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THE FIRE DETECTORS ARRANGEMENT IN ROOMS WITH NO STANDARD GEOMETRY

Abstract: *Fire protection systems present one of the most important systems of the object protection systems and they consists many different parts connecting in one unique system. One of those parts is fire detector. Detector presents one of the main elements of all real time systems that collecting data by measuring material and energetic changes of supervised occurrence. One of the most important tasks in projection of fire system is the type and arrangement of detectors in object. These tasks are regulated by proper standards. But, there are special cases, such as rooms with no standard geometry, where deviations are necessary and possible. This paper presents simulation check of smoke detectors arrangement in room with no standard geometry.*

Key words: fire, detector, simulation, arrangement, geometry.

INTRODUCTION

The purpose of fire protection systems is to provide information to the user about fire genesis in order to avoid human victims and material damage. Fire protection system is very complex system that has many different parts connecting in one unique system. Precision and correct work of every part of fire protection system has crucial importance in fire detection. The projecting of fire protection systems purports cognition of huge numbers of facts according to the object and possible development of fire. The most important results of the projection process are the right choice of fire detector and it's positioning into an object.

The arrangement of fire detectors in object presents one of the most important tasks in fire detection at early stage. There are several standards that deal with this problem: BS (British Standard), NFPA (National Fire Protection Association), НПБ 88-2001 (*Нормы пожарной безопасности*), DIN VDE 0833-2 and other.

The general rule for needed number of fire detectors and its positioning is to divide the supervised area with detector supervised area. There are lots of other factors that should be considered, such as shape and slope of the roof, barriers, girt, walls positioning, installation positioning, wholes into the walls positions, room height etc. The position of the detectors should be easy accessible, because of its testing and repairing. The reduction of the range between detectors leads that the system sensibility becomes higher. It is important to note that increment of fire detector numbers over the optimal limit brings small gain according to the price of the system. So, for that reason, it is important to find an optimal relation between performance increment and price needed for that.

In practice, the most of the supervised rooms are with rectangular shape rather then square shape, so it implies one edge decrease and other edge increase of rectangular that presents detector's covered area. For that reason, the recommendation in the case where the rooms are not with rectangular shapes, while planning, are that space should be divided on elementary rectangles areas. For these areas, the detectors arrangement should be planed as they were physically separated. There are also other recommendations for some special cases. For example, concerning heat detectors arrangement below plane ceilings, according to standard EN 54-14, heat and smoke detectors performances depend directly of distance from ceiling above detectors. As example, in table 1 is presented covering radius of heat detectors related to ceiling height (NN-usually doesn't apply, but it could in some occasions; NP- doesn't apply).

Table 1. *Covering radius of heat detectors related to ceiling height*

	Ceiling height [m]					
	≤4.5	>4.5≤6	>6≤6	>8≤11	>11≤25	>25
Detector type	Covering radius [m]					
Heat detectors EN 54-5 Class 1	5	5	5	NN	NP	NP
Smoke detectors EN 54-7	7.5	7.5	7.5	7.5	NN	NP

Detectors should be positioned that their sensor's element be in range of 5 % of room. Because of possible existence of cold limited (ceiling) layer, detectors shouldn't be positioned in the holes in ceiling. Also, for point types of detectors, none of points in the part that is protected should be out of radius given by standard (EN 54-14 Annex A - Specific recommendations, table A1, except expectations given in A.6.5.1.).

Based on these references of European standard, German standard detail defined covered area and radius (maximal range of some point in the room according to individual detector) related to room's surface and its height. In the table 2, there are covered areas of individual point smoke and heat detectors.

Table 2. *Maximal covered area A of point smoke and heat detectors*

room's surface [m^2]	point detector type	room's height	ceiling's slope [°]	
			up to 20	over 20
			A[m^2]	A[m^2]
up to 80	Smoke detector EN 54-7	up to 12	80	80
over 80	Smoke detector EN 54-7	up to 6	60	90
	Smoke detector EN 54-7	from 6 to 12	80	110
	Smoke detector EN 54-7	from 12 to 16	120	150
up to 30	Heat detector EN 54-5 (Classes A1, A2, B, C, D, E, F and G)	up to 6	30	30
	Heat detector EN 54-5 (Class A1)	up to 7.5	30	30
over 30	Heat detector EN 54-5 (Classes A1, A2, B, C, D, E, F and G)	up to 6	20	40
	Heat detector EN 54-5 (Class A1)	up to 7.5	20	40

- applied in dependence of occupation and ambient conditions

Rules noted in above tables 1 and 2 are illustrated in next figure 1 for symmetrical "ideal" arrangement of point smoke and heat detectors. Radiuses and covered area are in the order with characteristics given by current manufacturers of point smoke and heat detectors [1].

