Line Heat Detectors and Their Appliance in the Case of Auto Parking Garage

RADOJE B. JEVTIĆ, Electrotechnical school „Nikola Tesla“, Niš
IVANA D. JANKOVIĆ, Electrotechnical school „Nikola Tesla“, Niš

Professional paper
UDC: 699.812:006.3/.8
614.842.4
DOI: 10.5937/tehnika2206789J

Fire presents almost everyday occurrence in people`s life and work. The fight against fire must be fast and effective because consequences can be inconceivable, in the sense of human lives and material properties. Fire can occur everywhere: in the residential building, in factory, in hospital, in parking garage, in market, in school, anywhere where are people and their activities. Fire also can occur as natural disaster. One of ways how to fight against fire is to detect fire at early stage, as fast as possible. For that purpose, fire detectors are designed. This paper was written to show usage of line heat detectors in fire protection, their arrangement in objects related to different valid standards and computer simulation of line heat detectors in parking garages.

Key Words: *fire, detector, linear, simulation, garage, standard*

1. INTRODUCTION

Fire presents almost every day occurrence. Since fire has existed, it can be said that also fire protection has existed. With technological and science advancement, fire protection has also progressed. But statistic showed that even in the presence of modern fire protection huge fires do occur and cause huge material destructions and death cases in cities, woods etc.

Related to NFPA report, in period from 2009. to 2013. in United States, over 14500 fires in high-raised buildings were reported. Other NFPA report showed that average number of fires in buildings was between 3.510 and 4.220 per year, in United States, in period from 2008. to 2017. [1, 2]. Related to [3] total direct damage from wildfires in period from 1901. to 2014. was 54.828 (US$ million) with over 6 million affected people on global level. From September 2019. till February 2020, more than 12.6 million hectares in areas in Australi have been burned in bushfires occurred in Australia. During fires 434 million tonnes of CO_2 emitted in atmosphere, while 11.3 million of Australian citizen were affected by smoke and other particles-consequences of fire and smoke [4] Related to project „Prognoziranje opasnosti i rana detekcija - požara na području Istočne Srbije - podrška izradi planova gazdovanja šumama”, realized by Ministry of agriculture, forestry and water management, the complete number of wood fires on territory of Serbia without Vojvodina, in the period from 2012. to 2016. was 316. Related to [5] the complete damaged wood mass in period froom 2007. to 2016. was more than 119.046 m^3, annually average 11.905 m^3. These are just some of much and much examples how fire can be destructive for human life, work and environment.

The appearance and usage of fire detectors presents very important occurrence in fire protection. In basic, detector presents main element of every system for data collection. Detector presents part consisted of three elements: sensor element, element for transformation of determined dimension into electric dimension and element for signal conditioning. The main principle of detectors functioning is to detect some characteristic occurrences that fire produces, such as heat, flame and smoke. Detectors can be classified on different ways, in dependence of different factors and criteria (the way of activation, covered surface, number of states, the way of response, reset possibilities, reset ways, the way of installation, detection phenomena, detector`s configuration, collapsible possibilities etc.). Also, there are many different factors that can have a great influence on fire and fire development, and thereby, have a great influence on fire detectors selection (object`s geometry, ambient characteristics, disturbing factors etc.) [6, 7]. As an example, object`s geometry and materials that objects are built from have great influence in the sense of fire resistance. Fire load in some objects or object`s parts can

Author’s address: Radoje Jevtić, Electrotechnical school „Nikola Tesla“, Niš, Aleksandra Medvedeva 18
e-mail: milan.jvtc@gmail.com
Paper received: 10.10.2022.
Paper accepted: 21.10.2022.

achieve big values, while in other objects or object`s parts fire load can be small. Also, fire load in the most of cases can be unevenly distributed. This is particularly important for materials such as steel and concrete [8].

Generally, the limits of this paper don't allow that all fire cases and causes are presented and shown. But it is obvious that fire presents very danger everyday occurrence and it must be treated very seriously. The most important things related to fire are the right timed information and alarm about fire. It purported the existence and proper installation of fire detectors that can detect fire at early stage. Fire detectors must be properly chosen and installed, related to the valid standards.

This paper presents the role of line heat detectors in fire protection and their potential usage in auto parking garage protection presented with FDS simulation.

2. LINEAR SMOKE DETECTORS-WORK PRINCIPLE

Fire detectors can by classified on different ways and related to different criteria. Heat detectors present fire detectors that react on temperature changes and their uses are very frequent. The main division of heat detectors is on point heat detectors and line-type heat detectors. It is important to note that this division purported work method and coverage area and is directly imported for purpose of this paper, but also there are many other divisions of fire detectors.

