The Development of Operation Algorithm of Heat Detector with Variable Response Parameters

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***Abstract* — It has been identified that there are objects where ambient air temperature changes not only as a result of a fire, but also due to the operation of technological equipment and harsh climatic conditions. These changes affect the timing of work for the fire detector. These facilities include boiler rooms, kitchens, dryers, vehicles, etc. The article substantiates the need to develop a heat detector that would change its response parameters and at the same time would not contradict the regulatory requirements for its class. There have been proposed algorithms for the operation of a heat detector which changes the value of the static response temperature and the rate of rise temperature at which it responds. The algorithm of operation analyzes the speed of raising the ambient temperature without information about the operating modes of technological equipment and sets new values of the response based on the analysis.**

***Keywords* — fire alarm system, fire detector, heat detector, rate of rise heat detectors, fixed temperature heat detectors, static response temperature**

I. Introduction

The effective operation of a fire alarm system generally depends on the correct selection and placement of fire detectors (FD), which should ensure a reliable detection of the fire at an early stage of development. When selecting and installing the fire detectors, one must take into account the purpose and category of protected premises; features of technological process; equipment on site; materials that make up the fire load in the control area; directions of possible fire spread; space-planning characteristics of the room; ventilation and heating working process; placement and type of electrical networks, heating devices in a controlled room, etc. In addition, the effective operation of the fire alarm system depends on how effectively the algorithms of the FD operation are developed and programmed, what kind of response criteria are chosen as the basis, and how these criteria are met, how the seasonal, daily or hourly change in the response threshold of the FD is implemented. Creating a FD algorithm that allows early detection of a fire and error-free working process is considered a difficult task. The basis for the problem solution is in the compromise between the time of fire detection and the probability of false alarm. The greater sensitivity of the FD to the controlled signs of fire also means the greater likelihood of false alarm.

The working algorithm for the block of fuzzy correction of intelligent point multi-sensor FD with heat and smoke sensors is developed in the work [1]. It allows you to detect a fire at an early stage of development based on the established forms and parameters of input and output membership functions and illegible rules. Using a neural network, an intelligent detector algorithm has been developed that takes into account various environmental parameters, including temperature, to detect a fire [2]. In work [3] mathematical model is developed to optimize the time of response of the heat detector for the use in long and narrow rooms.

It is believed that heat detector (Fig. 1) has a higher inertia compared to smoke detectors and flame detectors. However, they are most effective in the case where a significant fire capacity with intensive heat release at the initial stage is foreseen, as well as when other types of detectors cannot be used because there are factors that can lead to their false positives. For example, due to the low smoke-forming capacity of combustible materials; when the spread of smoke is difficult; when there is a high concentration of any aerosol particles in the air that have nothing to do with the combustion process; because of the dustiness of the premises, etc. In general, heat detectors have a greater resistance to adverse environmental conditions than other types.

Fig. 1. The HI720 is a combination of fixed temperature and rate-of-rise heat detector SIEMENS

Heat detectors are rate of rise detectors and fixed temperature detectors (static detectors). Selecting the type of heat detector that you want to install at the facility is a hard task. For this purpose it is necessary to consider the class of detectors with values of their typical and maximum application temperature, minimum and maximum static response temperature, in accordance with the requirements of BS EN 54-5:2017 [4]. Clause 6.4.3 Technical Specification CEN / TS 54-14:2018 [5] sets out the requirements that the designer must follow in the process of selecting heat detector. Rate of rise heat detectors are more efficient than normal fixed temperature heat detectors. They are more suitable for use when the ambient temperature is low. In some cases, they can compete for efficiency with the smoke detectors. However, rate of rise heat detectors are more sensitive and can produce false alarms with significant temperature fluctuations due to technological processes and climatic conditions.

False alarms from rate of rise heat detectors may also be caused by a rapid temperature increase to normal room conditions following exposure to low temperatures [4]. Such a sequence may occur, for instance, in a loading bay of vehicles, airplane equipped with large doors to the outside: in winter, when the door is opened, the detectors are cooled, and after the door is closed there is a sharp rise in temperature. The detectors without a rate of rise response are better not to use.

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In [6-8], the display time of detectors was determined, depending on different types of detectors and different test conditions. The response time was estimated by the response time index and depended on the type of detector selected and its location. The dynamic characteristics of heat detectors in the time and frequency domains are determined on the basis of the transfer function [9].

There are facilities where the choice of heat detectors requires taking into account the rate of the ambient temperature change while remaining within the range of temperatures of use, not only from the effects of climatic conditions but also from the impact of process equipment. These include kitchens, boiler rooms, glass-roofed rooms, metal-coated attics and more. It is forbidden to install rate of rise heat detectors in such premises.

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According to statistics, a significant number of fires occur on vehicles [10]. They can last for several hours and can be operated in different temperature conditions. Statistical studies show that about two-thirds of vehicle fires originate from the engine compartment [11-13]. During the in-depth studies presented in [14-16], it was found out that the correct operation of both heat and smoke detectors is significantly dependent on their location and movement of air flows in the engine compartment, and the detection of fire at the early stage of development is problematical.

