Implementation of a Monitoring System for an Electrical Network Based on a Contactless Temperature Sensor and a Hall Effect Current Sensor

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***Abstract*— At any enterprise, the issue of human and environmental safety is important. One of the main threats in the production environment is the occurrence of fire and malfunction of electrical equipment. Fire warning systems provide immediate evacuation of people and fight against the source of fire. The article describes an electrical circuit system based on a non-contact temperature sensor and a Hall effect current sensor, which is needed for the warning and prevention of fire. The experiment showed that the data obtained is sufficient for a timely change in the current level in the conductors and to avoid an emergency. The article gives the introduction to the problem, theoretical information about a temperature sensor and a current sensor on the Hall effect, a description of the Bluetooth Mesh network topology, the development of a wireless network diagram for an electrical network monitoring system, and a conclusion on its practical use.**

Keywords*— Security, Wireless, Sensors, hall sensor, Bluetooth, temperature sensor, fire

I. Introduction (*Heading 1*)

One of the main ways to reduce damage from fires is the use of fire alarms, their disadvantage is that they are triggered immediately at the moment of fire, but there are systems that prevent its occurrence. So, for example, there are temperature and short circuit sensors in electrical networks, their use in domestic conditions and in 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 electrical network and malfunctions electrical equipment [1].

Purpose of the work: to analyze the operation of the contactless temperature sensor and Hall sensor and draw conclusions about the possibility of their joint use in a single monitoring system of the electrical network.

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

II. Constactless Temperature Sensor

Constactless temperature sensors are designed to monitor the temperature of remote or hard-to-reach objects. The absence of the need for touching allows proximity sensors to measure very large temperature ranges.

Currently, constactless temperature sensors are widely used in various security systems and alarms. The main advantage of such sensors is that they act in a directional manner and do not require attachment directly to the monitoring object. Also, there are devices that determine the temperature not only in a given direction, but also in sectors, which can be used in electronic intelligence, in everyday life. We suggest using sensors to detect faults in electrical circuit elements.

We use Omron D6T thermal sensor. Omron's D6T MEMS thermal sensors are an ultra-sensitive infrared temperature sensor that fully utilizes Omron's proprietary MEMS measurement technology. Since the D6T sensor can also monitor the temperature in space, it can also be used to constantly maintain an optimal temperature level, instantly detect unusual temperature changes, thereby detecting areas of overheating for early fire prevention [2].

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

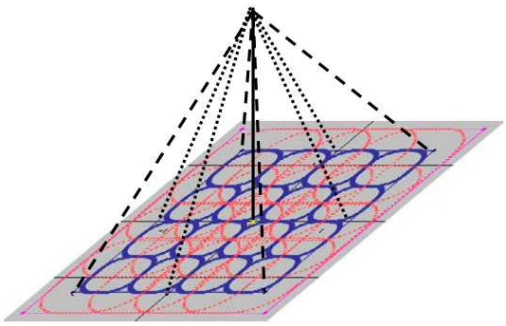

Fig.1. Temperature measurement by a thermal sensor of the entire surface area

We take an integrated microcircuit by the 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 unit must correspond to the following ratio:

$$L \approx S * 0.81,$$

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

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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.

III. Hall Sensor

Hall effect sensor - 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 constant current is placed in a magnetic field, a transverse potential difference arises in this conductor. Also referred to as Hall voltage.

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

The Hall effect in technology could be used only 75 years later, 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, as well as to determine the moment a spark was generated in internal combustion engines.

Later, with the development of microelectronics, it was possible to make a miniature sensor containing everything you need - a permanent magnet and a microcircuit with a sensitive element. Such a device has a number of undeniable advantages.

Firstly, the small size.

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

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

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

The ACS37612 is offered in 120 kHz and 240 kHz bandwidths to minimize response times. Fast response time allows timely detection of critical over currents in the electrical network. An ambient operating temperature range of –40 ° C to 150 ° C and a high level of ESD protection make it ready for harsh environments [3, 4, 5].

Therefore, the use of the selected magnetic field measurement sensor for monitoring current drops is optimal[6].

IV. Bluetooth Mesh

Bluetooth Mesh is a network topology used to establish communications between many-to-many (m: m) devices. The mesh topology available in Bluetooth LE enables large-scale networks of devices and is ideal for control, monitoring and automation systems where tens, hundreds or thousands of devices must reliably and securely communicate with each other [7].

V. 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.

Microchip's Pic16F15376 microcontroller [8] was chosen for the implementation of our project. The choice was made based on its merits:

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 and low-power applications.