One of the ways of realisations of heat detectors can be in the form of line-type heat detector (LTHD). There are many appliances of this kind of heat detector, such as parking garages, tunnels, hangars, warehouses, ensilages etc. Line-type heat detectors can be integral or non-integral. Their usage has been known since forty and more years. It is known that one of the first and the oldest form of line-type heat detector realization noted in 1970. This line-type detector used principle of liquid spreading in capillary tube and, because of that, it was known as capillary heat detector. Its appliance was great and it was considered by American NFPA 72 standard. Few years ago, the European standard EN 54-22: Resettable line type heat detectors, was developed.

The main intention of this standard was to consider all known ways of realizations of line type detectors. Related to this standard, every line-type heat detector should have four base elements: as the first is sensor element, as the second is functional unit, as the third is sensor control unit and as the fourth is control and indication equipment. After this standard, EN 54-28 was developed and this standard considered line-type heat detectors with disabled potential of resetting. Noted line-type heat detectors must be replaced after each activation of alarm. There are different technologies used for practical realization of line-typed heat detectors.

Semi-conductor technology is very frequently used for realization of line-typed heat detectors. These types of line-typed heat detectors are consisting of electrical line with integrated semi-conductor sensors. The most frequently field of usage for this line-type heat detectors are highways. The principle of work is based on temperature dependence of electrical characteristics of elements in sensor. The distance between sensors in such line-type heat detectors is usually from 1 meter to 20 meters. As example, related to EN 54-22 standard, the distance between sensors is from 7 meters to 8 meters. The total length of such line-type heat detectors is about 2.000 meters, where the accuracy of measurement is 0.5°C.

Optical cables present modern solutions for line heat detection. The characteristics of optical cables change under influences such as temperature, pressure and elongation. The main principle of work is that light inside cable turns what is the consequence of interaction between photons end electrons, what is known as Raman scattering. Measuring equipment for this line-type heat detector is very sophisticate. This line-type heat detector is completely immune on disturbances such as air flow or any kind of electromagnetic radiation.

Thermo-maximal linear detectors are also widely used as line-type heat detectors. They can be found in the form of parallel or twisted electrical lines with lightly melted plastic isolation. The principal of work is that under heat distribution temperature melts plastic isolation and leads to closure of electrical circuit, what implies alarm reaction. They can be also found in the form of coaxial cable. In that case, alarm state is initiated by capacity changes on coaxial cable, because coaxial cable presents line capacitor.

Related to rules for arrangement of line-type heat detectors, it is interesting that some standards are not detailed and precise for this type of heat detectors. For example, European standard EN-54 and British standard BS 5.839 very poor process this type of heat detector.

Related to Russian standard НПБ 88-2001, there were the same rules noted for each other distance of line-type heat detectors and covering area so as for point heat detectors. The arrangement of line-type heat detectors related to НПБ 88-2001 is presented in table 1.

Related to American NFPA 72 standard, the arrangement of line-type heat detectors must be such when they are mounted on the wall, the distance from the ceiling must not be bigger than 51 cm.

Table 1. The arrangement of line-type heat detectors related to НПБ 88-2001 [9]

The height of the room	Middle covering area of one heat detector	Maximal distance [m]	
		between detectors	from wall to detector
up to 3.5 m	up to 25 m^2	5 m	2.5 m
from 3.5 m to 6 m	up to 20 m^2	4.5 m	2 m
from 6 m to 9 m	up to 15 m^2	4 m	2 m

The arrangement of line-typed heat detectors related to NFPA 72 standard is presented on figure 1.

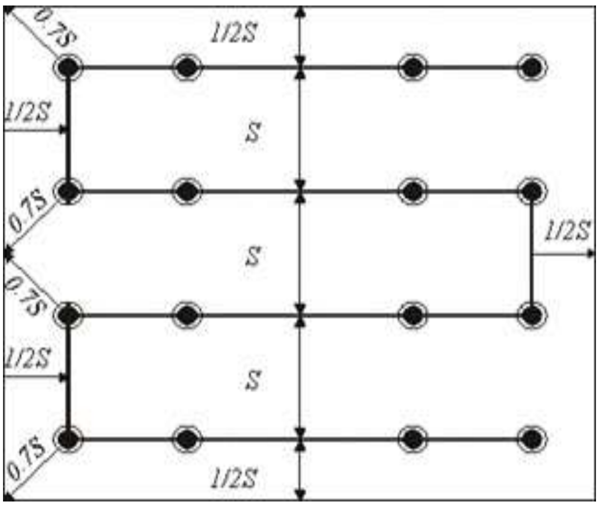

Figure 1 - Line-type heat detectors arrangement in order to NFPA 72 standard-S presents distance between line-type heat detector segments (lines), ▬▬ - presents segments (lines) of line-type heat detector, ⊙- presents point heat detector

Related to German VDE 0833-2 standard, covering area of line-type heat detectors was similar defined as covering area of point heat detector, what is presented in table 2.

