From the perspective of technological innovation, this study has made important breakthroughs in many aspects. First, in terms of system architecture design, a collaborative monitoring mode of ‘edge perception + cloud intelligence’ was creatively proposed (Syu et al., 2023; Lin et al., 2023), achieving a perfect combination of high efficiency and intelligence in data processing. Second, in terms of algorithm research and development, a series of dedicated data analysis algorithms have been developed to meet the special needs of power equipment monitoring, which significantly improves the accuracy of fault diagnosis. Third, in terms of data security, advanced encryption and authentication mechanisms are introduced to ensure the security and reliability of monitoring data. These technological innovations not only improve the overall performance of the system but also provide new ideas for the development of power equipment monitoring technology.

In the future, with the in-depth promotion of energy internet construction and the accelerated development of digital transformation, power equipment monitoring technology will usher in a broader development space. This research team will continue to deepen technological innovation, focusing on the following aspects: first, further improve the intelligence level of the system and develop more adaptive monitoring algorithms; second, expand the application scope of the system so that it can cover more types of power equipment; and third, strengthen the integration and innovation with other emerging technologies, such as digital twins and 5G communications, to create more advanced monitoring solutions. It is believed that through continuous technological innovation and application exploration, this intelligent monitoring system will play a more important role in ensuring the safe operation of the power system, promoting the high-quality development of the power industry and making positive contributions to the development of a clean, low-carbon, safe and efficient modern energy system.

2 Related work

With the continuous progress of science and technology and the improvement of people’s living conditions, power electronic technology has been continuously developed and widely used, which has promoted the significant growth of the national economy to a certain extent. Xiao (2022) suggested that power electronic technology education should focus on teaching students how to control general power electronic equipment and master the working principles of converter technology. He then applied this knowledge to the field of engineering. Curriculum reform should also keep up with contemporary trends to cultivate innovative and entrepreneurial talent to improve server utilisation and energy efficiency, Yuan et al. (2021) introduced the application of power electronics technology based on sustainable computing in smart grid systems. To realise the proper distribution of power fluctuations and avoid distribution imbalance, he used the dynamic control method considering the generation cost. Zhang (2021) reported that the use of power electronic products has made a significant contribution to promoting economic growth and improving people's standard of living. He recognised that there were still many problems with the use of power electronic equipment, which was also very important. The subject of his research and attention was intelligent fault diagnosis. Researchers have noted that China has become one of the largest energy-consuming countries and that electricity has played an increasingly important role in economic development, which is a major indicator of social progress.

In practice, infrared sensors have a significant effect on the security and reliability of power electronics technology. According to Bhan and Vikram (2019), the infrared detector technology in infrared sensors has always been a concern. The future demands of this discipline include high-temperature function, multispectral imaging, low cost, and high resolution, which are driving the continuous growth of power electronics technology. He focused on how infrared sensors were applied to power technology. Tan and Hooman (2018) reported that infrared detectors have become important tools for various applications, including medical imaging, environmental monitoring, and tracking military missiles. However, in recent years, many resources and studies have been devoted to enhancing the capability of infrared detectors, including reducing manufacturing costs, simplifying manufacturing procedures, and increasing production. Scholars believe that with the rapid development of the economy, power electronics are widely used in many fields.

With the rapid development of China's economy, the requirements of people's work and life on power electronics technology are also increasing (Chen et al., 2019). Power electronic state detection and monitoring are performed in this case. A live inspection of the equipment was carried out to determine the potential safety hazards of the equipment, and troubleshooting of equipment with potential safety hazards was conducted (Awasthi et al., 2022). Infrared sensor fault diagnosis based on edge computing for power equipment has become an important part of intelligent maintenance.

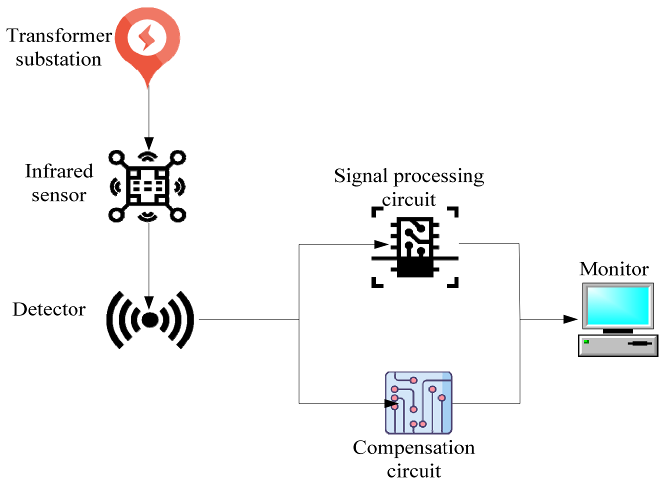
3 Power fault detection based on an infrared sensor

3.1 *Infrared sensor temperature measurement technology*

As an important part of the power supply system, power plays an important role in ensuring the normal production and life of power supply enterprises. Safe and stable operation directly affects the overall construction of the power grid. Therefore, it is very important to identify faults in power and take effective preventive measures in time. In the field of power fault detection technology, infrared sensing temperature measurement technology, ultrasonic detection technology, and thermal imaging technology all have their own characteristics and application scenarios. Compared with ultrasonic detection technology, infrared sensing technology has the advantage of non-contact detection, which does not require direct contact with the equipment under test, avoids interference with the normal operation of the equipment, and has a fast detection speed that can quickly obtain surface temperature information from the equipment. Ultrasonic detection technology has unique advantages in detecting internal defects in equipment (such as cracks and looseness); it has strong penetration ability and can detect problems deep inside equipment, which is beyond the reach of infrared sensing technology. Compared with thermal imaging technology, infrared sensing technology performs well in terms of temperature resolution, can more accurately measure small temperature changes on the surface of equipment, and has a relatively low cost, which is suitable for cost-sensitive application scenarios. However, thermal imaging technology can provide a more intuitive image of the overall thermal distribution of the equipment, which is convenient for operators to quickly understand the overall thermal status of the equipment and has advantages in large-area equipment monitoring. Advanced infrared sensor temperature measurement technology allows users to check quickly and conveniently without worrying about power failure, and it is an efficient detection method widely used at present.