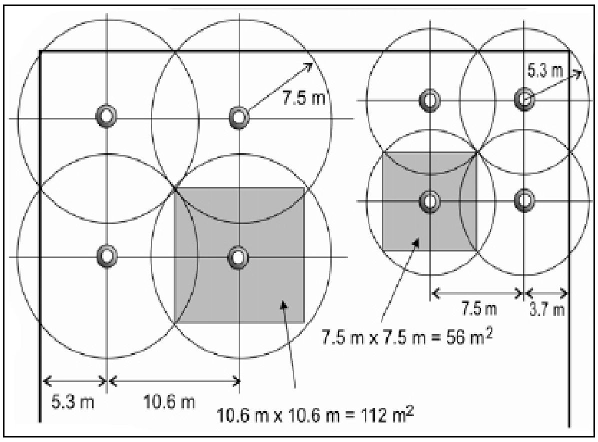

Figure 1. *Symmetrical arrangement of point smoke and heat detectors(figure source: M. Blagojević: The projection of fire detection systems)*

This approach in standard NFPA 72 is given by example on figure 2.

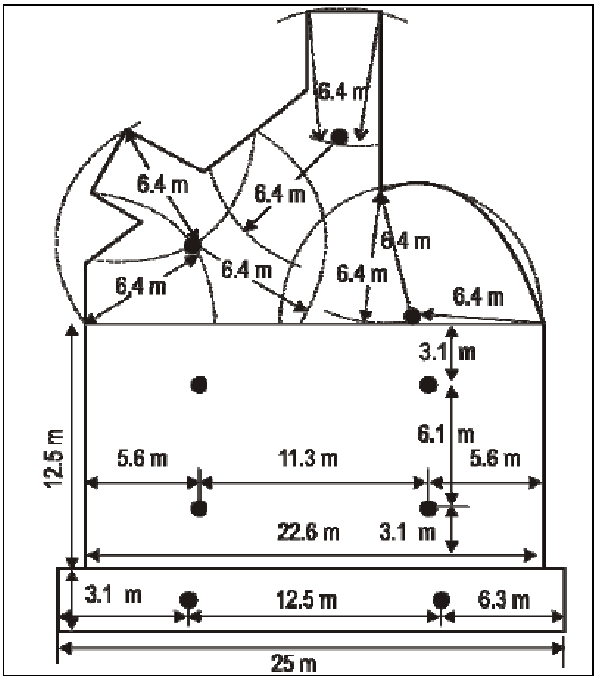

Figure 2. *An arrangement of point smoke and heat detectors in rooms with no standard geometry(figure source: NFPA 72 standard, National Fire Alarm Code, NFPA, Quincy, MA, 2007 edition, Figure A.5.6.5.1.2.)*

SIMULATION MODEL

Simulation results were realized by PyroSim 2012. PyroSim is a graphical user interface for the Fire Dynamics Simulator (FDS). The results of these simulations have been used to ensure the safety of buildings before construction, evaluate safety options of existing buildings, reconstruct fires for post-accident investigation, and assist in firefighter training. FDS is a powerful fire simulator which was developed at the National Institute of Standards and Technology (NIST). This approach is very flexible and can be applied to fires ranging from stove-tops to oil storage tanks. It can also model situations that do not include a fire, such as ventilation in buildings. FDS and the Smokeview visualization program are both closely integrated into PyroSim. In addition, PyroSim offers high-level 2D and 3D geometry creation features, such as diagonal walls, background images for sketching, object grouping, flexible display options, as well as copying and replication of obstructions [2, 3].

Simulation check was realized in PyroSim 2012 simulation model. There were three scenarios predicted: the first, where the fire source was positioned approximately in the middle of the object, the second, where the fire source was positioned at the right start part and the third, where the fire source was positioned at the left end part. The HRR (Heat release rate per area) of fire source was 800 kW/m^2 and its dimensions were 1 m x 1 m. The height of the room with no standard geometry was 3,2 m. The room with no standard geometry and its dimensions and the fire source for the first scenario is presented on figure 3, while the rooms with no standard geometry in 3D PyroSim presentation and smoke detectors arrangement are presented on figures 4 and 5.

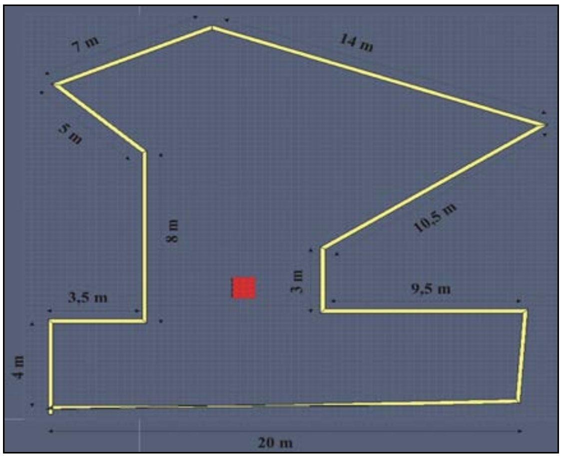

Figure 3. *The simulation model of the room with no standard geometry with its dimensions and fire source location for the first scenario in 2D PyroSim presentation*