The main references of German VDE 0833-2 standard are that line-type heat detectors are appropriate for height up to 9 m (line-type heat detectors A1 and A2), while the arrangement of those heat detectors should provide that distance between two different parallel sensor lines must be less then double value of the most biggest horisontal distance between any two point on ceiling level to detector. It is also important that line-type heat detectors shuld be 0.5 m away, at least, from the wall, equipement, or any other obstacle. Line heat detector must be separated into particular detector`s group in case that it transcends supervised area. Noted rules are the same for multipoint line heat detectors, where the arrangement of some sensor`s points were planed on the same way as in order with EN 54-5.

Table 2. Maximal covering area of line-type heat detectors [9]

Room area [m^2]	Detector`s type	Room height [m]	Slope of ceiling [°]	
			up to 20°	Over 20°
			A[m^2]	A[m^2]
up to 30 m^2	Line-type heat detector EN 54-22 (Classes A1 and A2*)	up to 6 m	30 m^2	30 m^2
	Line-type heat detector EN 54-22 (Classes A1*)	up to 7.5 m		
	Line-type heat detector EN 54-22 (Classes A1c*)	up to 9 m	15 m^2	
over 30 m^2	Line-type heat detector EN 54-22 (Classes A1 and A2*)	up to 6 m	20 m^2	40 m^2
	Line-type heat detector EN 54-5 (Classes A1* and A2)	up to 7.5 m		
	Line-type heat detector EN 54-22 (Classes A1*)	up to 9 m	15 m^2	30 m^2

It is obvious that the most standards don't define precisely mutual distance between parts of line-type heat detectors and covering area. One reason for that is the way of realization of line-type heat detectors. Other reason is the specificity of application for concrete purpose. Because of that, there are different ways of line-type heat detectors arrangement in some specific cases, such as tunnels, elevators, different engines, computer centers, parking garages, cable routes, conveyor belts, escalators, around chimneys, in the loft, in the recycling industry etc. For noted cases, manufactures of line-heat type detectors define rules of arrangement.

The example of line heat detectors usage on the house roof and chimney fire protection is presented on figure 2. Arrows on figure 2 show line heat detector on the roof and on the chimney. That is very good way for temperature control of roof and loft temperature, so as chimney temperature, especially in cases when the detection in the open space is required. The installation is very simple and fast.

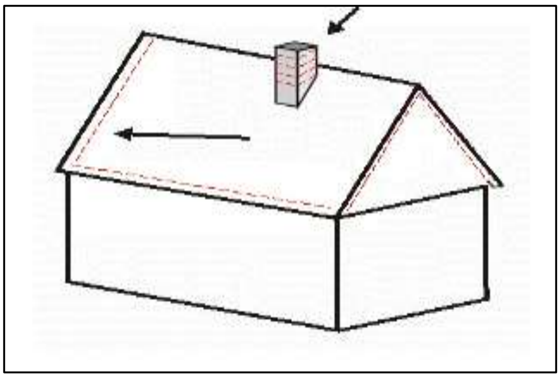

Figure 2 - An example of line-type heat detector arrangement on the roof and around the chimney

Parking garages present objects for accommodation of a large number of vehicles. The presence of fuel and oil in the car, fumes and other flammable materials or human`s caused inattention can easily lead to fire. Construction of parking garages dated from the start of XX century (from 1902 to 1903, the London Motor Garage with capacity of 200 cars). Today's parking garages present huge objects with capacities for several hundred vehicles and possess modern systems for fire protection. Those objects can be built as underground objects, objects in the ground level and multistory aboveground objects. But fires do occur even many safety precautions were realized. As example, there was a huge fire in Liverpool-Echo parking garage, in 2018, where great damage was done. Related to some information, approximately 1.400 vehicles were completely destroyed.

Parking garages are particularly interested for fire protection because the use of fire detectors is limited to carbon-monoxide detectors and line-type heat detectors due to the presence of exhaust gases (underground parking garages). Noted fire detectors can be arranged on the walls of parking garage or ceiling of parking garage in dependence of technical and structural properties. Related to rules for point heat detectors arrangement, the distance between lines of line-type heat detectors is 10.6 m, what means 5.3 m of covering area from each side of line-type heat detector, as it is presented on figure 3.

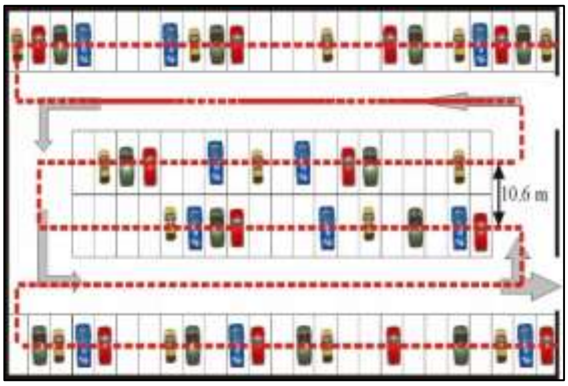

Figure 3 - An example of line-type heat detector arrangement in underground parking garage

In the cases of multistory aboveground parking garages, heat detection can be difficult due to the presence of increased air flow, humidity, etc. Those objects are usually open on several sides what purports much bigger volume, so heat distribution can be much harder for detection. Line-type heat detectors can also be used for those cases, but with two conditions.

