Implementation of an electrical network monitoring system based on a non-contact temperature sensor and a current sensor based on the Hall effect

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Abstract. The safety of people and the environment is an important issue at any enterprise. One of the main threats in the production environment is the occurrence of fire and the failure of electrical equipment. Fire alarm systems provide immediate evacuation of people and fight the source of fire. The article describes implementation of an electrical circuit system based on a non-contact temperature sensor and a Hall effect current sensor, which is necessary for fire prevention. The experiment showed that the data obtained is sufficient for timely change of current level in the conductors and prevention of emergency situation. The article consists of an introduction, theoretical information about the temperature sensor and current sensor based on the Hall effect, description of Bluetooth Mesh network topology, development of a wireless network diagram for the electrical network monitoring system, conclusion.

1 Introduction

One of the main ways to reduce damage from fires is the use of fire alarms; however, their disadvantage is that they are triggered immediately at the time of the fire, while there are systems that prevent its occurrence. there are sensors of temperature and short circuit in electric networks, their use in the domestic conditions and in the production could significantly reduce the number of fires, since according to statistics for 2020 in Russia, 34% of fires occur due to breakdowns in the electric networks and malfunction of electrical equipment [1]. No less damage is caused by fires in the Arctic, in particular in various fields and along pipelines, since this area is less developed by man, and, as a result, it is not always possible to prevent fires quickly. In addition, mining companies suffer significant losses due to equipment failures. Also, in the risk zone there are warehouses and tanks with various types of burning fuel [2]. A fire in such areas can lead to severe explosions or critical environmental pollution [3].

The purpose of the work is to analyze the operation of non-contact temperature sensor and Hall sensor and draw conclusions about the possibility of their joint use in a single electrical network monitoring system.

To achieve the goal, we will analyze the operation of a non-contact temperature sensor, consider options for using a Hall sensor to track the limit values of the current; develop a wireless communication scheme for a unified system for monitoring faults in an electrical network using a distributed Bluetooth Mesh network [4].

2 Non-constact temperature sensor

Non-constact temperature sensors are designed to monitor the temperature of remote or hard-to-reach objects. No need to touch allows non-contact sensors to measure very large temperature ranges.

Currently, non-constact temperature sensors are widely used in various security systems and alarm systems. The main advantage of such sensors is that they act directionally and do not require attachment directly to the monitored object. Also, there are devices that determine the temperature not only in a given direction, but also by sectors, which can be used in electronic intelligence and in everyday life, it is possible to implement the function of reading readings using modern laser systems [5, 6]. We suggest using sensors to detect faults in electrical circuit elements.

We use Omron D6T thermal sensor. Omron D6T MEMS thermal sensor is an ultra-sensitive infrared temperature sensor that makes full use of Omron's proprietary MEMS measurement technology. Since the D6T sensor can also track temperature in space, it can be also used to maintain optimal temperature levels at all times, instantly detecting unusual temperature changes, thereby identifying areas of overheating for early fire prevention [7].

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While standard temperature sensors can only measure temperature at one specific contact point, the D6T can measure the temperature of an entire area without contact.

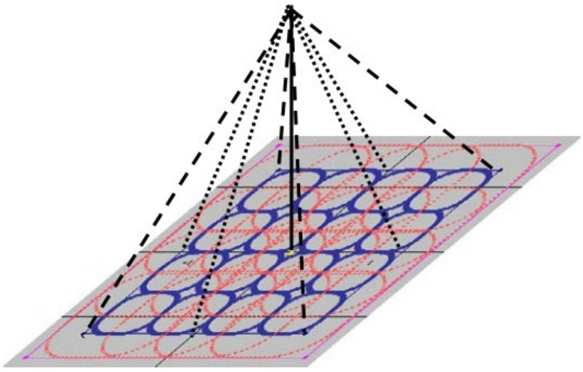

Fig. 1. Temperature measurement with a thermal sensor of the entire surface area.

We take the embedded microcircuit by its surface, and fix the sensor on the cover of the electrical network node. For the selected sensor the field of view is 90°. From this we get that the electrical node must correspond to the following ratio:

$$L \approx S * 0.81,$$

where L – the maximum length of the side of the microcircuit surface;

S – the distance to the sensor.

It can be concluded that the use of the selected sensor for monitoring the temperature on the surface of integrated circuits will be applicable in most nodes of the electrical network.

