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SMOKE AND HEAT DETECTORS ARRANGEMENT IN HALLWAYS

Abstract: *Fire protection systems present very complex real time systems that comprehend many different parts. Fire detectors present one of those parts. Fire detectors could be divided on several different ways depended on criteria. Very frequently used detectors in many fire protection systems were heat and smoke detectors. Their main role is to detect fire at early stage. Their number and arrangement in object is strictly regulated by proper standards. For some cases, there were certain differences between standards. This paper has written to show the potential arrangement of smoke and heat detectors in object with hallways realized by simulation in PyroSim 2012 simulator.*

Key words: detector, arrangement, simulation.

INTRODUCTION

The design of adequate fire system presents one of the most important tasks in objects design. It is very complex and responsible task that depends from many different factors, such as object purpose, object geographic location, nature and human surrounding of the object and similar. The main role of every fire protection system is the detection of fire at the early stage in order to protect and safe human lives and material properties. That implies that every part of fire protection system must working and functioning correctly and accurate. But, even with the strict respect of valid standards and regulates, the unpredictable situations with unpredictable fire development and very often, with human victims, could be occurred. This shows that fire protection systems, with all theirs parts, have to be constantly improved, in technical sense.

Fire protection system consists of many different parts, where the one of the most important parts is detector. This term "detector" is very frequently equalled with term sensor, but, many literatures, for example Anglo-Saxon, consider that detector presents wider concept than sensor and it comprises three parts: sensor part, converter part and part for signal conditioning (setting the amplification, filtering and normalization of the signal). The detector or sensor term doesn't mean the presence of the energy source for its functioning. Fire sensors could be divided on different ways and in dependence of different criteria (for example, according to activation way, according to work principle, according to response way and similar).

Very important task in fire protection is to define the correct and enough number of fire detectors for every supervised surface and precise determine their positions. There are more standards that treat this scope, such as: BS (British Standard), NFPA (National Fire Protection Association), НПБ 88-2001 (*Нормы пожарной безопасности*), DIN VDE 0833-2 and other.

In the ideal case, the needed number of fire detectors and theirs arrangement could be realized very simply: it is needed to divide supervised area with detector`s supervised area. But, in real, there are many other factors that could have great influence on fire detectors arrangement and number, such as shape and slope of the object`s roof, detectors distance from electric installation, the presence of barriers, potential usage of ventilations and air conditions devices during work time and similar. The most important thing is that fire detectors arrangement for every room or object must detect fire at early stage without appearances of false alarms. Of course, there are special cases for fire detectors arrangement that demand different approach and modifications.

Stairs present very interesting special case for fire detectors arrangement and decline from elementary regulates according to room's surface and height. The general rule implies that at least one fire detector should be positioned on stairs, right on the last floor`s roof. This rule is not valid unless there are presences of separations by doors between floors. In that case, the detectors are positioned on the floor in front of those doors. The detectors are positioned with arrangement that one detector is positioned on each three floors if the stairs height is bigger than 12 m and if there are no obstacles.

The distances of fire detectors from walls, furniture, stuff and many similar obstacles must not be less than 0.5 m unless in cases for hallways or object`s parts with width less than 1 m. If the furniture height in the room is less than 30 cm from the floor, they should be treated as septum walls because they stop smoke propagation.

In the passages, hallways and similar spaces with the width less than 3 m, distances between detectors could be 10 m, for heat detectors and 5 m, for smoke detectors. Also, one very important thing is, in the case with hallways crosses, one detector must be positioned at the cross place, related to the fact that maximal covering surfaces of detector shouldn't be transcended.

In the hallways and similar narrow rooms, the smoke spreading is directed which enables bigger distance between detectors, with the rule that dimension of supervised surface must be the same. That means that in the rooms with the width less or equal with the half of the distance (0.5 *S*), distance between detectors could be increased up to relation of $S_{max}=1.6\sqrt{A_m}$, what is presented on figure 1 and 2.