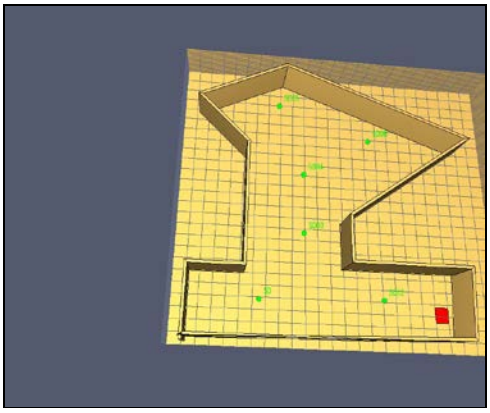

Figure 4. *The simulation model of the room with no standard geometry and fire source location for the second scenario in 3D PyroSim presentation*

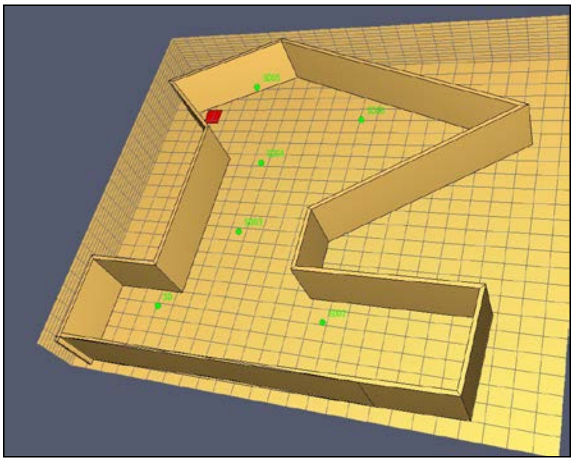

Figure 5. *The simulation model of the room with no standard geometry and fire source location for the third scenario in 3D PyroSim presentation*

SIMULATION RESULTS

The simulations were realized on laptop Fujitsu Siemens Esprimo Mobile V5535, with Intel Celeron 1733 MHz (13x133), 2GB of RAM and SiS Mirge 3 Graphics (256 MB). The simulation time was set on 200 seconds for every scenario. PyroSim simulation software demands very strong hardware configuration for more complex simulation model. Simulation results for every of tree scenarios with six smoke detectors are presented on figures from 6 to 23. In order to have a good base for results comparing, all scenarios were realized for five and four smoke detectors, optimally positioned according to NPFA 72.

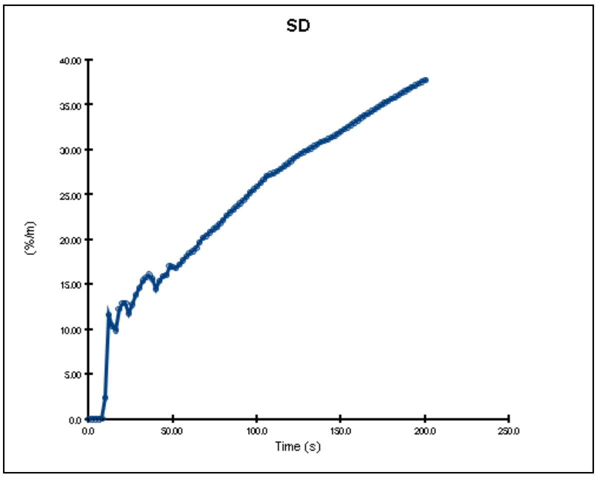

Figure 6. *Simulation results of smoke detector noted as SD for the first scenario*

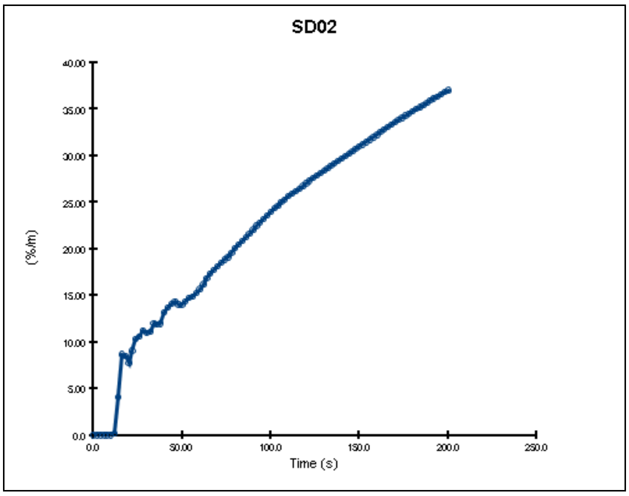

Figure 7. *Simulation results of smoke detector noted as SD02 for the first scenario*

