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Study and Design of Flexible Surface Temperature Sensors

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Abstract

In today's industrial environment, abnormal temperature of various large-scale equipments implemented in plant for production process, high- and low-voltage power distribution devices for building power supply, and important devices in equipment rooms such as central air conditioning, central hot water/steam, communications, agriculture, food, and healthcare systems…*etc.* always cost a lot to assets. This unexpected high temperature resulted from improper construction, poor environment, maintenance negligence, and usage overload can damage equipment itself or collapse major power, even bring industrial safety accident. Therefore, it is very important to have a low cost but fast reaction and highly accurate temperature sensing system to prevent from abnormal heating. It should also include sensor, information display, alarm, and signal transmission. This multi functions can then preventively deliver an alarm signal when abnormal temperature is detected.

This study mainly focuses on how to utilize an innovation patent of Flexible Surface Temperature Sensor (FSTS) develop an application solution to detect temperature variation generated from electromechanical system devices. The results of this study may provide electromechanical engineers and service related workers an innovative and effective reference in the field of mechatronics engineering or industrial production or process equipment maintenance.

Keywords: Abnormal temperature in devices, Flexible Surface Temperature Sensor (FSTS), surface temperature sensor

1. Introduction

In general, objects will exhibit temperature differences as a result of energy transfer among physical composition of a variety of substances. This energy is defined as "heat" in thermodynamics. Considering the properties of objects, the principles of this phenomenon [1] include; (1)heat generated by sliding friction surface between metals or contact with the surface of a metal; (2)heat generated by coils under a changing magnetic field, also known as thermal fault [2]; (3)heat caused by medium combustion; and(4)heat generated by radiation. Heat is a type of transferable energy at the condition of different temperatures between two objects. There are three ways to transfer heat: conduction, convection and radiation. When energy is supplied to a physical system in any form, the state of the system will inevitably undergo changes. Temperature is an indicator of heat energy and can immediately show the current status of the system.

The main causes for generating abnormal temperature in electrometrical devices [2–9] include (1)deformation, working at unsuitable angle or insufficient lubrication, and overloading of a motor bearing; (2)overloading of a transformer or when the temperature of its cooling oil is too high; (3)overloading, poor contact, and material degradation of a capacitor and resistor; (4)poor contact and overloading on a high-voltage circuit breaker switch, as well as poor contact of cable connection terminals; (5)overloading of a inductor and it's poor contact; (6) overloading of a power generator or heater, aging equipment and malfunction of thermal controller;(7) overloading of a busway, poor connectors, and wet short circuits. In order to detect locations where abnormal temperature occur in devices, one should examine if the heat generated is constant or transient, and carefully analyze the sensing components and the test method that should be used. These are essential to high-efficiency diagnostic assessment.

Methods to detect abnormal temperature in devices include the following [1]. (1) We should first consider the locations where the temperature is most likely to rise. (2) It is best to permanently attach the measuring components. (3)A sensor should have an on-site temperature display function and an alarm function. If transmission functions are available, then administrators can monitor the system remotely. Normally, there are no service administrators on site throughout the day. (4) In the electric motor and transformer example shown in Figure 1, a red arrows identify positions in device where heat is most likely to be generated . (5)Devices with measuring components can be roughly divided into the following types: temperature display, intangible (infrared), tangible (thermocouples, thermistors, resistive sensors), rods, implantable sensors, etc. The measuring components currently available on the market all have their own advantages and disadvantages, depending on their external appearance, functionalities, and properties. However, they are not suitable for electromechanical systems, especially devices in power systems.

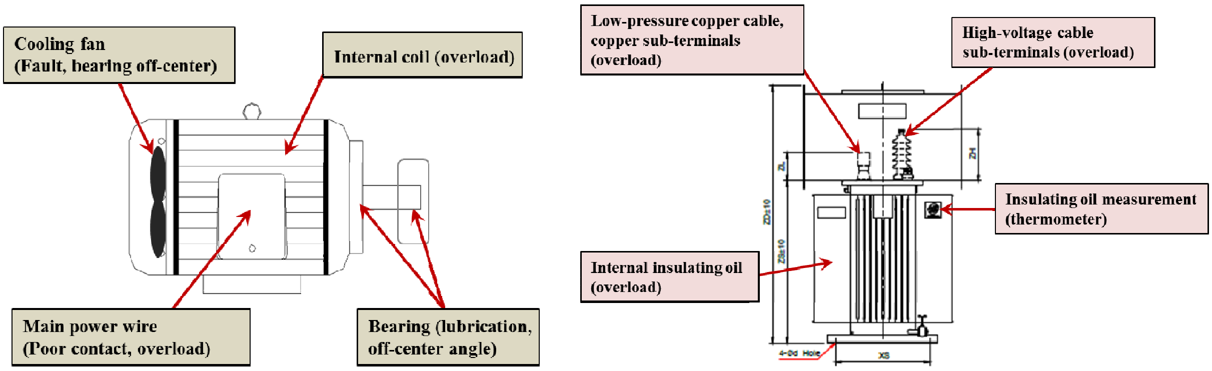


Figure 1. Locations where motors and transformers exhibit abnormal heating.

Therefore, this paper proposes a patented (ROC Patent No: M331662; People's Republic of China Patent No: ZL2010202939219)Flexible Surface Temperature Sensor (FSTS) [11, 12], a Resistance Temperature Detector (RTD) that uses resistive platinum components (resistive body Pt100Ω) as the core component. When applying this study to the practical design in electromechanical systems, a solution of these sensors integrated with an on-site electricity translation device should be the best tool for local monitoring and sensing abnormal temperatures in devices, and it also can do remotely monitor equipment through the use of wired communications technology [13] or wireless communication technology [14].