Devices have multiple PWM, multiple communication, temperature and memory functions, such as a memory access section (MAP) to support customers 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. Algorithm of the program, as follows:

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

VI. Development of a Wireless Network Diagram for an Electrical Network Monitoring System

It is necessary to implement data transfer between 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 outside the operation of wireless technologies. Also, an important requirement for the system is security. 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 [9, 10], built-in software that allows you to work with mesh topology, and also allows you to configure the network using AT commands.

Let's get a diagram of a wireless distributed network for a monitoring system (Figure 2). For the convenience of working with the measurement results, data from the client is transferred to a special cloud storage with its own authorization system via a wireless Wi-Fi network.

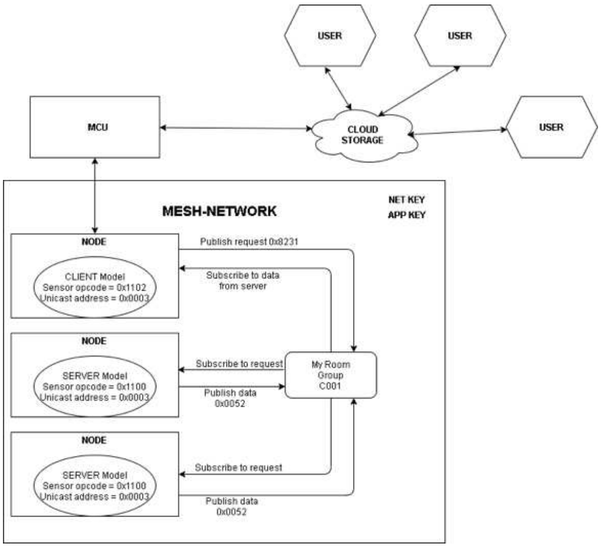

Fig.2. Diagram of a mesh network of a fault monitoring system in an electrical network for one room

VII. Realization of Experiment

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

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

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

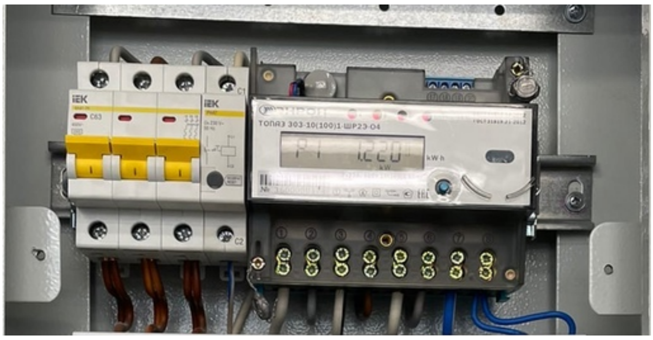

Fig.3. Object for measurement

The temperature sensor was installed 10 centimeters from the measured area. The measurement was carried out in the area of the connection of the conductors with the machines and the meter (Figure 4). This area is the most flammable, as the conductors in it are exposed to air and, therefore, corrosion.

Fig.4. Measurement area

The current readings were taken in turn in each conductor, which can be attributed to the disadvantages of this system, since one Hall effect sensor is not capable of measuring several objects at once. Further development will use the number of sensors equal to the number of measured conductors. The results of the experiment were visualized using the Windows.NET window application we developed (Figure 5).

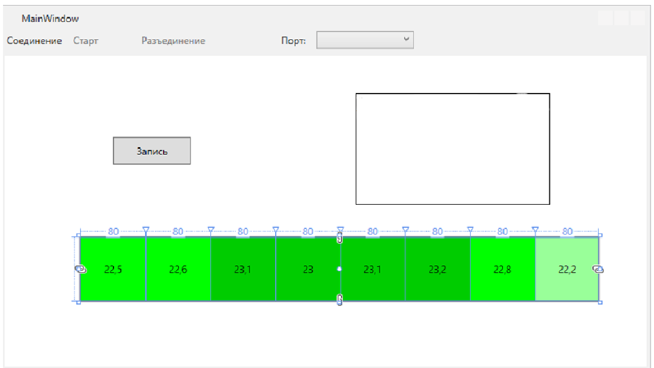

Fig.5. The results of the experimental measurement of the electric meter.

The temperature range was about twenty-three degrees. The values of the current in the conductors taken by us coincided with the readings of the electric meter.

Thus, according to the readings obtained, it can be concluded that the system is operational.

VIII. Conclusion

In conclusion, let us note the conclusions of this work:

- Analyzed the operation of a non-contact temperature sensor and found that its use will significantly reduce the risks of fire and damage in the electrical network;

- Considered the operation of the Hall effect sensor, chose the most suitable option for working with high currents, as well as with a short response time;
- Developed a wireless network scheme for communication between monitoring devices using Bluetooth Mesh technology;

When analyzing the operation of a non-contact temperature sensor and a current sensor based on the Hall effect and testing them, it was concluded that the system is operational. The introduction 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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