Heated objects have higher macromolecule activity. In this process, they emit infrared light of different wavelengths and release heat. Infrared detection technology draws the distribution of energy and displays the temperature of its surface through infrared induction so that the staff can conduct thermodynamic analysis on it (Dong, 2022). The working principle of the infrared sensor is shown in Figure 1.

Figure 1 Working principle of the infrared sensor (see online version for colours)



As shown in Figure 1, the working principle of the infrared sensor is to measure the temperature through the infrared sensor, which includes the detector. The detector also includes a signal processing circuit and compensation circuit, which are subsequently displayed. The detector is the eye of the infrared sensor. It emits heat and infrared radiation into the surrounding environment. Once it is turned on, the end of the detector is similar to a hand. The detector transmits this energy and light to the detector, which converts this energy into signals and then sends them to the display. This method avoids direct contact with the target and enables temperature measurement in space, and is therefore a good method for measuring the internal temperature of a circuit.

Under normal operation and failure status of power equipment, the position of its heat and hot spot must differ, and the thermal imager drawn by the infrared sensor must differ (Liu et al., 2022). This is also the basic principle of infrared sensor technology. The basic structure of the infrared sensor is shown in Figure 2.

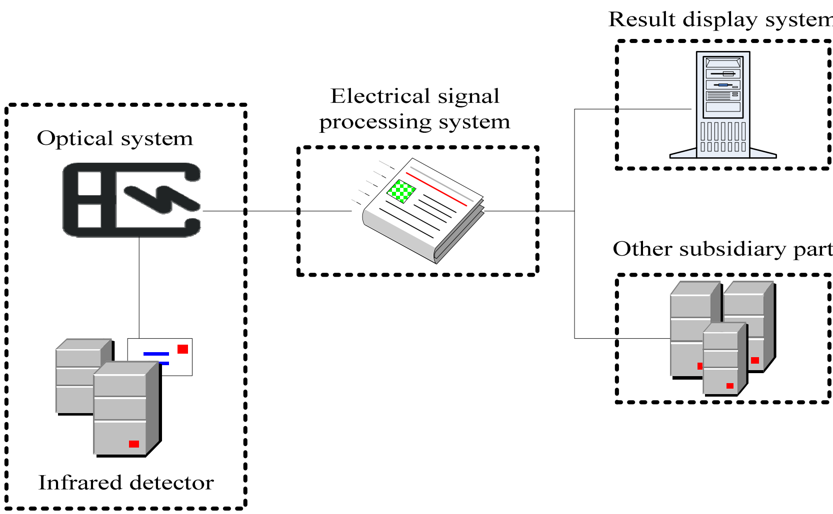
As shown in Figure 2, the basic structure of an infrared sensor includes an optical system, an infrared detector, an electric signal processing system, a result display system, and other auxiliary parts. The infrared detector converts the received infrared light energy into electrical signals. The sensitivity of the infrared sensor makes its measurement accuracy high (Hanbiba, 2021). At the same time, the photoelectric signal and electronic signal are used for processing, making its measurement speed very fast. Since the internal temperature of the equipment is very different from the external temperature, the instrument measures the average temperature of the equipment. The temperature conditions include a rise in temperature, a temperature difference, and a relative temperature difference.

The temperature rise is the difference between the surface temperature of an object continuously measured by the same measuring equipment and the surface temperature of the ambient temperature reference object:

$$T_s = t_{k1} - t_{k2} \tag{1}$$

where T_s represents the temperature increase, t_{k1} represents the surface temperature of the measured object, and t_{k2} represents the temperature of the ambient temperature reference body.

Figure 2 Basic structure of the infrared sensor (see online version for colours)



The temperature difference is the temperature difference between different objects or different positions of the same object measured by the same measuring tool:

$$T_c = t_1 - t_2 \tag{2}$$

where T_c represents the temperature difference, t_1 represents a high-temperature point, and t_2 represents a low-temperature point.

The relative temperature difference δ_t is the ratio between the temperature difference between two measured points and the temperature:

$$\delta_t = \frac{\tau_1 - \tau_2}{\tau_1} \times 100\% = \frac{(T_1 - T_0) - (T_2 - T_0)}{T_1 - T_0} \times 100\% \tag{3}$$

where τ_1 represents the temperature rise of the hot spot and where τ_2 represents the temperature rise of the corresponding normal point.

When the current is the same, the resistance change of the measured object can be reflected by comparing the change in the temperature difference so that the heating condition of the device can be more easily judged. To better evaluate the thermal conditions of the tested electrical equipment, a control group can be set to measure the ambient temperature in real life so that users can clearly understand the impact of the surrounding environment on the test results. This approach can eliminate the interference of external factors to draw accurate measurement conclusions.

3.2 Edge computing

At present, the monitoring technology of power equipment lacks a method based on a period of polymorphic data processing. On the one hand, it is necessary to extract valuable information from a large amount of data. On the other hand, because a large amount of data is needed for transmission, the network load and computing load are increased (Che, 2022; Lin, 2019). Given this situation, this paper develops and designs a power equipment status monitoring method based on edge operation.