2. Principles of a Flexible Surface Temperature Sensor

2.1 Fundamentals

Sensors are to convert_one_type of physical quantity into a different type of physical quantity which can be simultaneously transformed into electrical signals in order to control or activate system devices. A generic sensor is shown in Figure 2. In basic measurement formula, a sensor can transform physical quantities from certain hot objects into the electrical quantity such as current, voltage, resistance, frequency…*etc.*, at the output terminal. Before we use sensors, however, we need to consider what kind of the object is to be measured, what type of quantity is to be converted into, how to transform, and other mechanisms, such as the range of measurement, and the environmental conditions for the measurement.

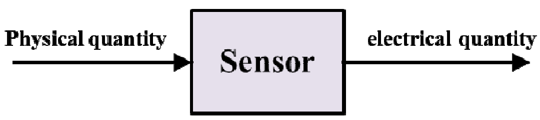


Figure 2. Representation of a sensor.

There are many types of temperature sensors. In terms of their properties, one is a static sensor and the other is a dynamic sensor [15]. In terms of technical aspects, one is Exposure measurement which performs a tangible measurement by directly contacting the measured object, and the other is Non-contact measurement which estimates temperatures based on detected heat radiated from objects. Different situation factors such as environment, purpose, usage, accuracy, cost…*etc.* different sensors are applied. But in general, thermoelectric conversion sensors are common tools for regular temperature monitoring, including thermocouples [16], thermistors [17], RTDs and infrared sensors that convert the infrared radiation emitted by the device to temperature. These types of sensors are small in size, high in accuracy, simple of structures, and very easy to use. It can be mounted directly onto the measured device.

2.2 Operating principles of resistive sensors

RTD is a sensor of natural metal's thermal reaction properties which mainly shows different related resistance value as the temperature increases. A RTD also can be composed of two more different metals. Their resistance coefficient could be very precise under strict quality control. A platinum RTD is currently the most stable temperature sensor. Its resistance at 0 ℃ is 100 Ω, and this is used as a standard specification. Generally, it is labeled as Pt100. [17].

When the temperature changes substantially, an RTD has excellent accuracy and stability. Generally, when the RTD is at 0 ℃, the accuracy can be as high as 0.01 Ω(0.026 ℃). Typical , the RTD of industrial grade fluctuates by less than 0.1 ℃/year. However, the resistance of an RTD is very small (100 Ω) and its variation is also minor ($> 0.4\,\Omega/℃$). This makes it difficult to use for measurement. Therefore, in order to precisely measure an extremely small change in resistance, we must establish a special power circuit architecture in order to reduce deviation from impedance in system components and wires.

The temperature coefficient is typically denoted as α (alpha) Of course, the values of αwill be different for different materials. For an RTD, even though each manufacturer has different specifications and definitions for α, it is generally defined as follows:

$$\alpha\ (\Omega/\Omega/℃) = (R100 - R0)/\ (R0 - 100\ ℃) \text{ -- } (2.1)$$

where R0 represents the resistance value when the RTD is at 0 ℃ and R100 represents the resistance value when the RTD is at 100 ℃. For example, the resistance measured is 139.11 Ω for a platinum Pt100 RTD with $\alpha = 0.003911$, when the temperature is 100 ℃. There are various products that use Pt100, and each is suitable for different measurements in different temperature ranges, as shown in Table 1.

Table 1. Applicable temperature ranges and grades for Pt100.

Mark	Operating temperature range	Grade	Resistance accuracy (Ω)	Temperature accuracy (℃)	Rated current (mA)
L	Low temperature −200 – +100 ℃	0.15	±0.06	±(0.15+0.0015*t*)	2
M	Medium temperature 0 – 350 ℃	0.2	±0.06	±(0.15+0.002*t*)	2
H	High temperature 0 – 650 ℃	0.5	±0.12	±(0.3+0.005*t*)	2.5

3. Structure and Specifications for a Flexible Surface Temperature Sensor

3.1 Pt100 Material Analysis

The wiring materials used in resistive bodies in RTDs have included platinum, nickel, and copper. A Platinum with superior linearization characteristics is more stable than other types of materials. Currently within the industry, platinum is also widely used as a resistive wire for resistive sensors. There are three standard models [18]: glass package, metal wing holder, and ceramic package.

The FSTS products discussed in this paper are Pt100 resistive body in a ceramic package. We arrange the platinum wires in a spiral shape, and then place crystalline alumina into the refined object body before sealing it. A standard platinum resistive body is designed for higher shock resistance, reproduce capability of temperature, and stability under long-term operation. This small sensor but with wide temperature range has excellent electrical and mechanical properties and is suitable for use in any environment or area for any purpose. In addition to the advantages and characteristics mentioned above, it also complies with international standards, including IEC751 Amd.2-1995, ASTM E1137-1995, and JISC 1604-1997. The characteristic curves for a platinum RTD are based on the coefficients of the three standard Callendar–Van Dusen equation [17]. In addition, they must have the following resistance characteristics:

R (0 ℃) = 100 Ω and---(3.1)

R (100 ℃) / R (0 ℃) = 1.3851. --(3.2)

From Equations (3.1) and (3.2), we can determine the temperature of the Pt100 resistive body, as the resistance increases by 0.3851 Ω with every 1 °C rise in temperature. If the Pt100 resistive body is connected to a certain current source, then, from the voltage measured at terminal of the Pt100 resistive body, we can calculate temperature of the outer shells of various corresponding devices under test. For example, if we connect a Pt100 resistive body to a certain voltage source, and we measure the current passing through the Pt100 resistive body, then we can calculate the temperature of the outer shells of various corresponding devices under test. Based on this conclusion, we use the change of resistance to design our system circuit with voltage, temperature conversion, and temperature sensing components.

3.2 Structural and specification analysis

There are many types of sensors available, depending on the measurement environment, the type of the device, the size of the device, the usage, and the different physical and chemical properties. In terms of external design, we select a product that can be simply applied and replaced, can withstand a harsh environment, and can easily adhere to a test object securely and durably. Figure 3 shows a FSTS recently patented by CHW Industrial Co., Ltd. and cross-sectional view of the structure. The main specifications are detailed in Table 2 [11, 12].