The first condition purports the presence of cope and fence that separates parking positions. The second condition purports presence of appropriate flame detector, in combination with line-type heat detector. One such example of the multistory parking garage with line heat detectors in combination with flame detectors is presented on figure 4 [9, 10, 11, 14, 12].

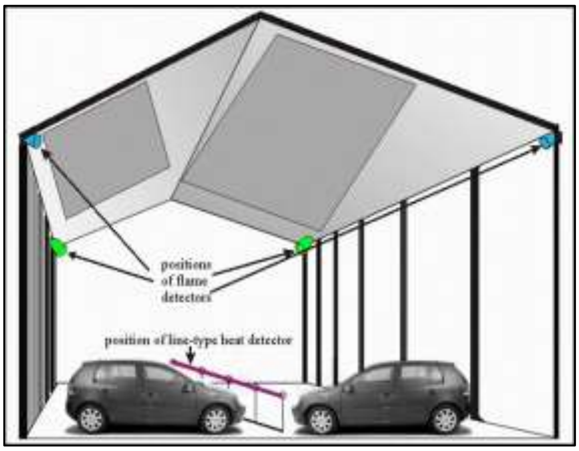

Figure 4 - An example of line-type heat detectors arrangement in combination with flame detectors in multistory aboveground parking garages.

3. SIMULATION AND SIMULATION MODEL

Simulation model for this paper was realized in FDS software, software specialised for fire and smoke simulation and spreading. There are several versions of this software on the market. For the purposes of this market, version 6.6 was used. The main thing about this software is the fact that fire, smoke and flame can be presented numerically.

Simulation model purported object made from concrete with dimensions 37.5 m x 36 m x 4 m. The complete number of presented cars in auto parking garage was 52. Cars were deployed in the four rows, two rows with 15 cars per row (the first row and the fourth row) and two rows with 11 cars per row (two rows in the middle of the garage). Every car had steel, plastic, glass, rubber and upholstery as basic materials that they were made of. The dimensions of every car were 4.5 m x 1.25 m x 1.4 m. The line heat detector was located on the ceiling, 0.5 m below. In FDS software, line heat detectors were simulated as determine number of point heat detectors. The fire source was modeled as burner with dimensions of 0.5 m x 0.5 m and HRR (Heat release rate per area) of burner for the first case 1.500 kW/m^2, for the second case 2500 kW/m^2 and for the third case 3.500 kW/m^2. For every simulation, burner was located at the seats. There were three different positions for burner: in the first line of cars, in the second line of cars and in the last line of cars. The activation threshold of heat detector was set to be 65°C. The complete FDS presentation with cars, line heat detectors position and dimensions of the auto parking garage are presented on figure 5.

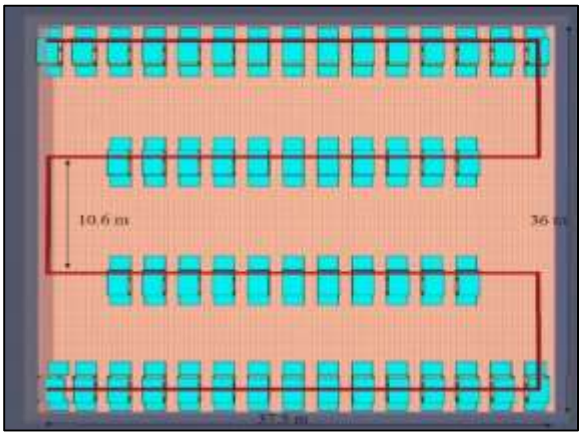

Figure 5 - The FDS presentation of auto parking garage with cars, line heat detectors position and dimensions

To compare realise results, there were realised simulations in the same auto garage for point heat detectors, arranged by valid standards (EN 54 and VDE 0833). There were also three different positions for burner: in the first line of cars, in the second line of cars and in the last line of cars. Every simulation was realized for the nearest point heat detector and for the farthest point heat detector.

The FDS presentation of the auto garage with the arrangement of the point heat detectors related to the EN 54 and VDE 0833 standard are presented on figure 6.