Infrared sensors and edge computing devices are deployed onsite in power equipment. Infrared sensors are responsible for collecting information such as temperature data from equipment. Edge computing devices perform preliminary processing, such as data denoising and feature extraction, on the collected data to screen for key data. The distribution substation can offload work with a large number of calculations, such as power monitoring and analysis and power analysis, to the main station server. By simply transmitting the calculation tasks and results, it does not need to consume many calculation and storage resources. This approach can effectively solve the problem of limited local area network (LAN) resources. The joint optimisation of computing resources and communication resource allocation is realised through edge computing and offloading technology (Mathews, 2019; Tulus and Jumadi, 2022).

In the case of high real-time processing, edge computing adopts the strategy of reducing delay to avoid the impact of unloading on the primary site on the quality of system work (Ai et al., 2018). If a calculation task is performed locally, the time required is as follows:

$$T_E = \frac{m}{v_E} \tag{4}$$

The local execution time of the calculation task is represented by T_E, the computing resources required to complete the calculation task are represented by m, and the local execution speed is represented by v_E. If the computing task is unloaded on the host server, the total time consumption includes three parts: the time when the required data are transmitted to the master station, the time when the master station performs the calculation work, and the time when the data are received from the master station, such that:

$$T_C = \frac{b_1}{B_1} + \frac{m}{v_C} + \frac{b_2}{B_2} \tag{5}$$

The time required for the task to be unloaded to the master station for execution is calculated, represented by T_C. When returning, the network bandwidth is represented by B_2. The energy consumption of computing task unloading to the main station mainly includes the energy consumption of transmission from unloading to the cloud and the energy consumption of the return from receiving, namely:

$$E_C = P_1 \cdot \frac{b_1}{B_1} + P_2 \cdot \frac{b_2}{B_2} \tag{6}$$

In the formula, E_C is the energy consumption of computing task unloading to the master station, and P_1 is the transmission power of data uploading. P_2 is the transmission power when data are received.

Infrared sensors are becoming increasingly mature and are intuitive, accurate, highly sensitive, fast, safe, and widely used. These sensors are an important means to detect the external heat and internal insulation of power equipment as soon as possible and can make reliability predictions for early fault defects of power equipment to improve traditional power equipment from preventive test maintenance to condition-based maintenance. Through the analysis of fault defects, the reliability of traditional power equipment can be predicted, thus realising preventive testing and state maintenance.

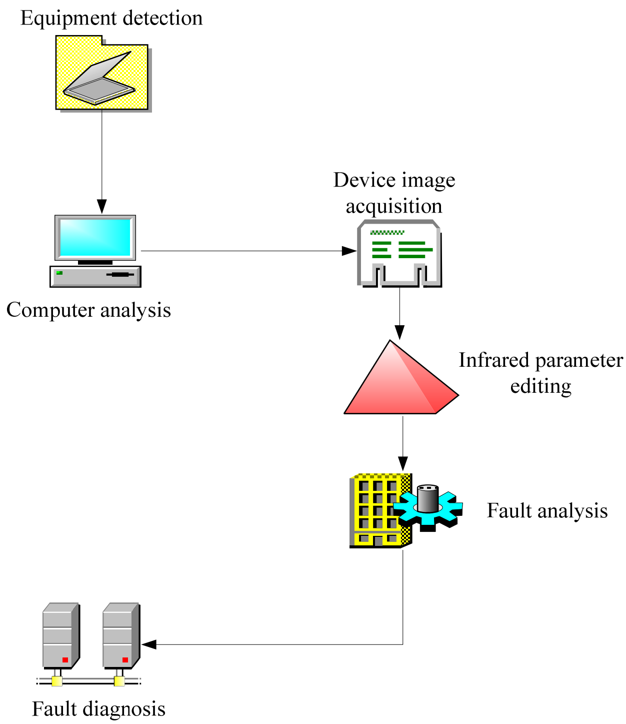
When deploying edge computing devices based on infrared sensors in actual power systems, it is necessary to reasonably select the installation location of the edge computing devices according to the distribution and monitoring requirements of the power equipment to ensure that it can stably receive the data collected by the infrared sensors. During the installation process, attention should be given to the protection of the equipment to avoid being affected by harsh environments such as high temperatures, humidity, and dust. For software configuration, appropriate computing task parameters need to be set according to different power equipment monitoring tasks. The communication parameters between the edge computing device and the main station server should be configured, including the network address, port number, data transmission protocol, etc., to ensure that the data can be transmitted accurately and quickly. In terms of data interpretation and processing, technicians should establish a reasonable threshold judgement mechanism based on the normal operating temperature range and historical data of the equipment. When the data processed by the edge computing device exceed the threshold, an early warning signal is issued in time. For transformers, the surface temperature is generally between 40°C and 60°C during normal operation. When the data collected by the infrared sensor are processed by edge computing and the temperature exceeds 65°C, it is judged as abnormal, and the equipment needs to be further inspected.

In battery-powered devices, long-term operation causes the battery performance to gradually degrade, affecting the overall energy efficiency of the device. The energy efficiency optimisation strategy of the device will face challenges, especially after the battery performance degrades, and the original optimisation scheme will no longer be applicable. Therefore, when performing energy efficiency optimisation design, in addition to considering real-time energy efficiency, it is also necessary to fully consider the impact of battery life. For devices running long-term, an adaptive optimisation mechanism is introduced to dynamically adjust the optimisation strategy to cope with changes caused by battery degradation. Future research should explore in depth how to balance device energy efficiency and battery life to ensure that the device maintains high stability and durability throughout its life cycle.