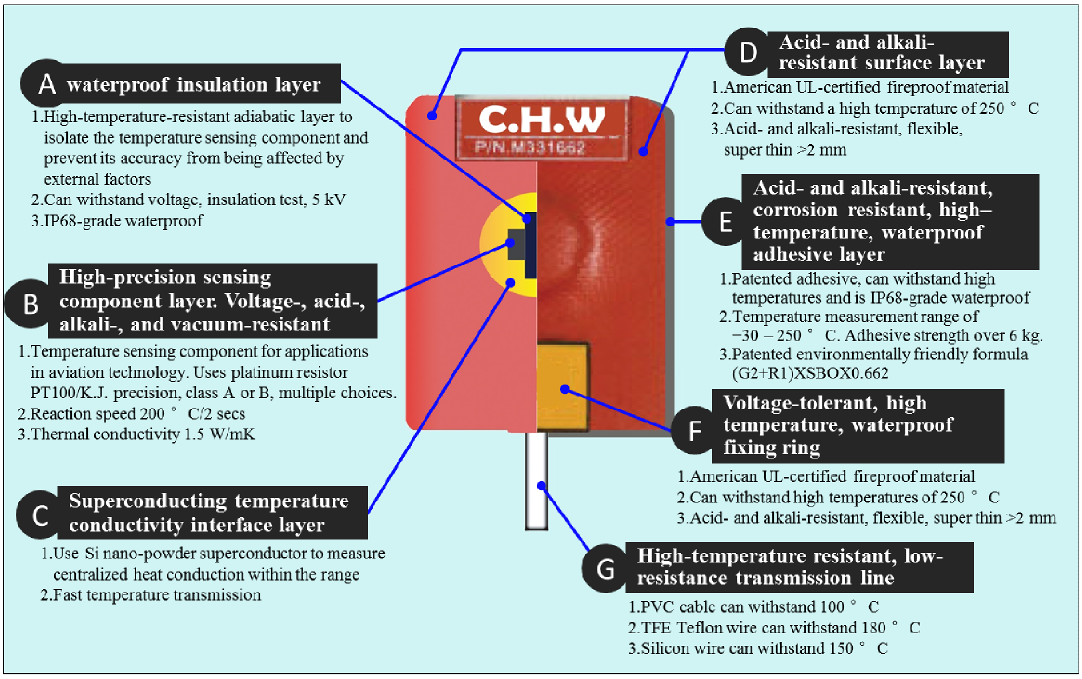


Figure 3. Cross-sectional view of the overall FSTS structure.

Table 2. Main technical specifications for the FSTS.

Item	Specifications	Remarks
Types of objects being measured	Pt100/ K.J. Thermistor, class A or B	
Reaction speed	200 ℃/2 sec	DINIEC751
Thermal conductivity	1.5 W/mK	ASTM D547D
Tear strength	150 lb/m^2	ASTM D264
Temperature range	−30 – 250 ℃	
Safety(PAD)	UL94HB/UL746C	E54153/E65361
Adhesion strength	in^2 1000(100 ℃) /500(150 ℃) / 400(200 ℃) / 300(250 ℃)(g)	
Corrosion resistance	Gasoline, acetone, cleaning solution, moderate to acidic and alkali agents, *etc*.	Splash testing
Waterproof level	IP68(Highest rating)	CNS14165
Dielectric voltage tolerance	5 kV	ASTM D-149-91
Installation	Adhesive(−30 ℃ – 200 ℃)/Silicone (>200 ℃)	
Wire	PVC(100 ℃)/Silicone(150 ℃)/Teflon(180 ℃)	

As shown in Figure 4, the FSTS was designed to have various external appearances, mainly because it is intended to be used in various locations with various environments. This makes it easier to adhere the FSTS onto the surface of the device being measured.

(a) (b) (c) (d)

(e) (f) (g) (h)

Figure 4. The various external appearances of the new FSTS: (a) for large areas, (b, c, d)for small areas, (e) for air temperature, (f) for tubular bodies (beam tubes or buckle types), (g) contact type, and (h) a temperature transmitter with a two-wire system.

(1) Figure 4(a) shows a temperature sensor design suitable for the following environments or areas: power plants, cogeneration plants, chemical plants, pipes with large diameters, and devices with large areas.

(2) Figures 4(b), (c), and (d) show temperature sensor designs suitable for the following

environments or areas: devices in electric power transmission and distribution, solar energy, telecommunications, power devices, and devices with small areas.

(3) Figure 4(e) shows a temperature sensor design suitable for the following environments or areas: air temperature sensors for healthcare, food refrigerators (freezers), communications rooms, disaster prevention and control centers, environmental control rooms, indoor temperature monitors for fire alarms, *etc*.

(4) Figure 4(f) shows a temperature sensor design suitable for the following environments or areas: devices in chemical plants, cogeneration plants, power plants, steaming devices, ice water pipes, hot water pipes, and various tubular devices.

(5) Figure 4(g) shows a temperature sensor design suitable for the following environments or areas: devices used for factory wheels, power devices, transportation devices, and bearing devices.

(6) Figure 4(h) shows a temperature sensor design suitable for the following environments or areas: collecting data from devices, such as the ones used in high- and low-voltage bus ways for large power transmission, devices used in a large area, and devices used over a long distance. A two-wire system with RS-485 transmissions is to be used.

4. System Design and Production of Flexible Surface Temperature Sensors

4.1 System designs for temperature sensing systems based on the environment in which the sensors are used

Temperature monitoring is very important in today’s industrial environment, such as in processing device in factories, devices supplying low and high voltages, central air conditioning, central hot water/steam equipment, communications, *etc*. However, due to improper construction, poor environment, negligence in maintenance, usage overload *etc*., the temperatures of such devices are often increased abnormally. It may cause numerous serious industrial accidents or injuries to personnel. In this paper, various types of patented products are introduced and the sensing technology is applied to measure surface temperatures on small areas of various devices.