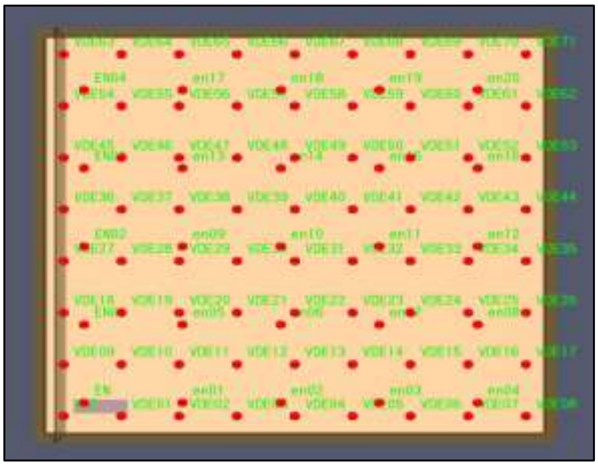

Figure 6 - The FDS presentation of the auto garage with the arrangement of the point heat detectors related to the EN 54 and VDE 0833 standard

SIMULATION RESULTS

The computer machine used for simulations was laptop Asus X415EA-EB512W laptop Intel® Quad Core™ i5 1135G7 14" FHD, 8GB RAM and 512GB SSD. It is a general recommendation that strong hardware and software configuration should be used for computer simulations. The simulation time was set on 240 seconds for each simulation, but, of course, times for complete realisation of simulations were much longer. Because of paper`s limitation in technical sense, only some of simulation moments and simulation results are presented on figures from 7 to 17, while the complete simulation results are presented on figure 18.

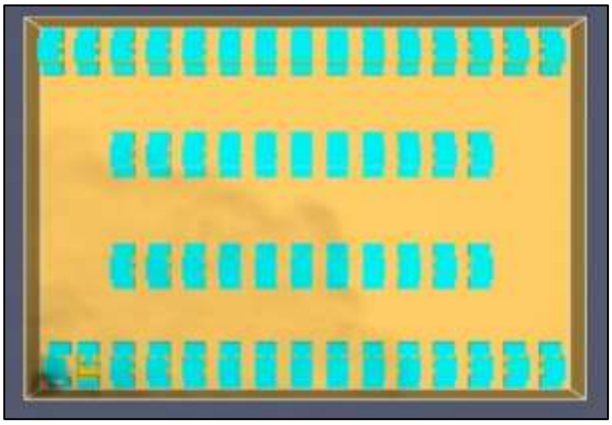

Figure 7 - Simulation moment for the first burner position, the first case

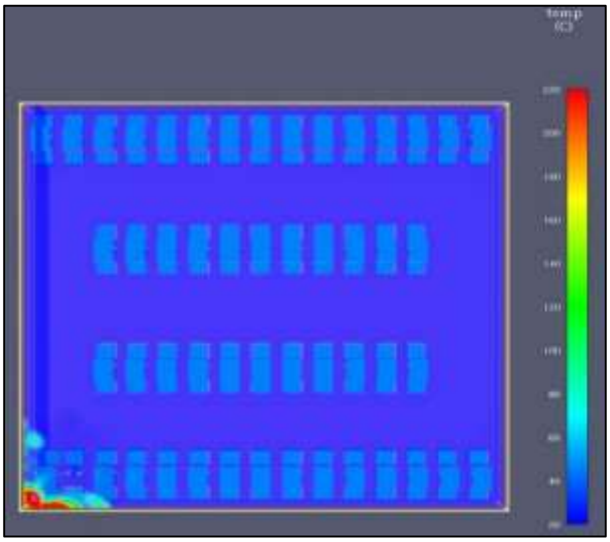

Figure 8 - Thermal presentation of simulation for the first burner position, the first case

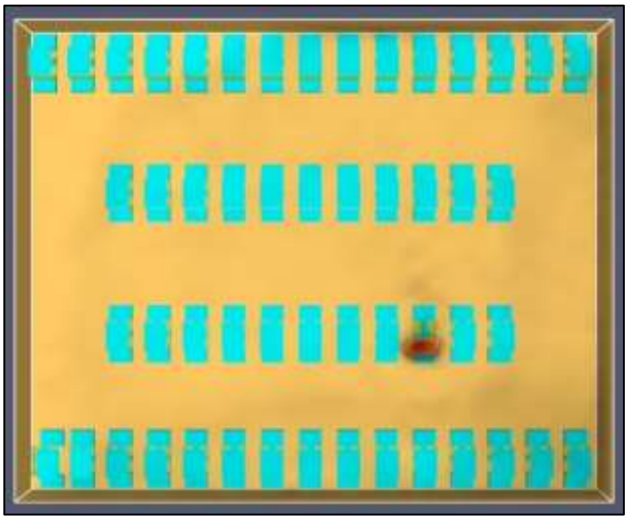

Figure 9 - Simulation moment for the second burner position, the first case

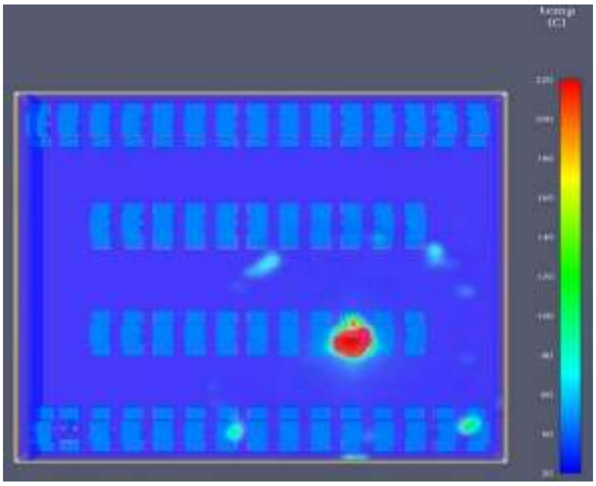

Figure 10 - Thermal presentation of simulation for the second burner position, the second case