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II. Problem statement

The purpose of the work is to develop and study the algorithm of operation of the heat detector, which, depending on the environmental conditions, would automatically change the value of the static response temperature and the value of the rate of rise temperature at which it responds. Thus, this algorithm will reduce the time of fire detection. Such detectors can be used in facilities where the ambient temperature changes very quickly in a short time due to the working process, as well as in facilities where the temperature depends on the rapid change of climatic conditions, for example, in non-heating rooms, cargo compartments of vehicles, glass-roofed rooms, metal-coated attics, etc.

III. Solving the problem

As a result of the industrial development of microprocessor technologies, there are fundamentally new ways of processing information of FD. They contain a microprocessor with their own non-volatile memory. Since the sensing elements form analog signals, and the microprocessor works with signals in digital form, the design of the FD includes analog-to-digital converters. The algorithm is programmed in the microcontroller. It manages the measurement process and processes the results, using a modern mathematical apparatus (algebra of logic, indistinct logic), on the basis of which it decides on the presence of fire.

The use of microprocessors in the detectors made it possible to implement any algorithm of operation without changing the elemental base, i.e. it simplified the process of implementation for the developed algorithm of operation.

We will develop an operation algorithm for the heat detector, which changes the value of the static response temperature and the value of the rate of rise temperature at which it responds. This algorithm will allow to take into account the change in ambient temperature not only from the influence of climatic conditions, but also from the influence of technological equipment. The block diagram of the developed algorithm of heat detector operation is shown in Fig. 2.

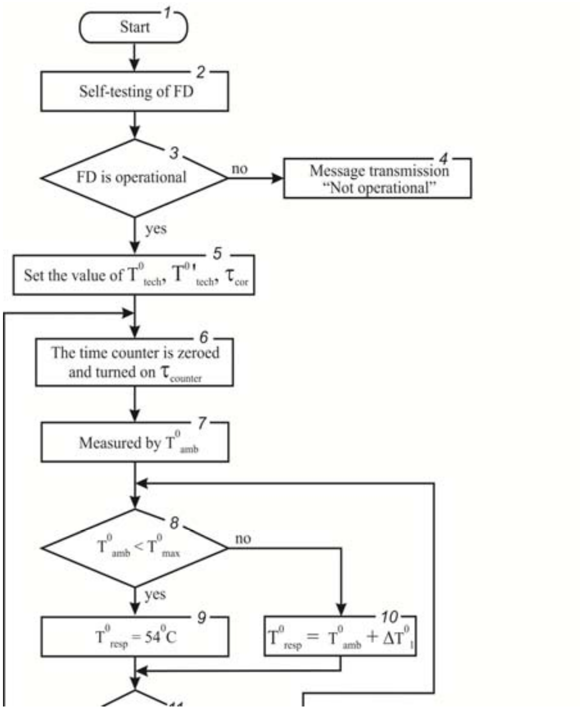

Fig. 2. Algorithm flowchart of heat detector operation with variable operating parameters

At this stage, it is also possible to implement an algorithm that will change the class of heat detector for which the value of $T°_{resp}$, is already known, according to BS EN 54-5: 2017 [4]. That is, $T°_{resp}$ will be known in advance and will vary step by step depending on the operating conditions. Part of this algorithm is shown in Fig. 2. This is where the transition from class A2 to class B occurs, and if the condition is not fulfilled $T°_{amb} < 65°C$, then to class C.

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Fig. 3. Part of the operation algorithm of the fire detector, which changes its class

In block 11, the ambient temperature of the object is compared with the maximum temperature that may be on the object $T^\circ_{amb} < T^\circ_{tech} + \Delta T_2^\circ$ (where $\Delta T_2^\circ < \Delta T_1$ and can be, for example, the same 4 BS which are indicated in BS EN 54-5: 2017 [4]. If $T^\circ_{amb} < T^\circ_{tech} + \Delta T_2^\circ$, a "Fire" signal is generated at the output of the heat detector. If not, then the ambient temperature value of the object is again measured and the rate of its rise is calculated (blocks 12, 13). In block 14, the value of the rate of rise temperature of the medium $T^{\circ\prime}_{amb}$ is compared with the value of the rate of rise temperature $T^{\circ\prime}_{спр}$, , at which the heat detector responds, for example $T^{\circ\prime}_{resp}$ = 8°C/min. If $T^{\circ\prime}_{amb} < T^{\circ\prime}_{resp}$, it means that the process equipment is not working and T°_{amb} is changing due to the impact of the climate. In block 15, the measured value of T°_{amb} and T°_{resp}.

IV. Implementation Model in MATLAB Simulink

The model of operation algorithm of the heat detector with variable response parameters is developed on the basis of the block diagram shown in Fig. 2 and implemented in the MATLAB Simulink software. The developed model is presented in Fig. 4.