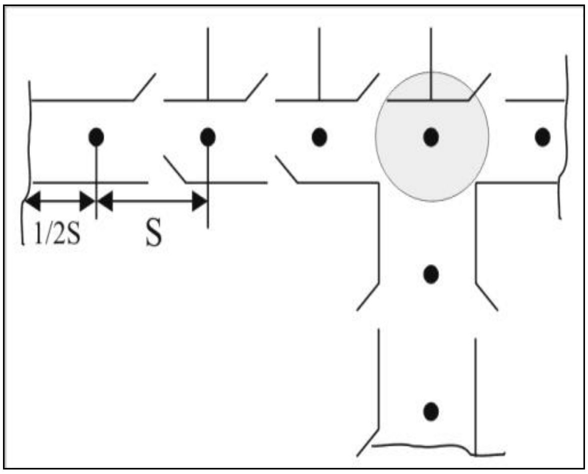

Figure 1. *The rules for fire detectors arrangement in hallways (figure source: Blagojević, Đ. M.: Alarm systems)*

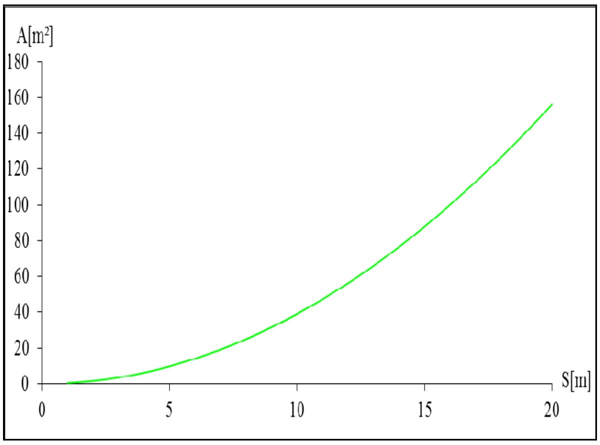

Figure 2. *Maximal distance between detectors in hallway (figure source: Blagojević, Đ. M.: Alarm systems)*

In some western countries standards, (for example, in British standards) the term for hallway (narrow rooms) is related for width of 5 m, so the rule for detector`s installation in this case is different. For hallways and corridors with length less than 5 m, if all other neighbour rooms are protected with detectors, the half of difference from 5 m and real hallway width is added on maximal allowed distance. Maximal distances between detectors in hallway according to the British standard are presented on figure 3 [1], [8], [9], [11].

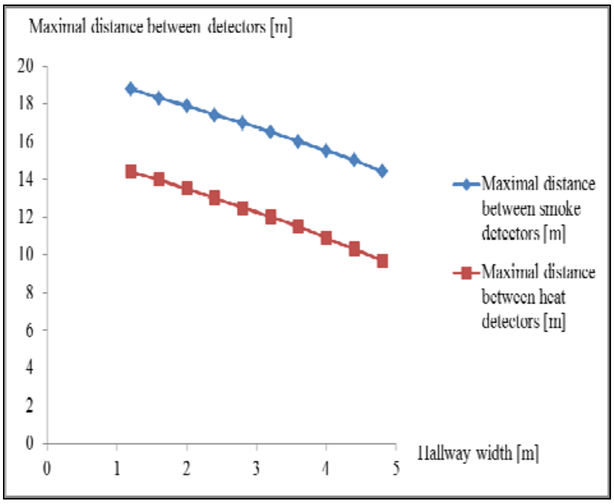

Figure 3. *Maximal distance between detectors in hallways*

SIMULATION MODEL

Simulation model for this paper was created in PyroSim software, version 2012. This software presents a power graphical user interface for the Fire Dynamics Simulator (FDS). FDS models can predict smoke, temperature, carbon monoxide, and other substances during fires that enables analyze under different fire situations and scenarios [2]. This software has many great possibilities and present very important engineering tool in fire protection systems design. One of the most important possibilities of this software is that every fire scenario could be analysed and simulated without any endanger of human lives and material properties.