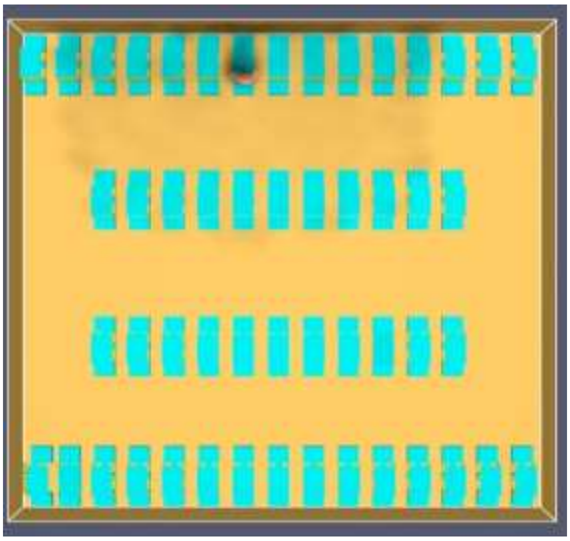

Figure 11 - Simulation moment for the third burner position, the second case

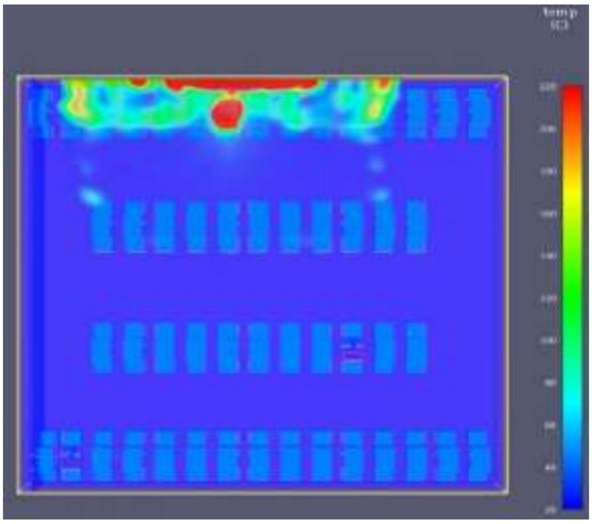

Figure 12 - Thermal presentation of simulation for the third burner position, the second case

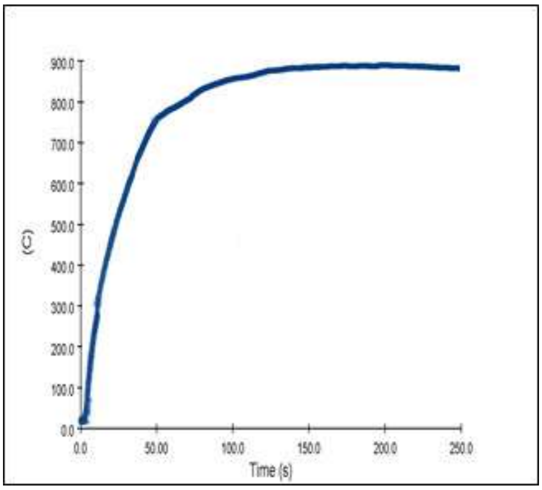

Figure 13 - Simulation results for the first burner position for line heat detector

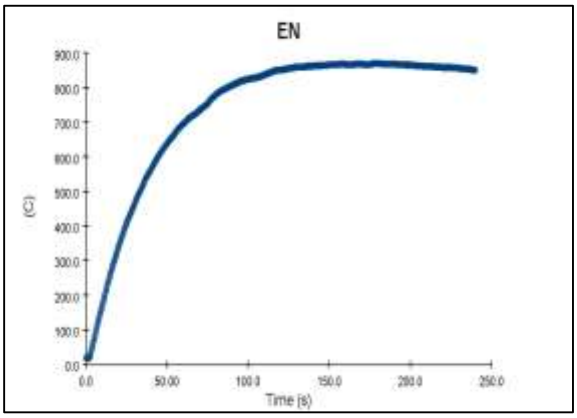

Figure 14 - Simulation results for the first burner position, for the nearest point heat detector related to EN-54 standard

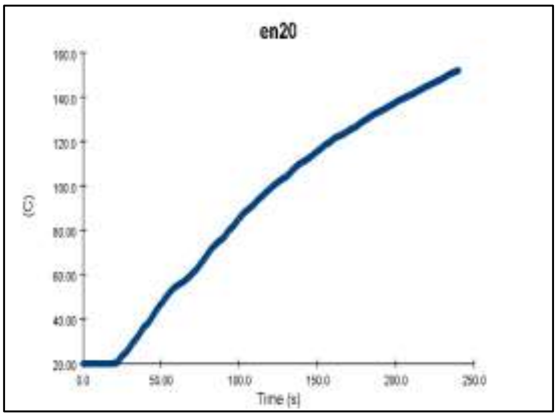

Figure 15 - Simulation results for the first burner position, for the farthest point heat detector related to EN-54 standard