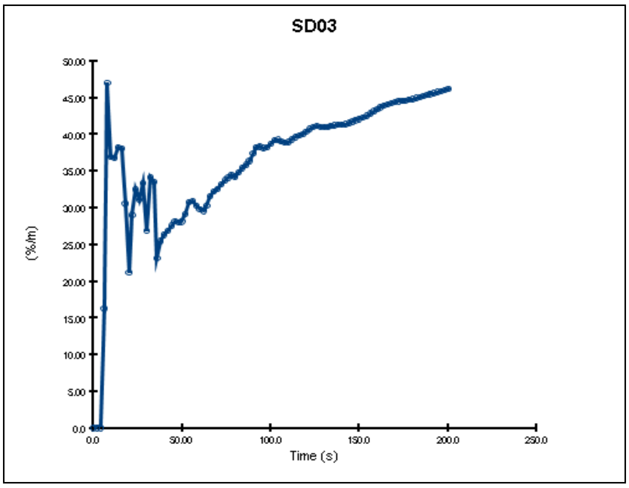

Figure 8. *Simulation results of smoke detector noted as SD03 for the first scenario*

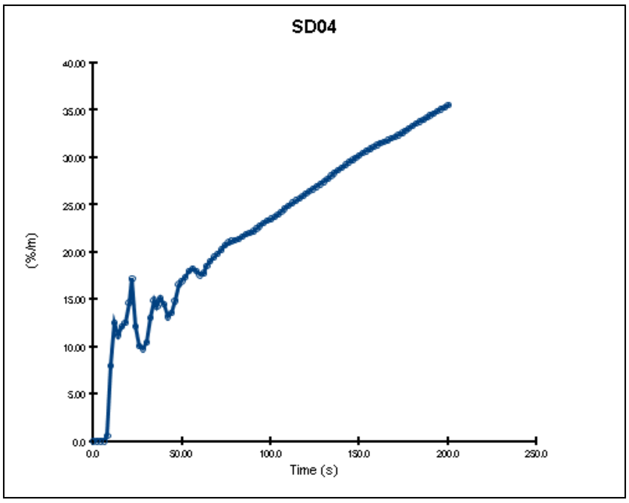

Figure 9. *Simulation results of smoke detector noted as SD04 for the first scenario*

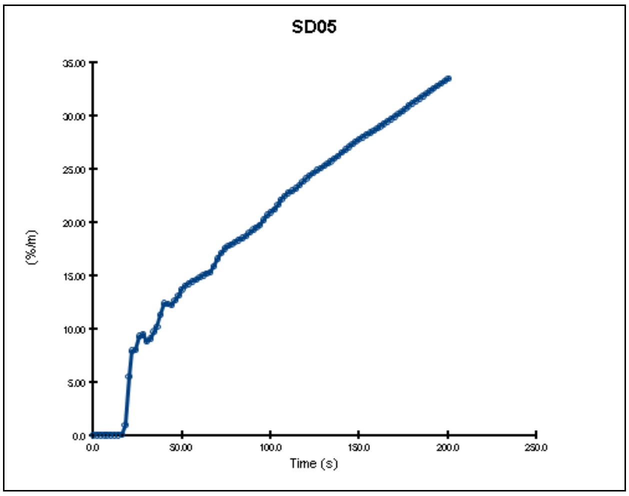

Figure 10. *Simulation results of smoke detector noted as SD05 for the first scenario*

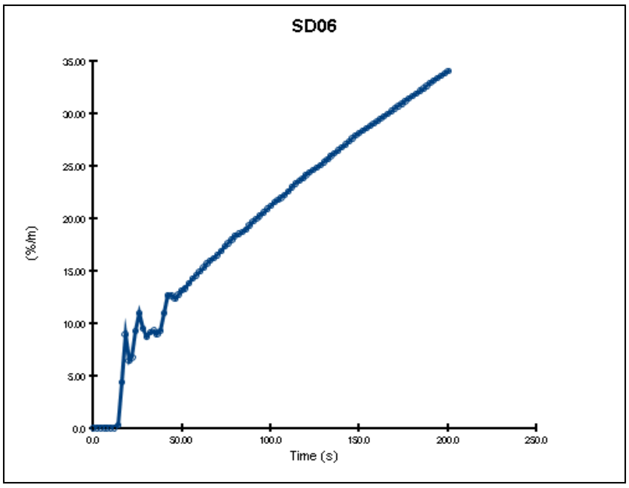

Figure 11. *Simulation results of smoke detector noted as SD06 for the first scenario*

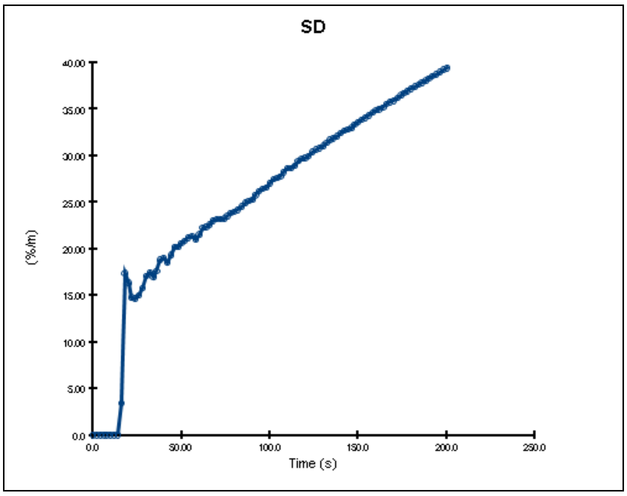

Figure 12. *Simulation results of smoke detector noted as SD for the second scenario*