The range of applications and environments in which temperature sensors can be used include: (1)high- and low-voltage electrical devices; (2)freezers or central air conditioning equipment; (3)central heating/steaming facilities; (4)communications rooms; (5)cogeneration plant and power plant facilities; (6)various types of factories, including Uninterruptible Power Supply(UPS), steel mills, cement plants, chemical plants, and other facilities; (7)environments and facilities for agriculture, fisheries, and aquaculture; and(8)environments and facilities for medical care, food, and hygienic workplaces.

Below are several practical applications, used to explore temperature monitoring in electromechanical systems, including planning and design .We cover the operational aspects of on-site temperature monitoring, as well as remote temperature monitoring. For the operational aspects of on-site temperature monitoring, we need to have sensing components, connecting wires, and alarm relays for digital temperature monitors. The main function of LCD display is to show real time measured temperature so that administrators can directly observe the temperature values of the test points.

4.2 Application to high- and low-voltage power system substations

As discussed in the Introduction, we have analyzed the diagnosis and sensing methods for abnormal temperatures in power devices, and explained the locations where devices exhibit heating or defects, as well as the suitable sensors. For devices in high- and low-voltage substations, as shown in Figure 5, we will explain in details which sensors should be used and the attachment location for the adhesives.

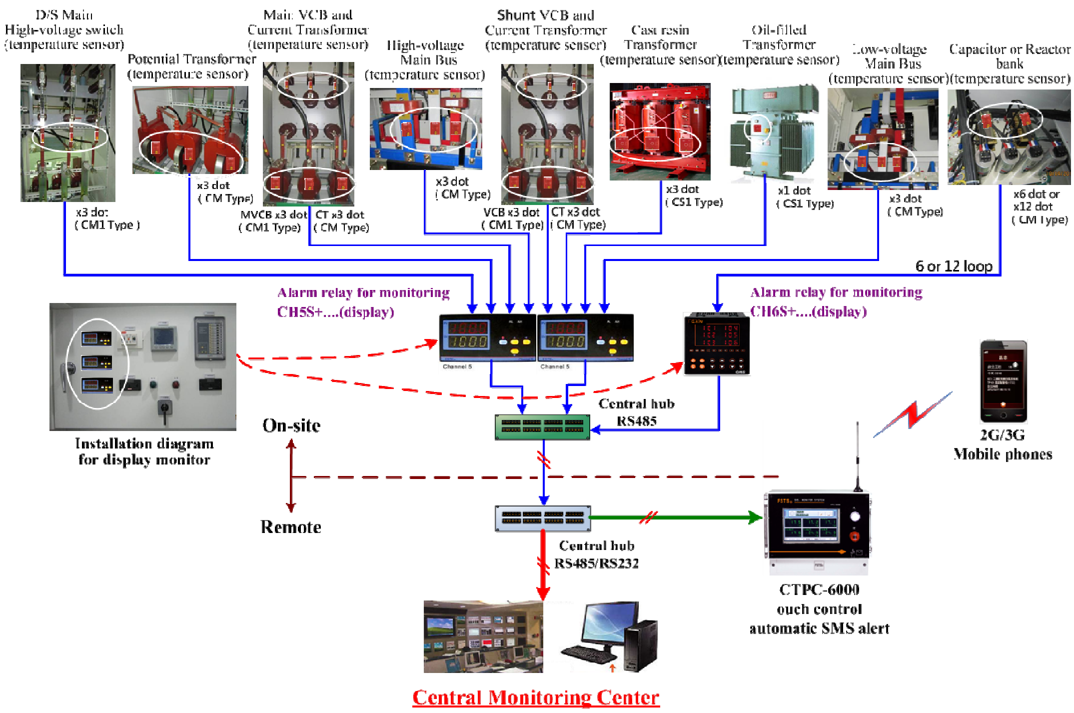


Figure 5. Reference for temperature test points in high- and low-voltage power transformer rooms.

The effective test points for high- and low-voltage devices, as well as the specifications, are selected as follows (see Figure 5):

1. Disconnecting Switch (DS): Test points are located on the processing unit of the cable header or the cable connection sub-terminal, as shown in Figure 4(c). There are a total

of three sampling points.

2. Potential Transformer (PT): Test points are located on the outer shell of the main body, and on the copper bars or cable connection sub-terminal, as shown in Figures 4(b) and (c). There are a total of six sampling points.
3. Vacuum Circuit Breaker (VCB): Test points are located on the cable connection sub-terminal for the VCB, as shown in Figure 4(c). There are a total of three sampling points.
4. Current Transformer (CT):Test points are located on the outer shell of the main body and on the copper bars or cable connection sub-terminal, as shown in Figures 4(b) and (c). There are a total of six sampling points.
5. Bus Bar: Test points are adhered to the surface of the heat shrink, as shown in Figure 4(b). There are a total of three sampling points.
6. Transformer (TR): Three samples are taken from the outer shell of the main body and the cast resin transformer, and one sample is taken from the oil-filled transformer, as shown in Figure 4(a).
7. Air Circuit Breakers (ACB): Test points are located on the bus bar or ACB connection sub-terminal, as shown in Figure 4(b). There are a total of three sampling points.
8. Capacitor bank(SC): Test points are located on the outer shell of each capacitor circuit or the external part of each reactor. The six circuits are sampled as shown in Figure 4(b), with a total of six sampling points.

Once the temperature sensors for each distribution board are installed, they must be connected to alarm relays for temperature monitoring via wires. Depending on the different environments, the alarm relays for temperature monitoring can be located inside the track display, on the surface of the display board, or on the wall-mounted box, in order to help administrators to directly observe the temperature values at the test points.

4.3 Application to a power generator room

The effective test points in a generator room are selected as follows (see Figure 6):

1. Generators (D/G): Test points are located on the outer shell of the generator and the bearing part, as shown in Figures 4(a) and (b). There are a total of three sampling points.
2. Air Circuit Breakers(ACB): Test points are located on the main bus war or the ACB connection sub-terminal, as shown in Figure 4(b). There are a total of three sampling points.