Infrared sensors can effectively solve the problem of thermal fault detection in equipment and can monitor equipment regularly or continuously under the condition of continuous power. The sensors do not affect the actual temperature distribution in actual work and can obtain a thermal image of the temperature distribution of the measured object; this can be easily compared with the adjacent position or different phases of the instrument, with higher temperature resolution and spatial resolution. Infrared sensors can accurately judge the change in thermal conditions inside an instrument (Lin, 2018). The fault diagnosis method of the infrared sensor is shown in Figure 3.

As shown in Figure 3, the fault diagnosis methods of infrared sensors include equipment detection, computer analysis, equipment image acquisition, infrared parameter editing, and fault analysis. Finally, it can diagnose the fault. Power equipment condition monitoring is a new technology that combines infrared thermal imaging technology, heat transfer, electrical engineering, and equipment fault diagnosis technology. With the maturity and perfection of modern power equipment condition monitoring, its remote, contactless, accurate, real-time, and fast characteristics have been widely considered by countries around the world and have developed rapidly. Therefore, in the operation and maintenance of power equipment, the use of infrared sensors is very effective.

Figure 3 Fault diagnosis method for an infrared sensor (see online version for colours)



3.3 Infrared imaging based on an infrared sensor

Infrared imaging technology is realised by using an infrared camera or intelligent infrared camera. It uses high accuracy to search for thermal faults in the full field of vision. Through the developed control software, the computer can turn on the infrared thermal imager regularly at a specific time and analyse the real-time image and temperature data of the specific instrument. Appropriate infrared cameras or intelligent infrared cameras are selected to be installed at the power equipment monitoring point to ensure that they can cover the equipment area that needs to be monitored. Through the developed control software, the computer is set to start the infrared thermal imager regularly for data collection. During the collection process, the infrared thermal imager uses its high accuracy to capture the infrared radiation on the surface of the equipment and generate a thermal image. According to the principle of real matter absorbing and releasing energy, the radiation brightness of an object is measured by comparing the radiation intensity of the object with that of the black body. The relationship between the radiation energy and temperature of the equipment is analysed by combining the emissivity of the material with the Stefan-Boltzmann law. Since the wind affects the measurement results, the measured temperature must be corrected. Finally, the computer analyses the collected real-time images and temperature data and judges whether the equipment has hidden dangers, such as overheating, by comparing the temperature data at different times and the temperature differences between different equipment. If an abnormality is found, an alarm is issued in time to notify relevant personnel to handle it. In this way, infrared imaging technology can remotely monitor the status of substation power equipment, in real time and online, and can promptly detect existing environmental problems and equipment overheating failures, making the safe operation of unmanned substations more reliable and promoting the development of power equipment status monitoring technology.

The more energy real matter absorbs, the more energy it releases. A comparison of the radiation intensities of an object and a blackbody can be used to measure the radiation efficiency of an object, namely, the radiance ε, whose ratio is less than 1:

$$\varepsilon = P_\lambda / P_h \prec 1 \tag{7}$$

In the formula, P_λ represents the energy radiation power of the actual object, and P_h represents the energy radiation power of the black body.

In daily monitoring, corresponding detection can be achieved by comparing the temperature. Only by understanding the radiation intensity of the power equipment can more accurate temperature data be obtained.

The Stefan-Boltzmann law accurately describes the influence of radiation power. The temperature of the material itself and its radiation are two decisive factors:

$$P = \varepsilon \sigma T \tag{8}$$

Because the emissivity depends on the properties of each material, the radiant energy of an object increases when its temperature increases, and the temperature also greatly affects it.

Because the wind quickly removes heat from the surface of the device, resulting in a decrease in the temperature of the power device and affecting the measurement process, the measured temperature is corrected via the following formula:

$$\Delta\theta_0 = \Delta\theta \exp(f / w) \tag{9}$$

where f represents the real-time wind power and where $\Delta\theta_0$ represents the temperature increase value measured by the instrument.

Infrared imaging technology can monitor the status of transformer power equipment remotely, in real time and online, and can identify existing environmental problems and equipment overheating faults in time. This makes the safe operation of unattended substations more reliable and promotes the development of condition monitoring technology for power equipment.

When deploying infrared imaging equipment, it is necessary to select the appropriate installation angle and position according to the shape, size, and monitoring focus of the power equipment to ensure that the infrared camera can fully capture the key parts of the equipment. During the installation process, the stability of the camera must be ensured to avoid vibration or shaking, which affects the image acquisition quality. In terms of software configuration, it is necessary to set parameters such as the image acquisition time interval, image resolution, and temperature measurement range. For high-voltage equipment at substations, the image acquisition time interval can be set to 5 minutes, the image resolution can be set to 640 × 480, and the temperature measurement range can be set to –20°C to 200°C. In terms of data interpretation and processing skills, operators must learn to analyse the colour distribution and temperature change trends of infrared images. Areas with higher temperatures appear red or yellow in infrared images. By observing the changes in the location and range of these areas, it is possible to determine whether the equipment has an overheating fault. The temperature correction formula is combined to process the measured data to improve the accuracy of the data. In windy weather, the temperature data are corrected according to the wind power and the measured temperature increase values to ensure the reliability of the monitoring results.