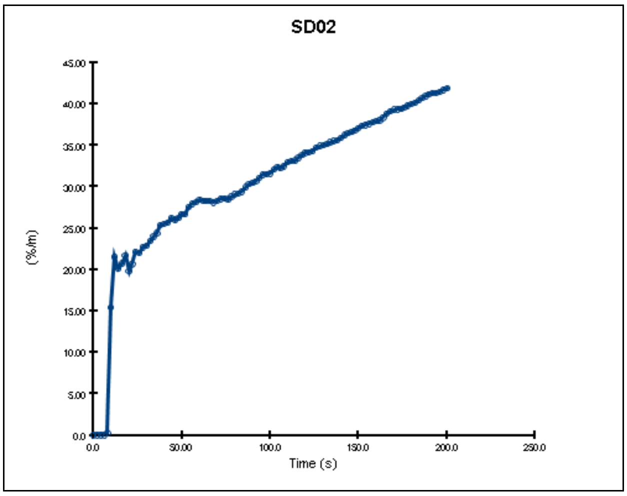

Figure 13. *Simulation results of smoke detector noted as SD02 for the second scenario*

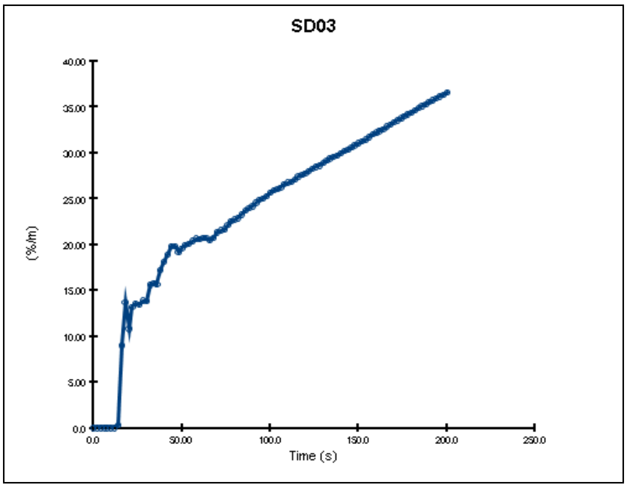

Figure 14. *Simulation results of smoke detector noted as SD03 for the second scenario*

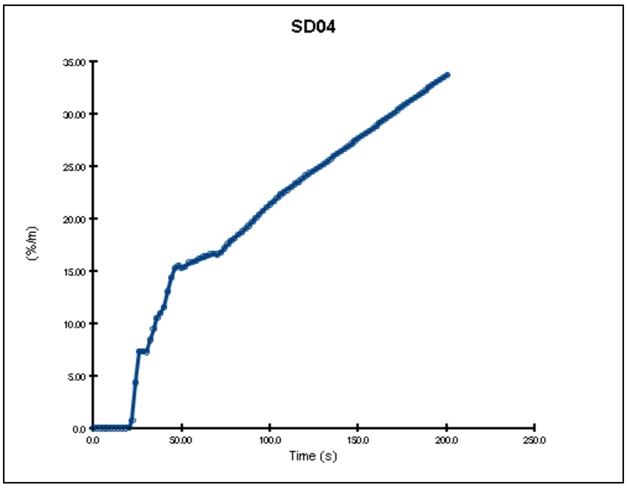

Figure 15. *Simulation results of smoke detector noted as SD04 for the second scenario*

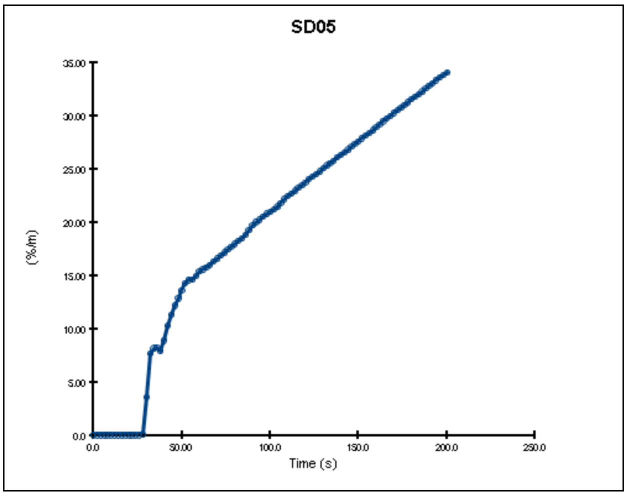

Figure 16. *Simulation results of smoke detector noted as SD05 for the second scenario*