Simulation model used for this purpose implied object with dimensions 38.3 m x 28.51 m x 3.2 m. The object had 15 different rooms with three long hallways. Walls of the object were from concrete with thickness of 0.2 m. There were 25 cupboards with different dimensions (width and height) made from oak wood and pine wood positioned in rooms. Also, there were 8 desks and 4 chairs made by plywood and metal parts positioned in the rooms. These objects were not visible on every figure because of HIDE function. The fire source was modelled as burner with dimensions of 0.5 m x 0.5 m and HRR (Heat release rate per area) of 450 kW/m^2. The burner’s positions were, for the first case, in the small room at the cupboard (marked on figure 1) while for the second case burner`s position were in the room near the object`s entrance, also at the cupboard (marked on figure 2).

2D object simulation model and 3D object simulation model in Pyrosim with marked burner`s positions and arrangement of heat and smoke detectors are presented on figures 4 and 5 [1], [7], [10], [12].

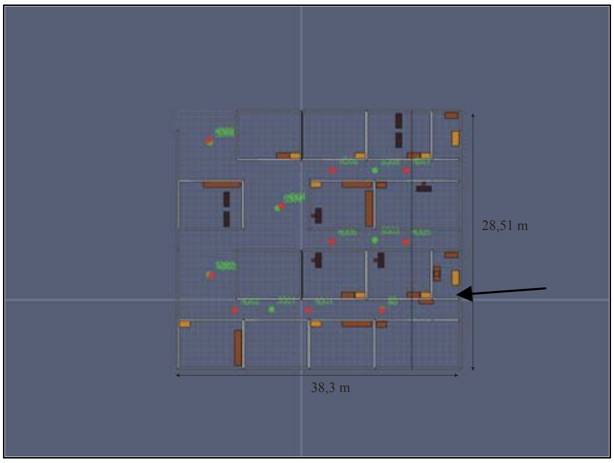

Figure 4. *2D object simulation model in Pyrosim 2012 with marked burner`s position and heat and smoke detectors arrangement*

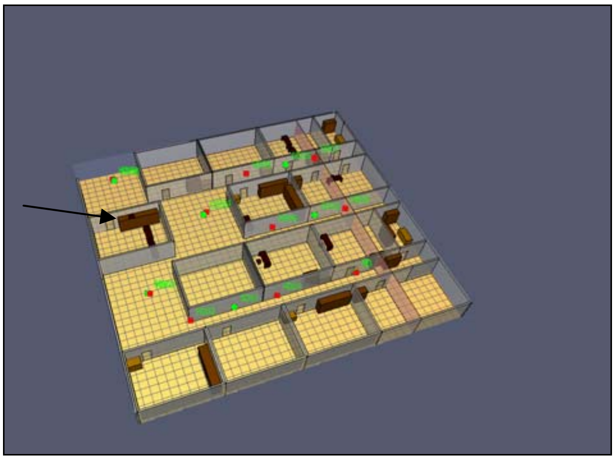

Figure 5. *3D object simulation model in Pyrosim 2012 with marked burner`s position and heat and smoke detectors arrangement*

FIRE SIMULATION AND SIMULATION RESULTS

The simulations were realized on laptop Lenovo B51-30-80LK00H6YA with Intel Pentium N3700 1.6 GHz (2.4 GHz), four cores, TDP 6W, 4GB of DDR3L memory at 1600MHz). The simulation time was set on 300 seconds for every simulation. The durations of complete simulations on noted laptop were about 22 hours, average. The simulation duration depends from many different factors, especially from simulation model complexity and mesh cells dimensions.

Realized simulation results for both cases in form of snapshots are presented on figures from 6 to 8, for the first case, and on figures from 9 to 11 for the second case.