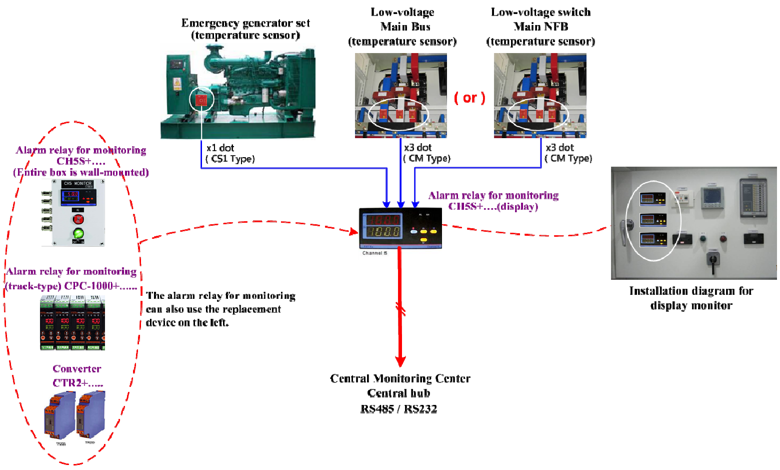
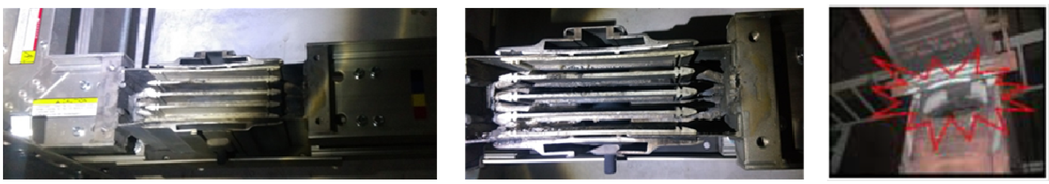


Figure 6. Reference for temperature test points on devices in a generator room.

4.4 Application to a bus way system in power backbone

The effective test points for a low-voltage bus way system in a power backbone are selected as follows (see Figure 7).

In a power system, a low-voltage bus way is responsible for the transmission and distribution of electricity. Its properties include the ability to load a large current, a small configuration space, an easy load distribution, and so on. It is more practical to use bus way than the cable wires for transmitting high current over 800 A. Generally, for a cable wire of length ranging from a few meters to hundreds of meters, straight connectors or 90° connectors for corners are used every 3 meters along the transmission path. Therefore, the number of connectors used is huge. Since power is transmitted over long distances under high current and large load, it will pass through different background locations with different environments and different temperatures. In addition, the uncertainty factors such as quality of construction, the connectors locked at the right position, humidity and long period of time under operation, make Safety to be a major concern. For example, in 2011, once had a tech optical plants, and a residential building in Tainan 2014, due to the power bus way burned tripped the accident, suffered heavy losses. [4]



As a result, we use a test point at a low-voltage power bus way to monitor temperatures for all straight connectors and 90° connectors at corners. Sampling is performed according to Figure 4(h), and real-time temperature data is transmitted to a central monitoring center. Any abnormal temperature in the system is detected as early as possible, so that administrators can be notified to attend to the situation as early as possible. This is beneficial to ensure electrical safety securing property and preserving life.

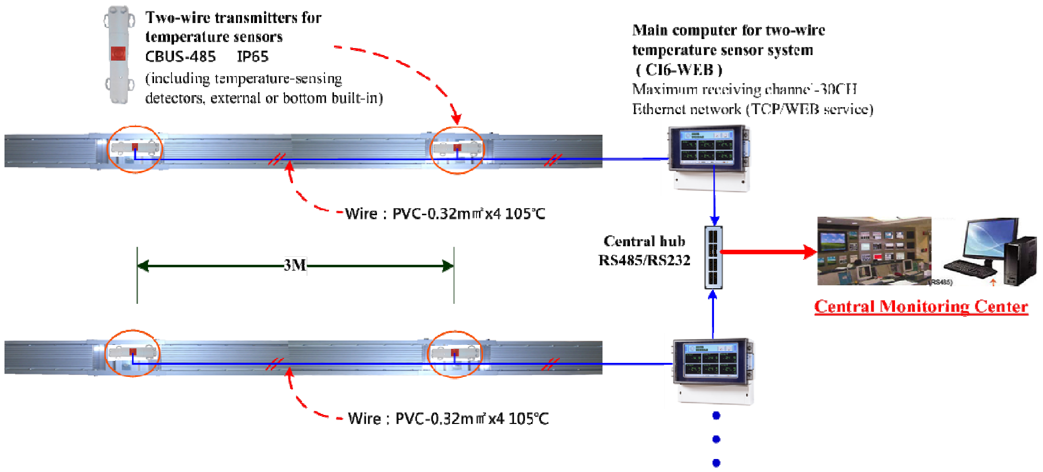


Figure 7. Reference for temperature test points for devices ina bus way system in a power mainline.

4.5 Application to a central air conditioning room

The effective test points for a central air conditioning engine room are selected as follows (see Figure 8).

Locations for the main temperature test points of a central water heating system include the outlet for ice water, the ice water returning terminal, the inlet for cooled water, and the outlet for cooled water. Another choice for measurement is the inlet/outlet air temperature of the air conditioning box. The conventional design method for construction is to implant a thermometer. However, there are two disadvantages associated with this method. One is that the structure of the steel pipe would become damaged (as one needs to dig a hole and then re-weld the joints, and then repaint). The other disadvantage is that an alarm relay for temperature monitoring cannot be installed in the field, so administrators cannot monitor on-site in real time. In addition, the pipeline is not suitable for an adhesive product because the wall of the pipe experiences condensation, and over time the adhesive product will not be secure. In order to solve the drawbacks mentioned above, the most beneficial construction method is to use a “beam tube buckle-type” temperature sensor (as detailed in Figure 4(f)) for all pipes. The real-time temperature sensor can display the values and produce an alarm on-site and can also transmit the data to a central monitoring center.