4 Power fault detection effects of different methods

4.1 Detection accuracy

It is impossible to achieve high accuracy in power equipment diagnosis through manual observation, while infrared sensors can extract information invisible to humans and can also correct the measured data. To prove that the infrared sensor proposed in this paper has a better detection effect, this paper makes an experimental comparison. The data were denoised and standardised in the preprocessing stage to ensure the accuracy of the measured data. The accuracy of the different methods was tested via variance analysis, and the processing and analysis process of the experimental data was transparent. Figure 4 shows a visualisation of the real-time monitoring interface of the edge computing platform.

Figure 4 Rendering of real-time monitoring system interface

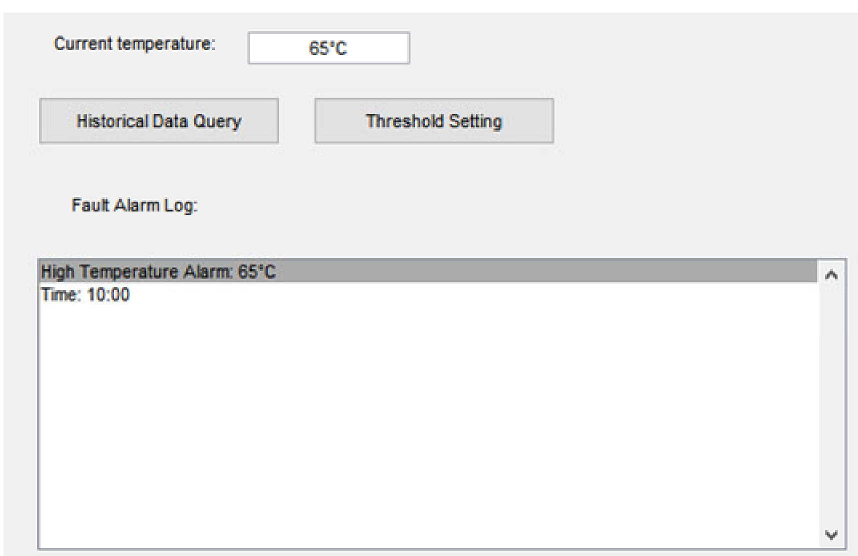
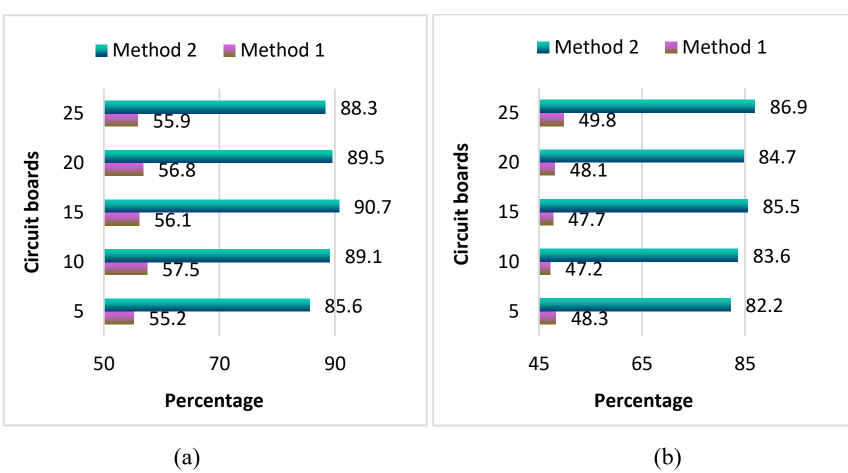


Figure 4 shows the visualisation interface of the real-time monitoring system, which is designed to conveniently display key information about the equipment's operating status. The current temperature is displayed at the top of the interface, allowing users to intuitively grasp the current temperature value in real time. The historical data query button allows users to trace back historical temperature data and analyse temperature change trends. The threshold setting button allows users to set temperature thresholds as needed, flexibly adapting to different monitoring needs. The fault alarm log area below records the fault alarm information. For example, the interface in Figure 4 records 'high-temperature alarm: 65°C' and the corresponding time 'time: 10:00', which allows users to quickly understand equipment abnormalities and promptly troubleshoot potential faults.

The experimental environment of this paper involves 60 circuit fault diagnosis technicians in a city in the laboratory with interference (environment 1) and in the laboratory without interference (environment 2). In the selection of experimental equipment, Seek Thermal infrared sensor is used. The Seek Thermal infrared sensor used in this experiment is produced by Seek Thermal, Inc. (headquartered in Irvine, CA, USA), and the model is Seek Thermal Compact Pro. The infrared sensor has high sensitivity and high resolution, and can accurately capture small temperature changes.. The experiment compares the traditional probe method used by technicians to detect the faulty circuit boards used in experiments (method 1) and the infrared sensor based on edge computing (method 2). Here, 50 faulty circuit boards are used as experimental data. Each laboratory has 25 faulty circuit boards. The temperature, humidity, and other environmental factors in the laboratory were ensured to be in a stable control state to avoid interference from external factors. All the experimental data were collected by 60 circuit fault diagnosis technicians and were recorded and calibrated to ensure the accuracy and repeatability of the experimental results.

The detection accuracies of the different methods in different environments are shown in Figure 5.

Figure 5 Detection accuracy of different methods in different environments, (a) detection accuracy of different methods in environment 1 (b) detection accuracy of different methods in environment 2 (see online version for colours)



As shown in Figure 5, in the case of experimental environment 1 in Figure 5(a), when the number of circuit boards is 5, the detection accuracy of method 1 is 55.2%, and that of method 2 is 85.6%. When the number of circuit boards is 10, the detection accuracy of method 1 is 57.5%, and that of method 2 is 89.1%. When the number of circuit boards is 15, the detection accuracy of method 1 is 56.1%, and that of method 2 is 90.7%. When the number of circuit boards is 25, the detection accuracy of method 1 is 55.9%, and that of method 2 is 88.3%.