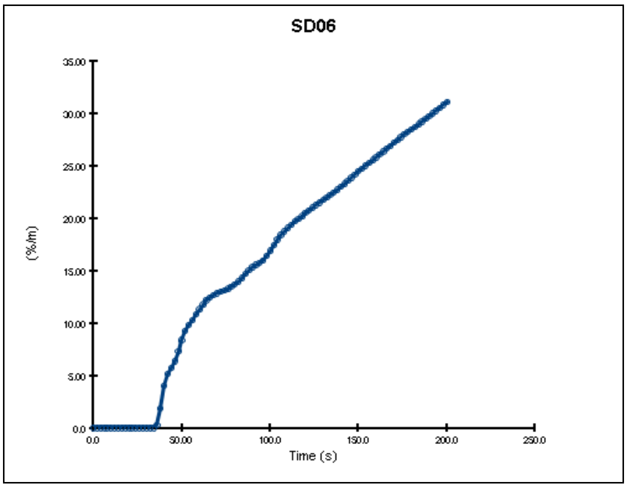

Figure 17. *Simulation results of smoke detector noted as SD06 for the second scenario*

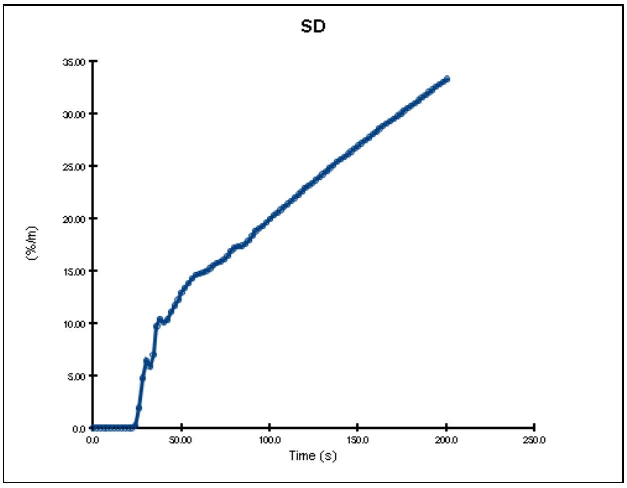

Figure 18. *Simulation results of smoke detector noted as SD for the third scenario*

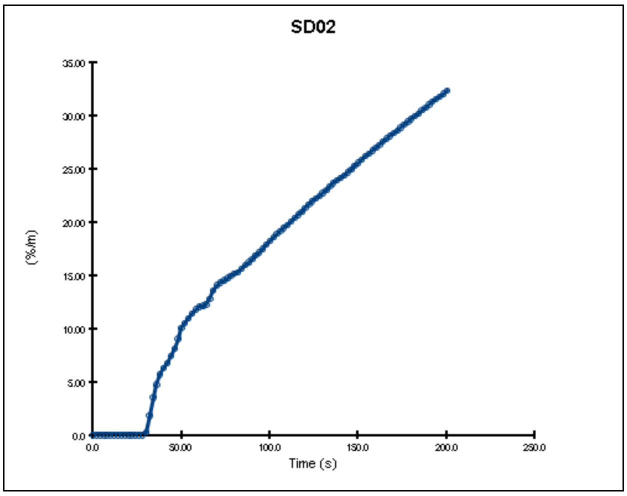

Figure 19. *Simulation results of smoke detector noted as SD02 for the third scenario*

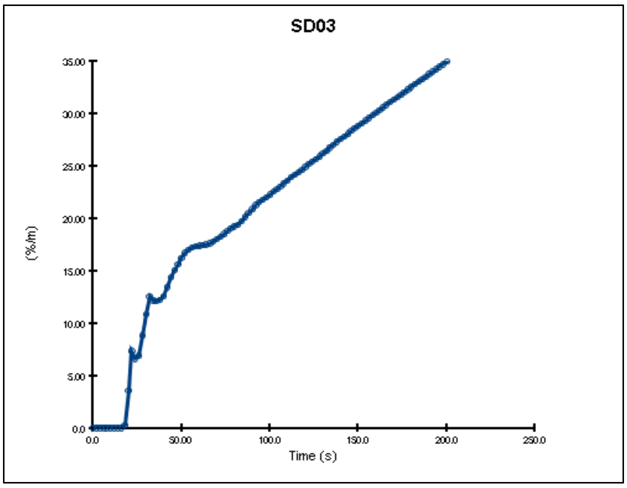

Figure 20. *Simulation results of smoke detector noted as SD03 for the third scenario*

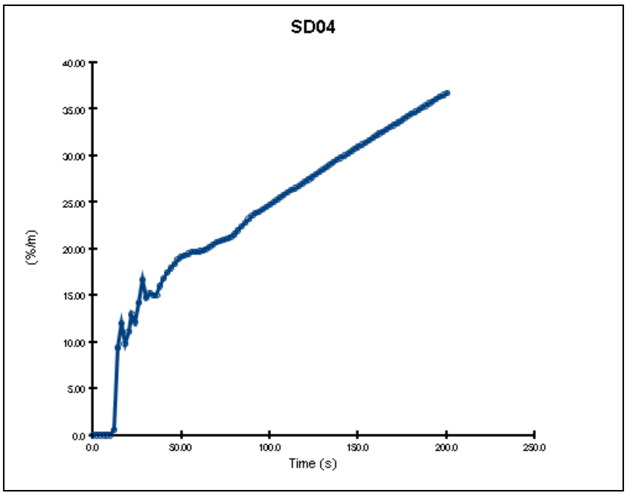

Figure 21. *Simulation results of smoke detector noted as SD04 for the third scenario*