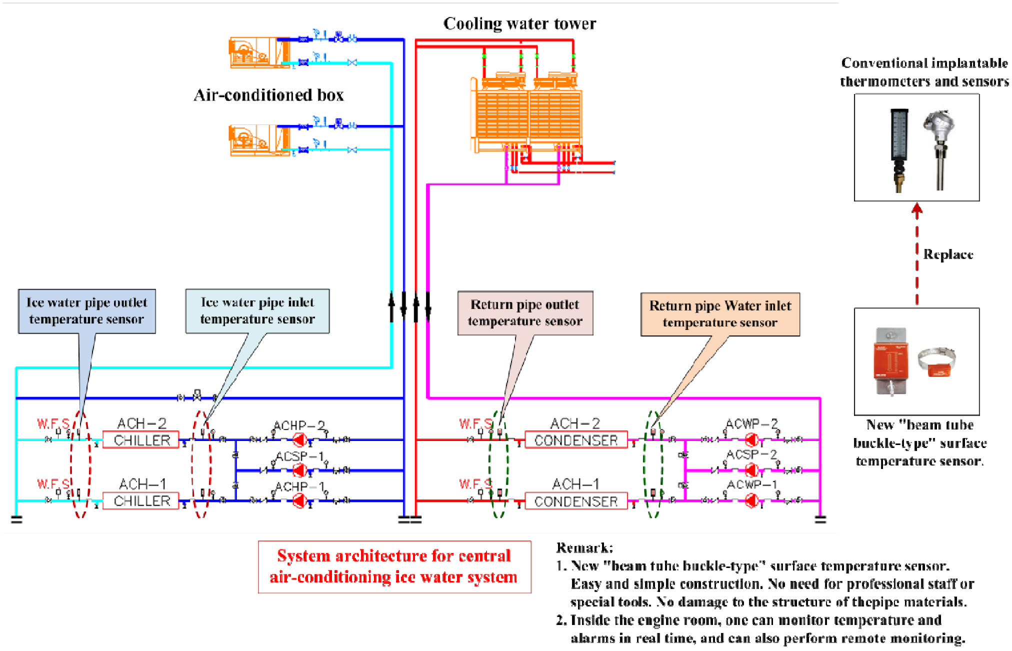


Figure 8. Reference for temperature test points for devices in a central air Conditioning engine room.

4.6 Applications to a central water heating equipment room

The effective test points for a central heating equipment room are selected as follows (see Figure 9).

Locations for the main temperature test points of a central water heating system include the outer shell of the water heater, the heat storage tank, the opening of the outlet pipe, the hot water circulation pipe, the return water pipe, *etc*. The conventional design and construction method is to implant the thermometer to measure the temperature. However, administrators must go into the equipment room in person and record the values visually. Furthermore, the temperature status and alarms of the overall system are often not included in the management of the central monitoring system. In a few cases, thermocouple probes are used for temperature sensing, but the construction method used often involves implanting the probes inside of the pipe. The disadvantages of this method are similar to the problems with the central air conditioning system mentioned above. There are two effective solutions. One is to use a temperature sensor for large areas on the water heater or water tank (as detailed in Figure 4(a)), and the other is to use a “beam tube buckle-type” temperature sensor (as detailed in Figure 4(f)) for all pipes. This real-time temperature sensor can display the values and produce an alarm on-site. And it also can transmit the data to the central monitoring center, if needed.

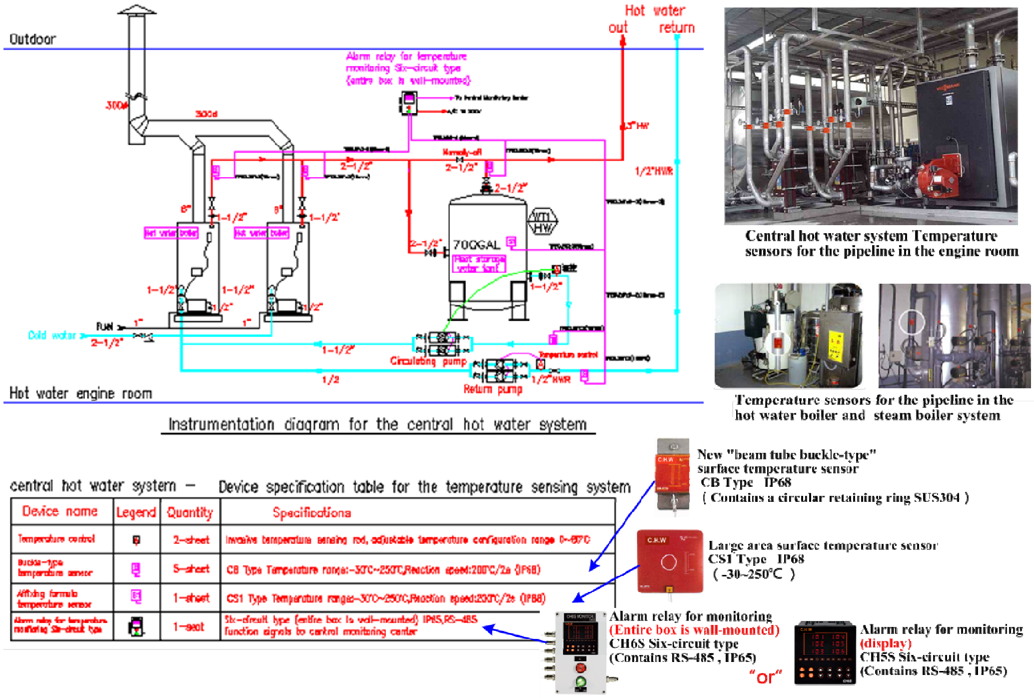
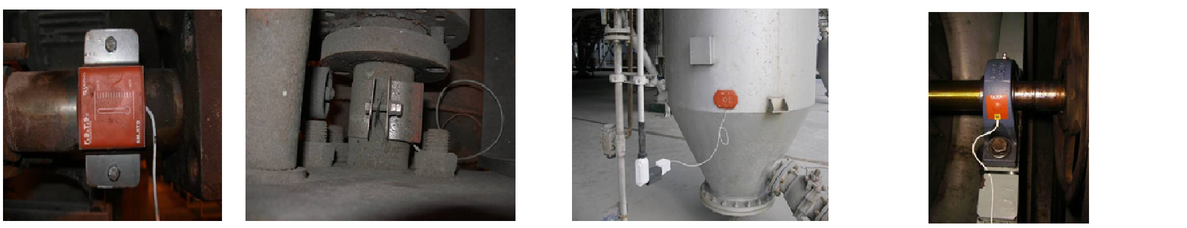


Figure 9. Reference for temperature test points for devices in a central water heating Equipment room.