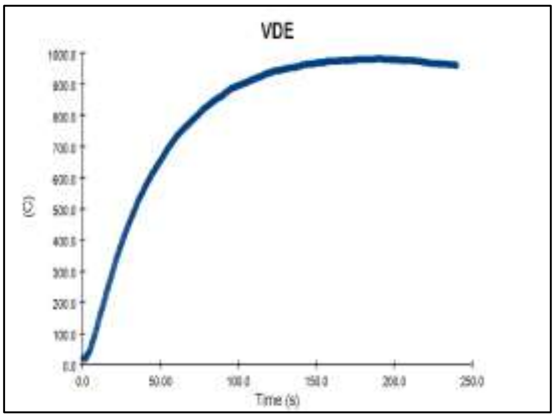

Figure 16 - Simulation results for the first burner position, for the nearest point heat detector related to VDE0833 standard

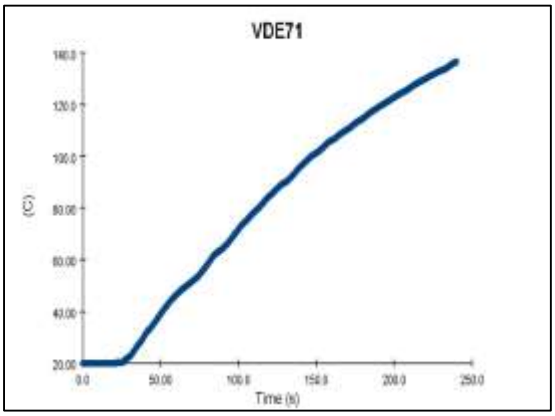

Figure 17 - Simulation results for the first burner position, for the farthest point heat detector related to VDE0833 standard

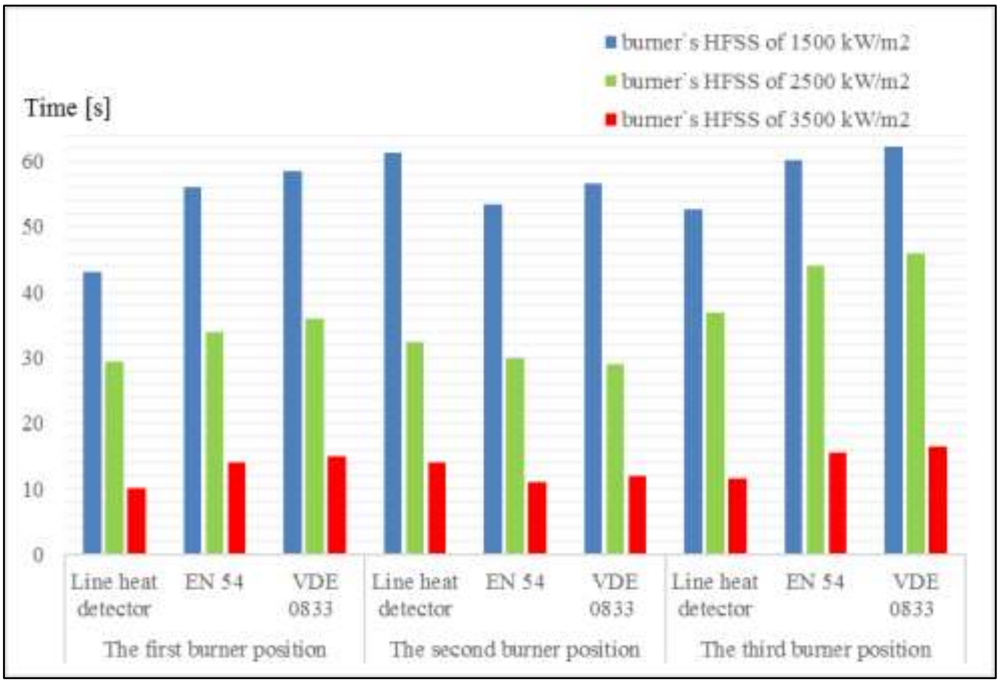

Figure 18 - The complete simulation results for all of three cases, for all of three burners positions and for all three burners HRR (1500 kW/m^2, 2500 kW/m^2 and 3500 kW/m^2

4. ANALYSE OF SIMULATION RESULTS

Simulation results for all of three cases (Heat release rate per area of 1500 kW/m^2, 2500 kW/m^2 and 3500 kW/m^2) for all of three burners positions showed that there is no big difference between line heat detectors (figure 13) and point heat detectors in the sense of the shortest time needed for detector`s reaction.