In Figure 5(b), in the case of experimental environment 2, when the number of circuit boards is 10, the detection accuracy of method 1 is 47.2%, and the detection accuracy of method 2 is 83.6%. When the number of circuit boards is 20, the detection accuracy of method 1 is 48.1%, and that of method 2 is 84.7%. When the number of circuit boards is 25, the detection accuracy of method 1 is 49.8%, and that of method 2 is 86.9%. Method 2 shows greater accuracy in both environments, which is related to the excellent performance of the infrared sensors. Method 2 adopts edge computing offloading and an efficient data transmission strategy, which reduces delay and error and can effectively improve detection accuracy.

The greatest advantage of an infrared sensor is that it does not need to use the circuit principle, nor does it need to comprehensively understand and analyse the circuit principle, so it can quickly find the fault. In addition, the sensor can also realise real-time detection without changing the parameters of the circuit board, thus avoiding changes in high-frequency signals in the detection process. Infrared sensors have broad application prospects in the production, use, maintenance, and other aspects of power electronic equipment.

4.2 Test time

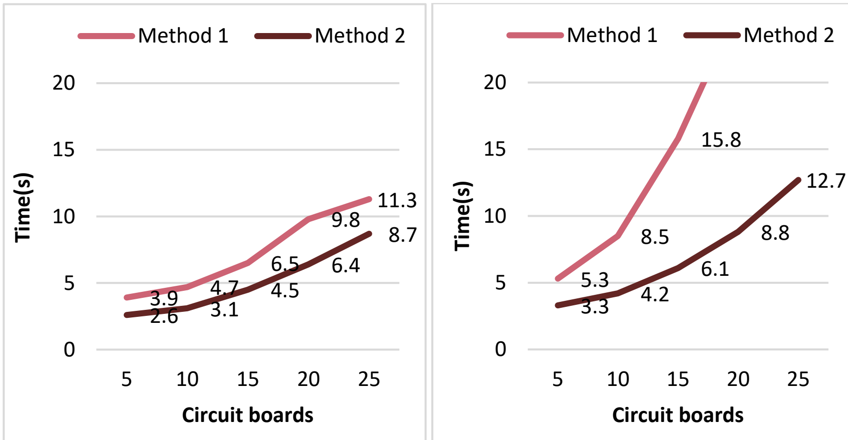
Infrared sensors have been increasingly used in the operation and maintenance of substations, especially in the detection of hidden dangers and equipment problems, which has changed the traditional inspection mode of substation operation and maintenance and greatly improved the inspection efficiency of substation equipment. This paper analyses the detection time of circuit boards by different methods. The detection times of the different methods in different environments are shown in Figure 6.

As shown in Figure 6(a), the times taken for methods 1 and 2 to detect five faulty circuit boards in environment 1 are 3.9 s and 2.6 s, respectively; methods 1 and 2 take 4.7 s and 3.1 s to detect 10 faulty circuit boards; methods 1 and 2 take 6.5 s and 4.5 s to detect 15 faulty circuit boards; and methods 1 and 2 take 11.3 s and 8.7 s to detect 25 faulty circuit boards.

According to Figure 7(b), the times taken by method 1 and method 2 to detect 5 faulty circuit boards in environment 2 are 5.3 s and 3.3 s respectively, and the times taken by method 1 and method 2 to detect 10 faulty circuit boards are 8.5 s and 4.2 s, respectively. Methods 1 and 2 take 25.6 s and 8.8 s to detect 20 faulty circuit boards, and methods 1 and 2 take 33.9 s and 12.7 s to detect 25 faulty circuit boards.

The application research of infrared sensors is large-scale work, and the application of its branch fields still needs to be practised so that the substation operators can master its application skills and use.

Figure 6 Detection times of different methods in different environments, (a) detection times of different methods in environment 1 (b) detection times of different methods in environment 2 (see online version for colours)



(a) (b)

4.3 *Effect comparison*

The infrared sensor can judge the deterioration and development trend of equipment status and performance by analysing and processing data such as the routine inspection, online status monitoring, and fault diagnosis of power equipment. Planned maintenance is carried out before the equipment fails and before the performance drops to an unbearable limit, which overcomes the deficiencies of routine post-maintenance, preventive planned maintenance, excessive maintenance, and blind maintenance. The occurrence of electric power accidents after fault detection via method 1 in this paper is shown in Table 1.

Table 1 Occurrence of power accidents after fault detection via method 1

Frequency	*Number of people*	*Percentage*
A lot	24	40%
Commonly	18	30%
Less	9	15%
A few	6	10%
Few	3	5%

After using method 1 for fault detection, 24 technicians reported that the frequency of power accidents was ‘a lot’, accounting for 40% of the total number of power accidents; 18 reported ‘commonly’, accounting for 30%; 9 reported ‘Less’, accounting for 15%; 6 reported ‘a few’, accounting for 10%; and 3 technicians reported ‘few’, accounting for 5%