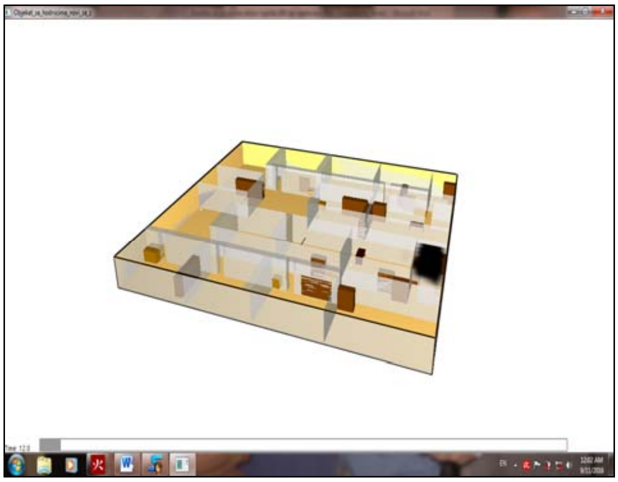

Figure 6. *The presentation of the potential fire propagation after 12 seconds for the first case*

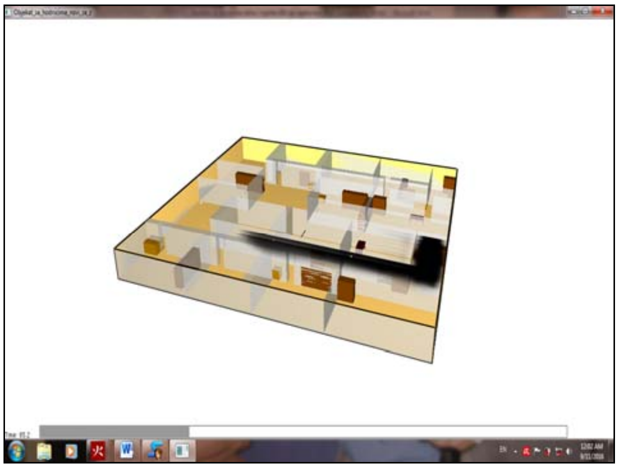

Figure 7. *The presentation of the potential fire propagation after 85.2 seconds for the first case*

Figure 8. *The presentation of the potential fire propagation after 298.8 seconds for the first case*

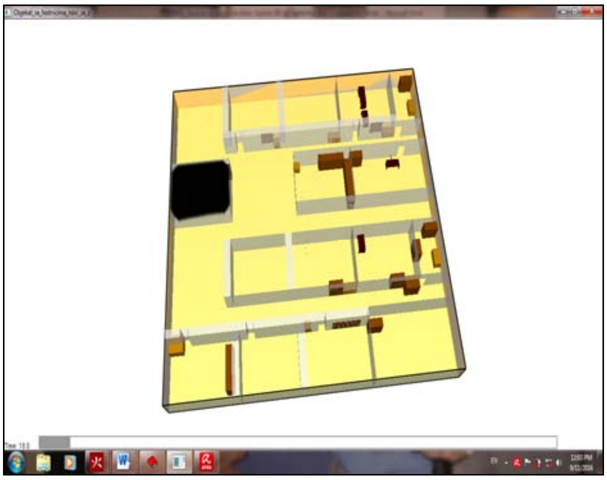

Figure 9. *The presentation of the potential fire propagation after 18 seconds for the second case*

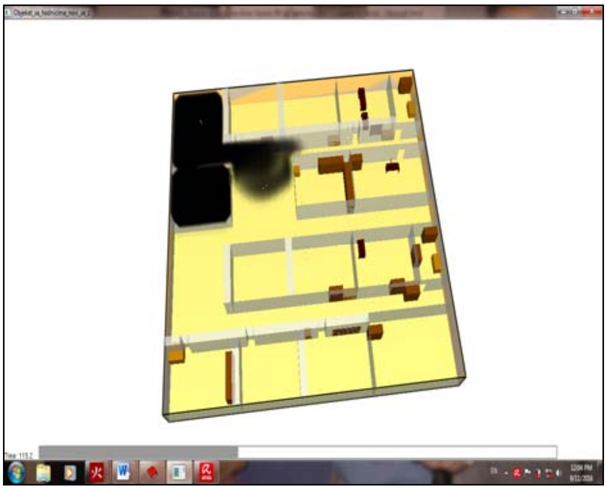

Figure 10. *The presentation of the potential fire propagation after 115.2 seconds for the second case*