3 Hall Sensor

Hall-effect sensor is a measuring transducer for measuring the magnitude of a magnetic field.

This is a Hall-effect sensor, the essence of which is that when a conductor with a direct current is placed in a magnetic field, there is a transverse potential difference arises in this conductor, also referred to as the Hall voltage.

The direction of deflection of the electrons in the conductor is perpendicular to the direction of the magnetic field. On different sides of the plate the density of electrons will be different, which will cause a potential difference. This is detected by the Hall sensor.

It took 75 years for the Hall effect to be used in technology, when the production of semiconductor films with the desired properties was established. Hall sensors first appeared in automobiles to measure the angle of the camshaft or crankshaft position to determine the moment of ignition in internal combustion engines.

Later, with the development of microelectronics, it became possible to manufacture a miniature sensor containing everything necessary - a permanent magnet and a chip with a sensitive element. Such a device has a number of undeniable advantages.

Firstly, it is small in size.

Secondly, the electrical signal from the sensor has, according to the terminology of specialists, a rectangular form: when turned on, it immediately gains a definite and constant value and does not have a burst character. This is a big plus for electronic control.

The sensor has other advantages, but let's mention the disadvantages. The main one is inherent to any electronic circuit: the sensor is sensitive to electromagnetic interference arising in the power supply circuit. In addition, the Hall-effect sensor is more expensive than a magnetoelectric sensor and theoretically less reliable, since it contains an electronic circuit, but large-scale production and technological development minimize these factors.

We use the Allegro ACS37612 sensor in our work. It allows AC and DC measurements without the need for an external core or field concentrator shield. It is designed for electrical networks where hundreds of amperes are flowing through a busbar or printed circuit board.

The ACS37612 is available with 120 kHz and 240 kHz bandwidths to minimize response times. Fast response times allow timely detection of critical overcurrents on the electrical network. Ambient operating temperature range from –40°C to 150°C and a high level of ESD protection make it ready to work in harsh conditions [8].

Therefore, the use of the selected magnetic field measurement sensor for monitoring current drops is optimal.

4 Bluetooth Mesh

Bluetooth Mesh is a network topology used to link many-to-many (m: m) devices. The mesh topology available in Bluetooth LE enables creation of large-scale device networks and is ideal for control, monitoring and automation systems where tens, hundreds or thousands of devices need to communicate with each other reliably and securely [9].

5 Development of a monitoring device for an electrical unit

The monitoring device includes:

1. Contactless temperature sensor Omron D6T
2. Hall effect sensor ACS37612
3. Wireless module
4. Microcontroller.

The Pic16F15376 microcontroller by Microchip [10] was chosen for the implementation of our project. The choice was made based on its advantages:

1. Availability on the market
2. Relatively low price on the market
3. High reliability
4. Availability of the necessary periphery.

The PIC16F15376 microcontrollers contain analog, core-independent peripherals and communication peripherals combined with eXtreme Low-Power (XLP) technology for a wide range of general-purpose [11] and low-power applications.

The devices have multiple PWM, multiple communication, temperature and memory functions, such as a memory access section (MAP) to support clients with data protection and bootloader applications, and a device information area (DIA) that stores factory calibration values for improving the accuracy of the temperature sensor.

The contactless temperature sensor supports I2C communication. Let's connect it to the microcontroller using the appropriate inputs.

The selected Hall sensor is connected to one of the analog inputs on the microcontroller.

We will develop software for a microcontroller using the MPLABX IDE development environment. The algorithm of the program is as follows:

1. Collecting data from a contactless temperature sensor
2. Collecting data from the Hall sensor
3. Formatting the received data
4. Transferring data to an external device via the UART interface.

6 Development of a wireless network diagram for an electrical network monitoring system

It is necessary to implement the data transfer between the individual measuring devices, within one of the premises, the room in which the switchboard is located. The peculiarity of the location of the sensors is that some of them may be out of the range of wireless technology. Also, security is an important requirement for the system. Based on this, the use of a mesh topology is optimal.

The NINA-B312 module from u-blox was chosen to create the network. The device has support for the most recent version of Bluetooth v5.0 [13, 14], built-in software that allows to work with mesh topology, and allows you to configure the network using AT commands.

Here is a diagram of the wireless distributed network for the monitoring system (Figure 2).