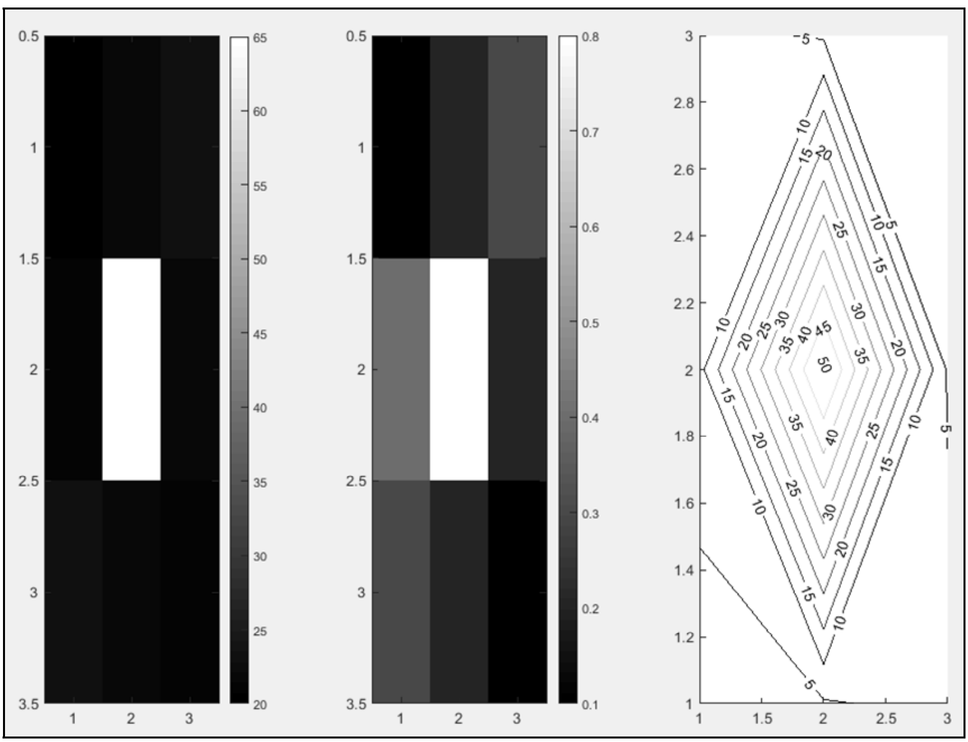
Table 2 shows the occurrence of power accidents after fault detection via method 2.

Table 2 Occurrence of power accidents after fault detection via method 2

Frequency	*Number of people*	*Percentage*
A lot	0	0%
Commonly	2	3.3%
Less	6	10%
A few	22	36.7%
Few	30	50%

As shown in Table 2, no technical personnel believe that there are many electric accidents after using method 2 for fault detection, accounting for 0% of all accidents. Two technicians believe that the occurrence of electric power accidents is average, accounting for 3.3%, whereas six technicians believe that the occurrence of electric power accidents is relatively small, accounting for 10%. 22 technicians believe that there are very few electric accidents, accounting for 36.7%, and 30 technicians believe that there are almost no electric accidents, accounting for 50%.

Figure 7 Multisensor data fusion effect, (a) infrared data (b) ultrasonic data (c) fusion result



(a) (b) (c)

An infrared sensor is the key technology of equipment status detection. The fault diagnosis of the external sensor involves monitoring the equipment status. Through comprehensive analysis of the historical status of equipment, people can understand its objective status and obtain its development trend. Equipment diagnosis is the bridge between condition monitoring and condition maintenance. If the fault diagnosis of the equipment cannot be carried out, then condition-based maintenance cannot be carried out. The use of infrared sensor condition-based maintenance can reduce the maintenance cost of power equipment; this can shorten the outage time and greatly promote the reliability of power equipment detection. Figure 7 shows the effect of multisensor data fusion.

In the field of multisensor data fusion, different types of sensor data have advantages, and fusion can achieve more comprehensive and accurate detection. Figure 7 shows infrared data, ultrasonic data, and their fusion results. Figure 7(a) shows the visualisation results of the infrared data, which are presented in a thermal map image. The colour reflects the temperature difference of the object and intuitively shows the thermal distribution characteristics of the monitored object. Figure 7(b) is an ultrasonic data image, which uses grayscale colour mapping. The grayscale value reflects information such as the intensity of the ultrasonic signal and can present the structure or distance of the target object. Figure 7(c) is a contour map after the fusion of the two. The infrared and ultrasonic data are processed comprehensively, and the numerical changes in the fused data are displayed in the form of contour lines. The key information of each sensor dataset is retained, and more potential features are mined through fusion, providing a richer and more reliable dataset for subsequent analysis and decision making and improving the detection effect and accuracy.

The application of infrared sensors based on edge computing in power electronics technology proposed in this paper has high detection accuracy and low detection delay. The experimental results show that this method performs better than traditional detection methods do in various experimental environments. Although this system has high application potential, in theory, it may still face certain challenges in actual deployment. Owing to the wide variety of power equipment, ensuring that different types of power equipment are compatible with the edge computing system and operate stably is a key technical problem in the application of the system. Network fluctuations can also affect real-time data transmission and processing. Although edge computing can reduce the computational burden of the main server when the LAN is unstable or the bandwidth is insufficient, it still affects the response speed and accuracy of the system. Future research can focus on exploring how to optimise the system to cope with more complex operating environments and evaluate its actual deployment effect in large-scale power systems.

The scope and depth of the current experimental verification are still limited, and it fails to fully cover all possible fault types and scenarios. In future research, we will focus on expanding the scale of the experiment to cover additional types of power equipment faults, including common fault types such as short and open circuits inside power equipment, as well as fault scenarios under different operating environments such as high temperature, high humidity, and strong electromagnetic interference. We will further study the application effect of infrared sensors based on edge computing in power electronics technology, evaluate their performance under more complex actual working conditions, and provide a more solid experimental basis for the widespread application of this technology.