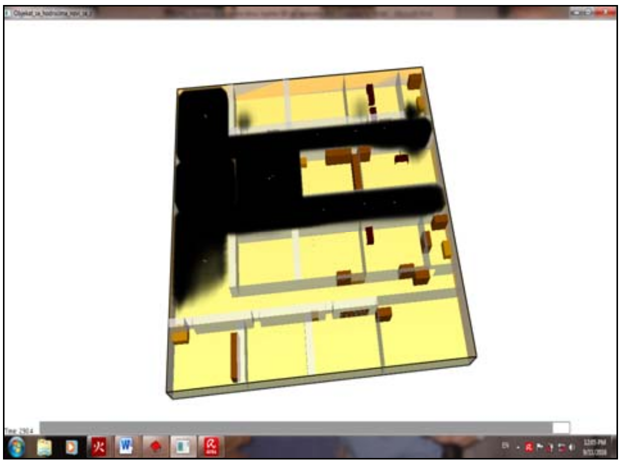

Figure 11. *The presentation of the potential fire propagation after 290.4 seconds for the second case*

Realized simulation results for the first case in form of diagrams, as examples for the nearest and farthest smoke and heat detector, are presented on figures from 12 to 15, because of the limit size of this paper. The complete numbers of diagrams for both cases were 36, what significant exceeded paper size.

It is also important to note that the reaction temperature for heat detectors was 75 °C and the response time index (RTI) was 100 $m^{1/2}s^{1/2}$, while the activation threshold for smoke detectors was 3,25 % of obscuration.

The complete simulation results for every smoke and heat detector apart during simulation time are presented on figures 16 and 17. The positions of smoke and heat detectors on figures 16 and 17 were the same as the positions of those detectors in simulation and on figures 4 and 5 [1], [3].

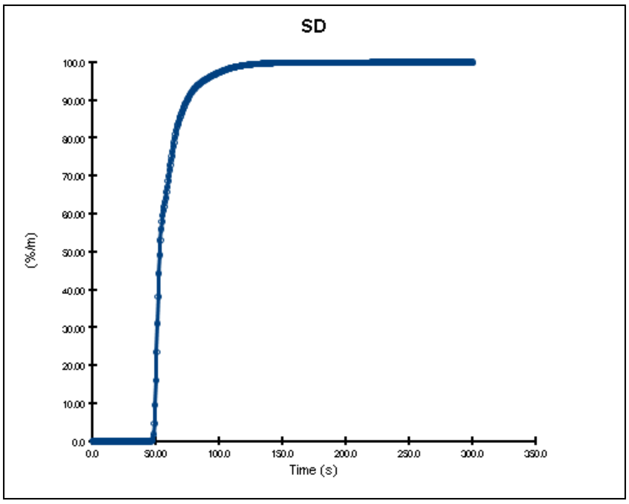

Figure 12. *Simulation results for the nearest smoke detector for the first case*

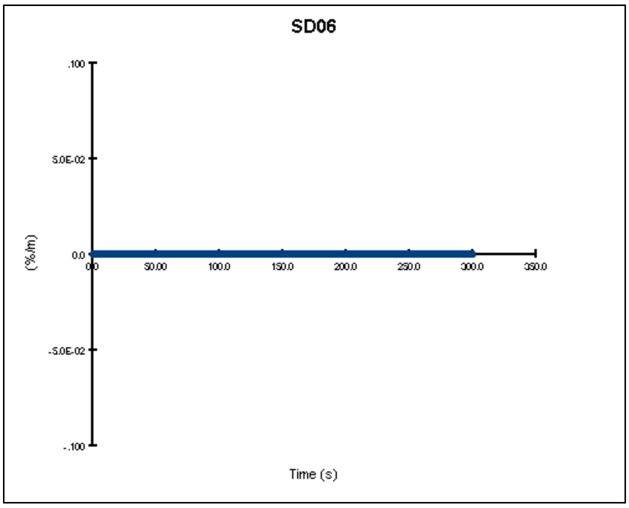

Figure 13. *Simulation results for the farthest smoke detector for the first case*