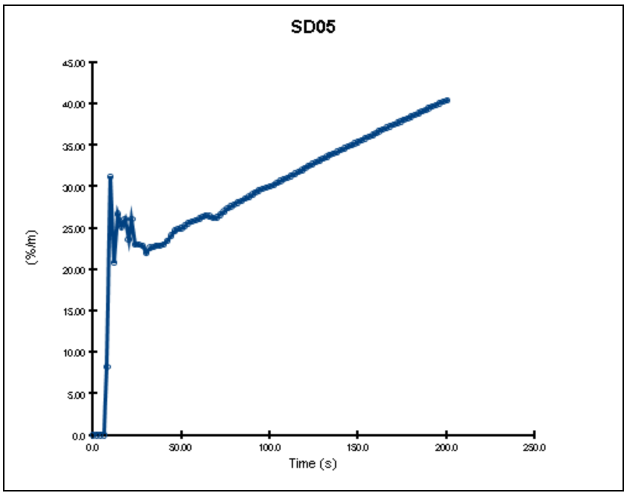

Figure 22. *Simulation results of smoke detector noted as SD05 for the third scenario*

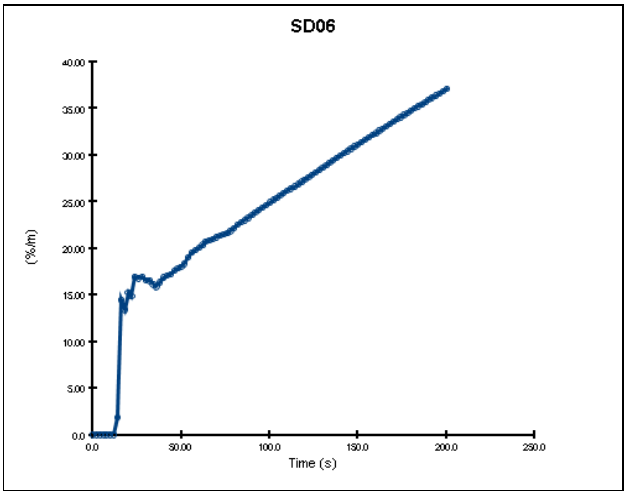

Figure 23. *Simulation results of smoke detector noted as SD06 for the third scenario*

RESULTS ANALYZE

The complete simulation time was approximately 55 minutes for every realized simulation. The activation threshold for smoke detectors was 3,25 % of obscuration. For that time, in every scenario, all of smoke detectors were activated. Simulation results that present reaction time for the nearest smoke detector and reaction time for all smoke detectors, for six, five and four smoke detectors in room are presented on figures from 24 to 26. The reason for simulations with different number of smoke detectors is in the fact that minimal number of detectors is determined by quotient of room surface and detector's supervised area. So, there was logical question would bigger number of detectors increase the safety and sensitivity and, at the same time, decreases reaction time of some detectors [7].

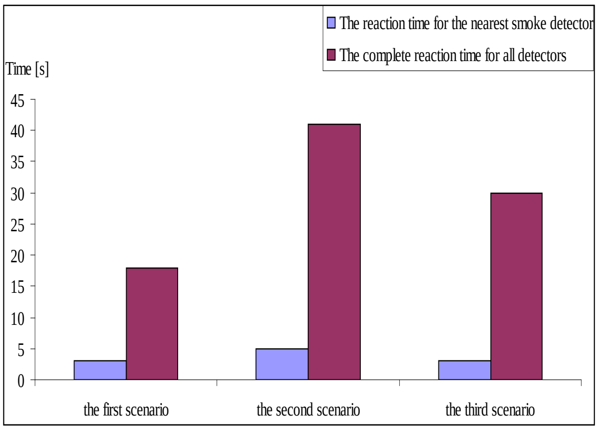

Figure 24. *Reaction time for the nearest detector and complete reaction time for all detectors, for every scenario, for six smoke detectors*

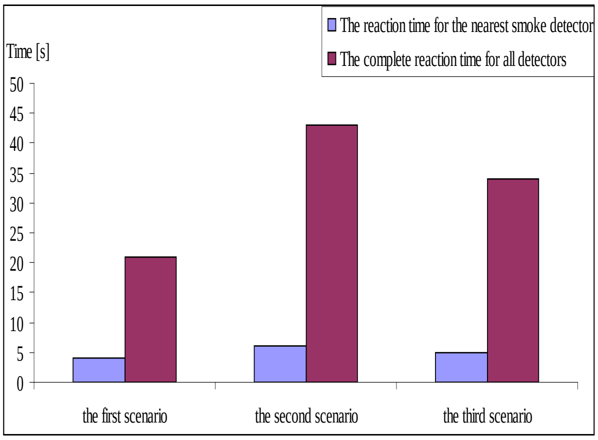

Figure 25. *Reaction time for the nearest detector and complete reaction time for all detectors, for every scenario, for five smoke detectors*