5 Conclusions

In the future, competition in the international market will be dominated by high-tech power electronics technology. At present, China's power electronics technology is not mature enough, which is far from the needs of China's economic development, especially under the great influence of other countries, so people should be aware of the courage to solve difficulties and challenges. Infrared imaging, computer computing, and other technologies are combined with infrared sensors, and the surface temperature is measured and diagnosed through the radiation of electrical energy. The infrared sensor has broad application prospects. In future work, the infrared sensor could be combined with the practical application of substation operation and maintenance work. Through the cooperation of various technologies, one should strive to find the most suitable solution to make the operation and maintenance of the substation more comprehensive and convenient; this can make the operation and utilisation of social electricity more secure.

Declarations

All authors declare that they have no conflicts of interest.

References

Ai, Y., Mugen, P. and Kecheng, Z. (2018) 'Edge computing technologies for internet of things: a primer', *Digital Communications and Networks*, Vol. 4, No. 2, pp.77–86, https://doi.org/10.1016/j.dcan.2017.07.001.

Awasthi, M., Kumar, A., Kumar, D. and Pal, I.J. (2022) 'Electric power system monitoring and theft detection using power line communication', *International Journal of Engineering, Science and Information Technology*, Vol. 2, No. 2, pp.79–85, https://doi.org/10.52088/ijesty.v2i2.254.

Bhan, R.K. and Vikram, D. (2019) 'Recent infrared detector technologies, applications, trends and development of HgCdTe based cooled infrared focal plane arrays and their characterization', *Opto-Electronics Review*, Vol. 27, No. 2, pp.174–193, https://doi.org/10.1016/j.opelre.2019.04.004.

Che, X. (2022) 'Communication architecture of power monitoring system based on incidence matrix model', *Applied Mathematics and Nonlinear Sciences*, Vol. 7, No. 1, pp.83–92, https://doi.org/10.2478/amns.2021.1.00098.

Chen, X.H., Liu, Y.L. and Shao, R. (2019) 'Design and implementation of auxiliary teaching system for power electronic technology course', *Journal of Anqing Normal University (Natural Science Edition)*, Vol. 25, No. 1, pp.108–112.

Dong, M. (2022) 'High-speed programmable photonic circuits in a cryogenically compatible, visible-near-infrared 200 mm CMOS architecture', *Nature Photonics*, Vol. 16, No. 1, pp.59–65, https://doi.org/10.1038/s41566-021-00903-x.

Hanbiba, S. (2021) 'Water environment monitoring system based on wireless sensor network', *Academic Journal of Environmental Biology*, Vol. 2, No. 1, pp.39–47, https://doi.org/10.38007/AJEB.2021.020105.

Lin, B.S., Peng, C.W., Lee, I.J., et al. (2023) 'System based on artificial intelligence edge computing for detecting bedside falls and sleep posture', *IEEE Journal of Biomedical and Health Informatics*, Vol. 27, No. 7, pp.3549–3558, https://doi.org/10.1109/JBHI.2023.3271463.

Lin, H. (2018) 'Mid-infrared integrated photonics on silicon: a perspective', *Nanophotonics*, Vol. 7, No. 2, pp.393–420, https://doi.org/10.1515/nanoph-2017-0085.

Lin, X. (2019) 'Two-dimensional spintronics for low-power electronics', *Nature Electronics*, Vol. 2, No. 7, pp.274–283, https://doi.org/10.1038/s41928-019-0273-7.

Liu, S., Wang, J., Wang, Z., Yu, B., Hu, W., Liu, Y. and Hu, Y. (2022) 'Brief industry paper: the necessity of adaptive data fusion in infrastructure-augmented autonomous driving system', *2022 IEEE 28th Real-Time and Embedded Technology and Applications Symposium(RTAS)*, Milano, Italy, pp.293–296, https://doi.org/10.1109/RTAS54340.2022.00031.

Mathews, I. (2019) 'Technology and market perspective for indoor photovoltaic cells', *Joule*, Vol.3, No. 6, pp.1415–1426, https://doi.org/10.1016/j.joule.2019.03.026.

Syu, J.H., Lin, J.C.W., Srivastava, G. et al. (2023) 'A comprehensive survey on artificial intelligence empowered edge computing on consumer electronics', *IEEE Transactions on Consumer Electronics*, Vol. 69, No. 4, pp.1023–1034, https://doi.org/10.1109/TCE.2023.3318150.

Tan, C.L. and Hooman, M. (2018) 'Emerging technologies for high-performance infrared detectors', *Nanophotonics*, Vol. 7, No. 1, pp.169–197, https://doi.org/10.1515/nanoph-2017-0061.

Tulus, M.A.A. and Jumadi, A.S. (2022) 'Home electrical lighting system: remotely control and power monitoring', *Progress in Engineering Application and Technology*, Vol. 3, No. 1, pp.614–623.

Xiao, W. (2022) 'Exploration on teaching reform of power electronic technology under the background of mass entrepreneurship and Innovation', *Advances in Education, Humanities and Social Science Research*, Vol. 3, No. 1, pp.126–126, https://doi.org/10.56028/aehssr.3.1.126.

Yuan, Z., Weiqing, W. and Shan, H. (2021) 'Application of sustainable computing based advanced intelligent power electronic technology for smart grid systems', *International Journal of Computers and Applications*, Vol. 43, No. 5, pp.453–461, https://doi.org/10.1080/1206212X.2019.1576993.

Zhang, M. (2021) 'Research on intelligent fault diagnosis technology of power electronic circuit', *Journal of Frontiers of Society, Science and Technology*, Vol. 1, No. 7, pp.126–129.