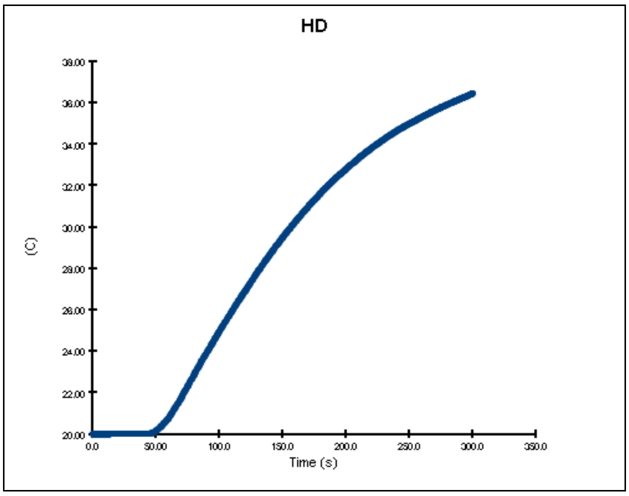

Figure 14. *Simulation results for the nearest heat detector for the first case*

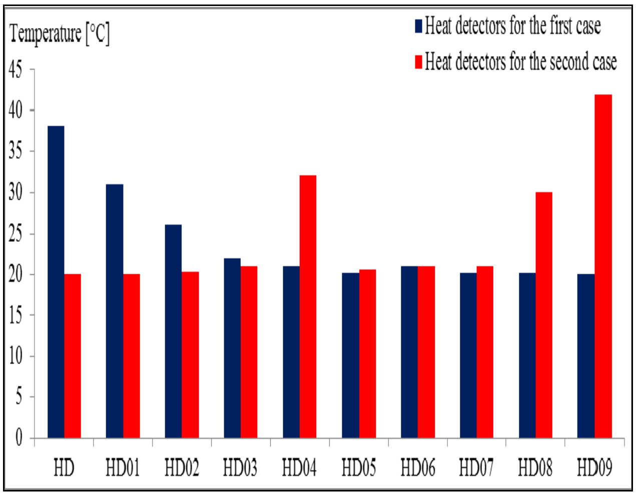

Figure 17. *The complete simulation results for both cases for every heat detector apart*

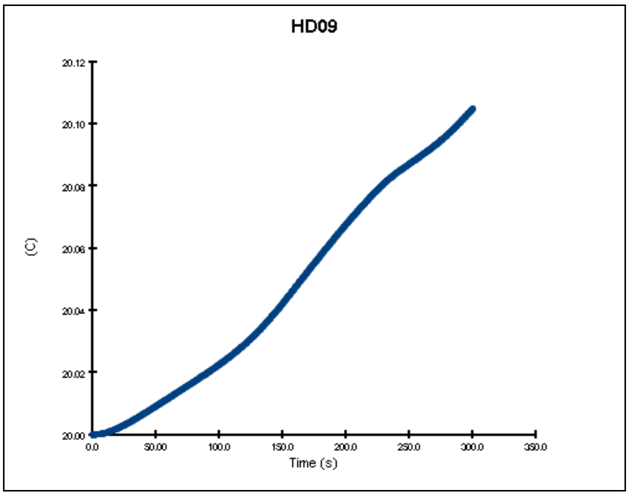

Figure 15. *Simulation results for the farthest heat detector for the first case*

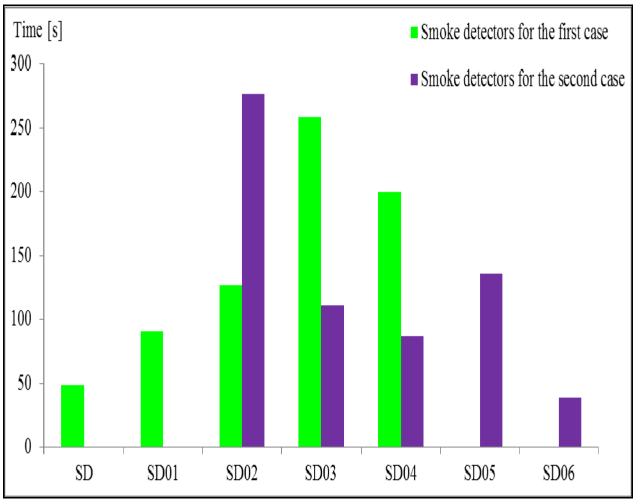

Figure 16. *The complete simulation results for both cases for every smoke detector apart*

ANALYZE OF SIMULATION RESULTS

Realized simulation results showed two potential cases of the fire and smoke propagation at the object with hallways where the fire started. Both cases purported fire with great smoke propagation. Burners for both scenarios were positioned on the cupboard made by oak wood.