4.7 Applications to other electromechanical equipment

In all related industries category, the considerations of a proper environment for operating an electromechanical system to have the device perform continuously its required function in quality should include equipment life cycle, effectively manage its temperature. at A routine check of normal system operations is a key to secure the standard values of a device. Figure 10 shows cases in which FSTS is used in other industries.



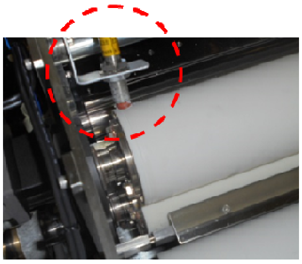
Tubular-type - Abnormal temperature detection for long-range sootblower angular valve in the power plant

Large area - abnormal temperature detection for ash conveyor

Small area - MRT vehicle body Bearing abnormal temperature detection

Communications room/cabinet temperature and humidity sensing monitor

Small area – temperature detection for UPS capacitor Banks



Contact - temperature detection for Rubber rollers in electronics factories

Figure 10. Images of temperature sensing devices on related electromechanical devices.

4.8 Application to a remote temperature monitoring system via wired communication

Earlier, we discussed how to set up test points for various electromechanical devices operating in the field and converse a measured physical values to current temperature values and show the values on a digital display screen. A central temperature monitoring system for an overall electromechanical device must consist of the following parts: sensing components in the field, wiring, an electrical relay for the temperature monitor (or convertor), hubs, and interface of circuit converters for RS-485 and RS-232 in the remote central monitoring center, as well as graphic control software program, monitoring computers, *etc*.

In latest wired communications technology, a Central Monitoring System (CMS) [13] is currently the major Programmable Logic Device (PLA). Its architecture typically has three main frameworks, which depends on different environmental applications of controllers. Direct Digital Control (DDC) is mainly applied to monitor temperature and humidity at multi-points in general air conditioners. Other electromechanical devices generally use a PLC, or use a Remote Terminal Unit (RTU), when the areas are widespread and the stability of the alternative wired communication is considered. A PLC and an RTU can replace each other as they can be applied differently depending on the location and application considerations.

The RS-485 interface is currently used in accordance with the general practices of industrial control. The related products introduced in this paper are all equipped with a RS-485 communication interface, and they all have MOBUS RTU format with remote transmission capabilities. Figure 11 shows the connections between a central monitoring computer and various temperature sensors. For the central computer, regardless of whether the system architecture is wired or wireless, the software programs in the central monitoring computer for the central monitoring system should contain the following parts: (1) a data transmission format at the application layer; (2) a graphical monitoring system, as shown in Figure 12; (3) an alarm system; (4) a program with historical records; (5) a program producing graphical plots, as shown in Figure 12.

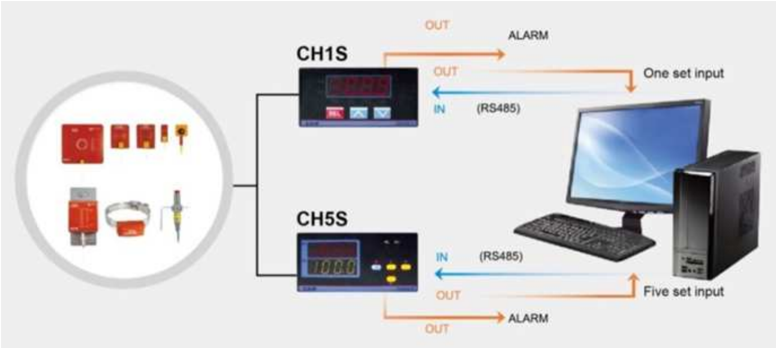


Figure 11. Connections between a central monitoring computer and various Temperature sensors.

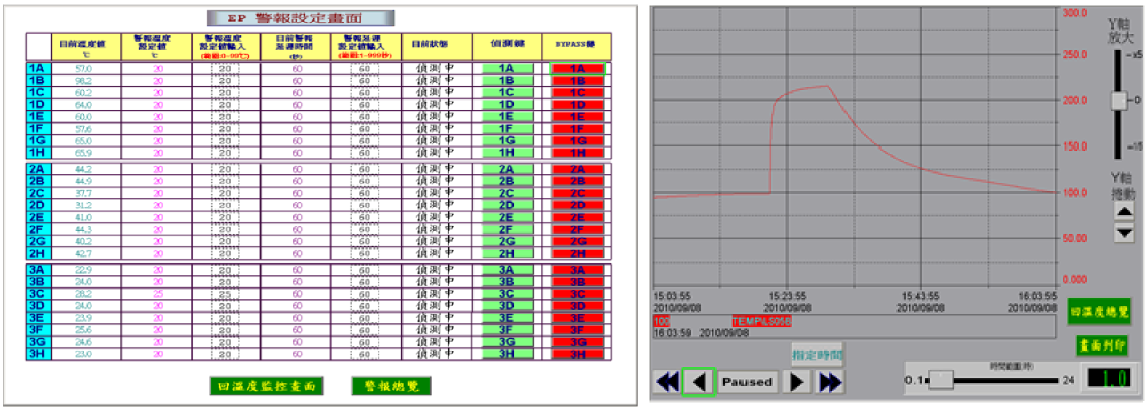


Figure 12. Images of central monitoring, graphical monitoring, and system plots.