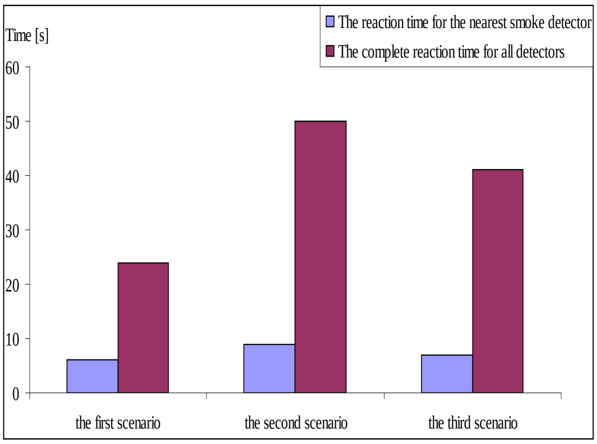

Figure 24. *Reaction time for the nearest detector and complete reaction time for all detectors, for every scenario, for four smoke detectors*

It is also important to note that, for smoke detectors, maximal covered area is in the range from 60 m^2 to 100 m^2, for standard heights (residential space, for example), with the fact that some manufacturers provide maximal covered area of 120 m^2. But, according to the fact that room's height directly influences on smoke rarity degree, for heights from 4,5 m, the chosen smoke detectors are with covered area of 80 m^2 or 60 m^2 what in the most depends of fire risk degree defined for object.

The room's shape for this paper was chosen arbitrarily, to provide appliance of noted rules. The fire source power appropriates to middle fast model of fire spreading. This fire model implies, for example, tree furniture and pieces of furniture with small quantity of plastic, which could be found in administrative storage, library or similar room and it also, could be appropriate to, let say, TF1 test fire model (standards ISO 7240-9 and EN 54-9 define conditions, methods and characteristics for test fires). It is very easy to check noted facts with different fire models (slow, fast and extremely fast) in this software.

CONCLUSION

The simulation of the fire propagation and behavior of its consequences presents very effective engineering tool in the fire prediction, checking of optimal detectors arrangement, fire propagation and many other useful information. According to the simulation results, it is possible to realize many important tasks such as to determinate the potential directions of the fire propagation, to fix and eliminate errors made in the object projection and realization, which is not possible without direct testing, which is uneconomic and hard to realize, and, in many cases, shown destructive on people and material properties [4-6]. According to the example in this paper, it is possible to determine the optimal smoke detectors arrangement and to determinate minimal and maximal time needed for detectors activation. Also, it can be seen that bigger number of smoke detectors doesn't bring bigger time dilatation, in this example. The differences between minimal reaction times for every scenario with six smoke detectors were small (3 seconds, 5 seconds and 3 seconds) also the differences between complete reaction times for every scenario (18 seconds, 41 seconds and 30 seconds). The differences between minimal reaction times for every scenario with five smoke detectors were small (4 seconds, 6 seconds and 5 seconds) also the differences between complete reaction times for every scenario (21 seconds, 43 seconds and 34 seconds). The differences between minimal reaction times for every scenario with four smoke detectors were small (6 seconds, 9 seconds and 7 seconds) also the differences between complete reaction times for every scenario (24 seconds, 50 seconds and 41 seconds).

Generally, this and similar simulation results showed that every object should have a unique approach of fire protection, respecting all of possible demands, roles, regulative and conditions. The detectors selection with their arrangement always must provide right time reaction and fire detection with acceptable price. These examples showed that increasing of detectors number doesn't bring great time reduction in sense of detection [12].

This research could be continued in several aspects, such as simulation with arrangement of fire detectors according to some typical way (triangle, hexagonal) or simulation of no typical objects with special content inside (for example, objects with different kind of roof with curvatures in theirs form and similar). These and similar results have great value not only in fire prediction, propagation and elimination but also in prediction and realization of possible evacuation routes for humans to leave the object safely [8-11].

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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 U PROSTORIJI SA NESTANDARDNOM GEOMETRIJOM

Radoje Jevtić

Apstrakt: *Sistemi za zaštitu od požara predstavljaju jedne od najvažnijih sistema za zaštitu objekta i sadrže mnogo različitih delova povezanih u jedan jedinstven sistem. Jedan od tih delova je detektor požara. Detektori predstavljaju neke od glavnih elemenata svih sistema koji rade u realnom vremenu i koji prikupljaju podatke merenjem materijalnih i energetskih promena nadziranih pojava. Jedan od najvažnijih zadataka u projektovanju sistema za zaštitu od požara je tip i raspored detektora u objektu. Ovakvi zadaci su regulisani odgovarajućim standardima. Međutim, postoje specijalni slučajevi, kao što su prostorije sa nestandardnom geometrijom, gde su devijacije neophodne i moguće. Ovaj rad predstavlja simulacionu proveru rasporeda detektora dima u prostoriji sa nestandardnom geometrijom.*

Ključne reči: požar, detektor, simulacija, raspored, geometrija.