Complete results presented on figure 16 showed reaction time for every smoke detector apart. The nearest smoke detector for the first case reacted for 49 seconds, while the nearest smoke detector for the second case reacted for 39 seconds. In both cases, two the farthest smoke detectors didn't react because conditions for detector`s activation didn't realize (the obscuration was less than 3.25%).

Complete results presented on figure 17 showed reaction time for every heat detector apart. The temperature for the nearest heat detector for the first case was 38 °C, while the temperature for the nearest smoke detector for the second case was 42 °C. The temperatures for the farthest detectors, for both cases were barely more than 20 °C. In both cases, none of the positioned heat detectors reacted, what was approximately expected related to the fact that the burners HRR were 450 kW/m^2.

CONCLUSION

The simulation of the fire and smoke propagation for presented object with hallways showed realized results for smoke and heat detectors positioned in object according to presented arrangement. As it was noted, hallways present special cases in fire detectors arrangement and demand different rules for fire detectors than other classic objects and object`s parts. The importance of realized results was in the determining of fire and smoke propagation directions and in determining of reaction times for both types of detectors. Of course, other arrangement of heat and smoke detectors was possible but it is important to note the fact that bigger number of detectors bring small benefit in sense of detection but significantly increase the price.

Generally, simulation results enable to determinate all potential directions of the fire, smoke and flame propagation, to note and eliminate errors made in the object`s fire protection system design and realization, what is , in real situations, very often uneconomic and hard for realization [13].

Very important benefits that could be gained by simulation are the prediction of the potential evacuation routes and complete time needed for evacuation of all occupants inside some particular object, which is of the crucial importance according to the human safety, especially in the objects with lot of humans inside, such as schools, sanitary objects, residential objects, nurseries etc. Very easy and safely, the speeds of occupants and speeds of fire and smoke propagation could be compares and analysed [4], [5], [6].

This paper again showed the significance of simulation software usage. On the realized simulation model, it is possible to analyse fast and safely, many different effects that could be occurred during fire, such as air flow influence on fire and smoke propagation, nozzle arrangement and influence on fire etc.

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BIOGRAPHY

Radoje Jevtić was born in Aleksinac, Serbia, in 1973.
He received the diploma in electrical engineering for automatics and electronics from Faculty of electronic engineering at University of Niš, then diploma in magistar of technical sciences from Faculty of occupational safety at University of Niš and PhD diploma in technical sciences from Faculty of occupational safety at University of Niš. His main areas of research include fire and burglary protection systems, simulations, fire and burglary sensors, etc. He is currently working as professor of vocational subjects at Electrotechnical school Nikola Tesla in Niš.

RASPORED DETEKTORA DIMA I TOPLOTE U HODNICIMA

Radoje Jevtić, Milan Blagojević

Rezime: *Sistemi za zaštitu od požara predstavljaju veoma kompleksne sisteme koji rade u realnom vremenu i sastoje se od mnogo različitih delova. Detektori požara predstavljaju jedan od tih delova. Detektori požara mogu biti podeljeni na nekoliko različitih načina u zavisnosti od kriterijuma. Veoma često korišćeni detektori u mnogim sistemima za zaštitu od požara su detektori dima i toplote. Njihova glavna uloga je da detektuju požar u ranoj fazi. Njihov broj i raspored u objektu su strogo regulisani odgovarajućim standardima. U nekim slučajevima, postoje određene razlike u standardima. Ovaj rad je napisan da pokaže mogući raspored detektora dima i toplote u objektu sa hodnicima realizovan simulacijom u PyroSim 2012 simulatoru.*

Ključne reči: detektor, raspored, simulacija.