5. Measurement Results and Discussion

In previous sections, we covered the new FSTS, including the principles, structure, size, and system designs for the types of places in which the FSTS can be used. Below are some operational results we perform practical temperature measurements, in different types of environments for different devices, using the new FSTS, the conventional temperature-sensing rod and infrared temperature-sensing gun, respectively. The disadvantages and advantages are compared in Table 3.We can see that the new adhesive temperature sensor is relatively superior in terms of properties, materials, structure, and specifications.

Table 3. Comparing a conventional stainless steel temperature-sensing rod with An adhesive temperature sensor.

Name and details	**Conventional Temperature Sensing Rod**	**New FSTS**
Construction attachment	Must have open holes to interlock. (will to damage the pipe structure.	Can be adhered freely (easy construction)

	Not an easy construction.)	
Reaction Speed	Slow reaction (Heat is only conducted via radiation of the pipe material)	Fast reaction, can be up to 200 ℃/2 sec (Surface conduction)
Voltage tolerance	Metal shell is an electrical conductor (cannot be used)	Can tolerate5-kV voltage (non-conductive)
Measurement of charged body	Rod-type, cannot be used.	Can be adhered directly. Can withstand 5-kV (non-conductive). Can be adhered to a heat sink when the charged body is greater than 5 kV.
Shape of the measured object	Unable to measure irregularly shaped objects (such as a cylinder)	Soft and flexible, can measure a variety of irregularly shaped objects

In addition, comparing the properties of the metal pipe in terms of the construction methods, we can clearly see from Figures 13 and 14 that the new FSTS is a superior temperature sensor that can be used in electromechanical devices.

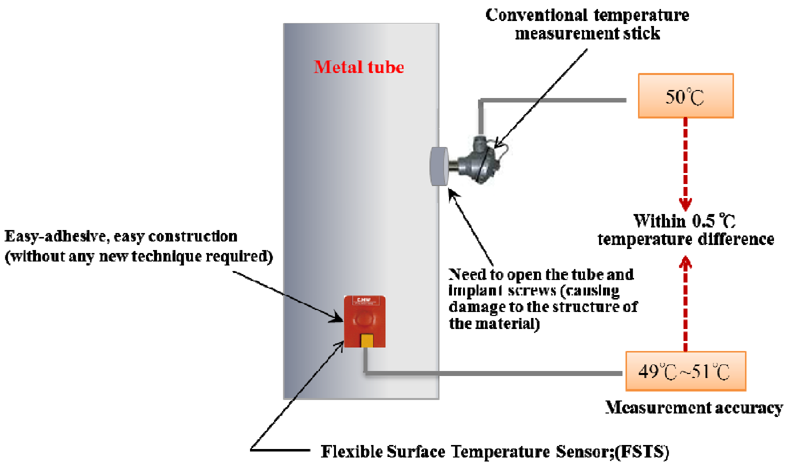


Figure 13. Comparing a conventional stainless steel temperature-sensing rod with the new FSTS in terms of construction methods.

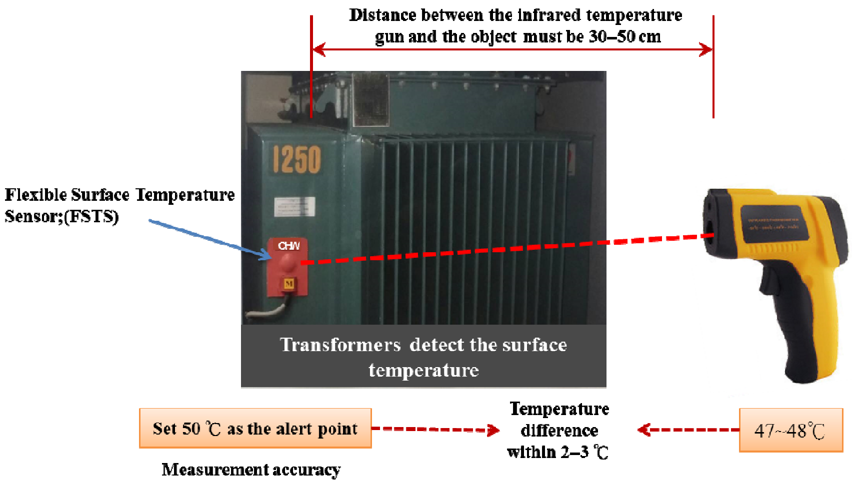


Figure 14. Comparing a conventional infrared temperature-sensing gun with the new FSTS in terms of practical temperature measurements.

6. Conclusion

The temperature sensor has been widely applied in modern life, equipments in both field of home and industrial, agricultural, food, medical hygiene. This demonstrates how important temperature sensors are to ensure that a device can be operated stably. Since different locations have different requirements for temperature monitoring, the sensors that can be selected will also be different.

This paper proposed an innovative and practical technology application, and also proposed the use of a Flexible Surface Temperature Sensor to sense abnormal temperatures in electromechanical system devices. From an analysis of product performance, practical applications of the technology, operational design and application in the field, and application of remote monitoring system designs, the case studies provided all demonstrated FSTS to be worthy of further analysis.

Modern technology advances further every day and continue to be improved. For a long time, electromechanical unit designs generally could not provide optimal countermeasures to solve the problem of abnormal temperatures in electromechanical system devices. Thus, the authors of this paper utilized their years of practical working experience and performed various systematic analyses, presented in Chapter IV of this paper. It is hoped that this research can provide considerable value in terms of reference and assistance.

(For the Flexible Surface Temperature Sensor in this paper, the product has obtained a patent from the R.O.C. Ministry of Economic Affairs Intellectual Property Office (Patent No.: New Model No.: *M331662*) and a patent from the People's Republic of China State Intellectual Property Office (Patent No.: *ZL2010202939219*).)

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