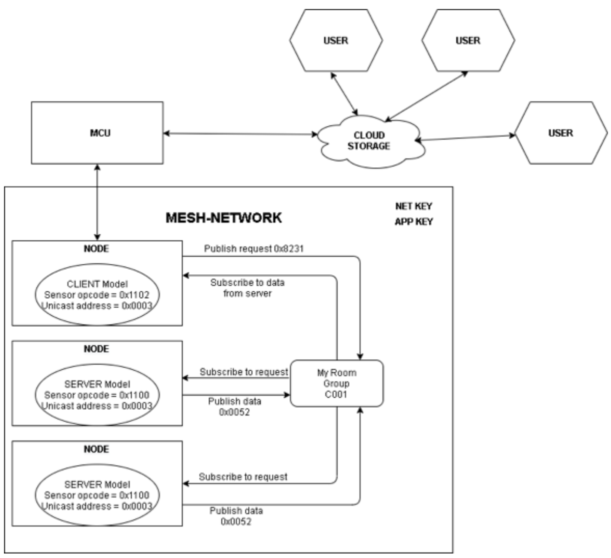

Fig. 2. Diagram of a mesh network of a fault monitoring system in an electrical network for one room

For the convenience of working with the results of measurement, the data from the client via a wireless Wi-Fi network are transmitted to a special cloud storage with its own authorization system.

7 Realization of the experiment

Experimental measurement of temperature and current level in conductors was carried out on an electricity meter. For the visualization of the experiment, a window application for Windows was developed in the Visual Studio development environment in the C# programming language using the ".NET" technology.

The temperature data and data from the Hall-effect sensor are displayed on the main panel in the form of a defined area divided into cells by temperature values and tabular data.

For the experiment, temperature indicators and current values were measured in a cabinet with an electricity meter and automatic switches.

Fig. 3. Object to be measured

The temperature sensor was installed 10 centimeters from the measured area. measurements were carried out in the area where the conductors were connected to the machines and the meter (Figure 4). This area is the most fire-hazardous, as the conductors in it are exposed to air and, therefore, to corrosion.

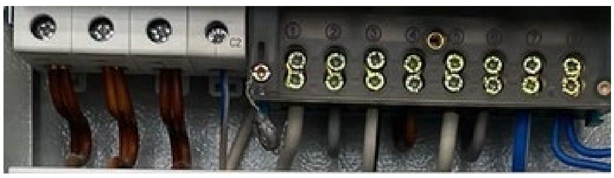

Fig. 4. Measurement area

Current readings were taken alternately in each conductor, which can considered a disadvantage of this system, since one Hall-effect sensor is not capable of measuring several objects simultaneously. In future developments the number of sensors will be equal to the number of measured conductors. The results of the experiment were visualized using the Windows.NET window application developed by us (Figure 5).

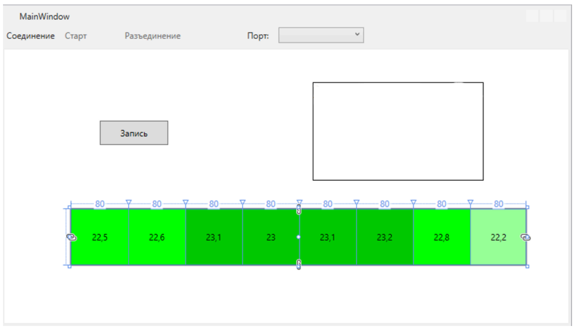

Fig. 5. The results of the experimental measurement of the electric meter

The temperature range was about twenty-three degrees. The current values in the conductors we took coincided with the electric meter readings.

Thus, we can conclude from the readings obtained that the system is operational.

8 Conclusion

The conclusions of this work are as follows:

- The operation of a non-contact temperature sensor was analyzed and it was found that its use will significantly reduce the risks of fire and damage to the electrical network.
- The operation of the Hall-effect sensor was considered andthe most suitable options for working with high currents, as well as with a short response time were chosen.
- A wireless network scheme for communication between monitoring devices using Bluetooth Mesh technology was developed.

When analyzing the operation of a non-contact thermal sensor and current sensor based on the Hall effect and testing them, it was concluded that the system is workable. Implementation of such a system will make it possible to avoid fires and their consequences not only in production or mining, but also in domestic conditions.

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