Fig. 4. Algorithm model of heat FD operation in MATLAB Simulink

In order to make sure that the proposed operation algorithm of the heat detector with variable response parameters works correctly, a number of different cases can be simulated. Since heat detector does not distinguish the reasons for a change in the ambient temperature, we investigate different cases of temperature change.

Case 1. We simulate a situation where the temperature at the installation site of the heat detector is equal to T° = 25ºC, and at a time t = 1 min there is an increase in temperature due to the fire, with a the rate of rise temperature of $T^{\circ\prime}$ = 6ºC/min, which is lower than the rate of rise response temperature of detector $T^{\circ\prime}$ = 8ºC/min. The heat detector operates as the fixed temperature heat detector. The simulation results are shown in Fig. 5, with the following symbols: curve 1 – ambient temperature at the object (input signal acting on the heat detector); curve 2 – the rate of rise temperature $T^{\circ\prime}$; curve 3 – heat detector output signal corresponding to logic "0" – the heat detector is in standby mode, to logic "1" – FD is in "Fire" mode. When the room temperature reaches a minimum static response temperature of 54 ºC (t = 5.8 min), the heat detector will go into "Fire" mode. The heat detector operates according to the algorithm in cyclic mode (blocks 12-16) and does not go to block 17 (Fig. 2).

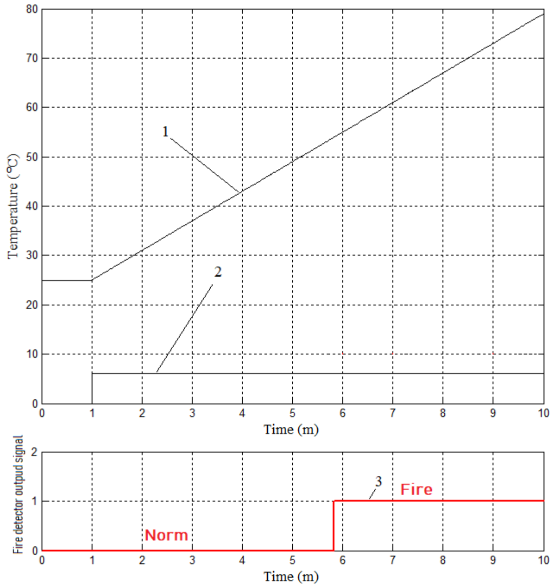

Fig. 5. Simulation results of heat detector operation when the temperature changes due to the fire: curve 1 - ambient temperature T°_{amb}; curve 2 - the rate of rise temperature $T^{\circ\prime}$; curve 3 - the output signal of the heat detector.

Case 2. Let us investigate how the heat detector will work if the ambient temperature changes due to the operation of technological equipment. The simulation results are shown in Fig. 6.

Fig. 6. Simulation results of the heat detector operation when the temperature changes due to the operation of technological equipment: curve 1 - ambient temperature T°_{amb}; curve 2 - the rate of rise temperature $T^{\circ\prime}$; curve 3 - the output signal of the heat detector.

Case 3. Let us ivestigate how the heat detector will work if the ambient temperature changes due to the fire at a rate of rise temperature $T^{\circ\prime}$ = 10ºC/min. The simulation results are shown in Fig. 7.

Fig. 7. Simulation results of heat detector operation, when the temperature changes due to the fire, the heat detector operates at the static response temperature: curve 1 - ambient temperature T°_{amb}; curve 2 - the rate of rise temperature $T^{\circ\prime}$; curve 3 - the output signal of the heat detector.

Case 4. Let us investigate how the heat detector will work if the ambient temperature changes with the rate of rise temperature $T^{\circ\prime}$ = 14ºC/min. The simulation results are shown in Fig. 8.

Fig. 8. Simulation results of the operation of the heat detector, when the temperature changes due to the fire, the heat detector operates at a rate of temperature rise: curve 1 - ambient temperature T°_{amb}; curve 2 - the rate of rise temperature $T^{\circ\prime}$; curve 3 - the output signal of the heat detector.

V. Conclusions

1. The timing of ignition detection and the likelihood of the heat detectors false alarms from third-party sources are significantly influenced by the conditions in which they are operated. In addition, the effective operation of the heat

detectors depends on how effectively the algorithms of its operation are developed and programmed, what kind of response criteria are chosen as the basis, and how these criteria are met, how the hourly, daily or seasonal change in the response threshold of the heat detectors is implemented. An algorithm for the operation of a heat detector has been developed, which changes the value of the static response temperature and the rate of rise temperature at which it responds. These values change on the basis of the analysis of the ambient temperature change rate without information on the operating modes of technological equipment.

2. The proposed operation algorithm of the heat detector with variable response parameters has been implemented in the MATLAB Simulink software. The simulation results have confirmed the correctness of the decisions made.

3. The heat detector with variable response parameters can be used to protect objects that need to take into account the change in ambient temperature and its rate of rise not only due to sudden changes in climatic conditions, but also due to the operation of technological equipment.

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