It can be seen that differences between different reaction times mostly depend from heat source and thickness of the detectors (the second burner`s position).

For the point heat detectors, for every burner`s position there were detectors with the fastest reaction (figures 14 and 16) and detector that didn't react at all, because the heat source was too far (figures 15 and 17). However, simulation results showed that both ways of protection, for this case of auto parking garage, with line heat detector or with point heat detectors can be used, in the sense of proper reaction. Of course, from case to case, in dependence from many different factors, it will depend which way for protection be used.

5. CONCLUSION

Line heat detectors present detectors that have been in use more than forty years. They can be realised on different ways and the spectre of their usage is very wide.

One of the very good ways for checking fire protection systems and solutions is the use of proper simulation software. The main advantages of simulation software use are precision, effectivity, safety and cheapness.

Of course, the choice of appropriate fire detector presents very serious, professional and always open task. It is very important to synchronize, as much as possible, all demands [13, 14, 15, 16].

REFERENCES

[1] Ahren M. High-rise building fires, NFPA Research, pp. 1, 2016, [Internet], Available on: https://www.-nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Building-and-life-safety/oshighrise.pdf

[2] Campbell R. Fires in Structures under Construction or Renovation, NFPA Research, pp. 2, 2020, [Internet], Available on: https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports-/Building-and-life-safety/osFiresI,nStructuresUnderConstruction.ashx).

[3] Doerr S, Santin C. Global trends in wildfire and its impacts: perceptions versus realities in a changing world, *Philos Trans R Soc Lond B Biol Sci*, doi:10.1098/rstb.2015.0345, 371(1696), 2016.

[4] [Internet], https://www.abc.net.au/news/science/-2020-03-05/bushfire-crisis-five-big-numbers/120-07716 (accessed 16.11.2020)

[5] Avramović D, Mihajlović E, Petković A. Indicators of forest fire conditions in state forests of Serbia in the period from 2007 to 2016, In *Zastita na radu put uspešnog poslovanja - XIV International Conference*, Divčibare, Vol XIV, pp. 215-222, 2017.

[6] Blagojević Đ. M. *Alarm systems*, Faculty of occupational safety in Niš, ISBN 978-86-6093-025-7, Niš, pp. 34-36, 70-75, 2015.

[7] Jevtić B. R. Selection of the fire detectors and their arrangement in object, *Bezbednost*, UDK 343+-351.74./75(05), YU ISSN 0409-2953, Vol 1/2015, pp.197-215, Belgrade, Serbia, 2015.

[8] Mešić H, Džidić S. (2015). Uticaj debljine pokrovnog sloja betona na otpornost na požar armiranobetonskih ploča prema Eurocode 2, In Conference: *10 Međunarodna konferencija RIM 2015*, *Razvoj i modernizacija proizvodnje*, Dubrovnik, Croatia, 2015.

[9] Blagojević ĐM. *Projektovanje sistema za dojavu požara*, AGM Book, Belgrade, ISBN 978-86-86363-89-3, pp. 144-157, 2018.

[10] Jevtić BR, Blagojević ĐM. On a linear fire detection using coaxial cables, *Thermal Science*, Vol. 18, No. 2, pp. 603-614, 2014.

[11] Jevtić, B. R. *Evacuation from a parking garage,* Safety Engineering, ISSN-2217-7124, Niš, Vol 9, No. 2, pp. 75-80, 2020.

[12] Rogner A, Hao-wei Y. Semiconductor Based Line Type Heat Detector Following European EN54-22 Standard, *Procedia Engineering*, Vol. 11., pp. 1-9, 2011.

[13] Jevtić BR. The importance of fire simulation in fire prediction, *Tehnika*, Vol 1., ISSN 0040-2176, Beograd, pp. 153-158, 2014.

[14] Jevtić BR. The fire simulation as a safety advantage in fire prediction and fire protection, *Safety Engineering*, Vol 5, No. 1, ISSN-2217-7124, Niš, Serbia, pp. 21-28, 2015.

[15] Jevtić B. R. The significance and use of simulation software in fire protection, *Path to a Knowledge Society-Managing Risks and Innovation PaKSoM 20121*, *3rd International Virtual conference*, 2021.

[16] Jevtić BR. The Smoke Detectors Arrangement in Rooms with Girts Related to British Standard BS 5839-1, *Tehnika*, Vol 1, pp. 129-133, ISSN 0040-2176, UDC: 62(062.2) (497.1), Belgrade, Serbia, 2022.

REZIME

LINIJSKI DETEKTORI POŽARA I NJHOVA PRIMENA U SLUČAJU AUTO PARKING GARAŽE

Požar predstavlja svakodnevnu pojavu u životu i radu ljudi. Borba protiv požara mora biti brza i efikasna zato što posledice mogu biti nepredvidive, u smislu ljudskih života i materijalnih vrednosti. Požar se može desiti bilo gde: u stambenoj zgradi, fabrici, bolnici, u parking garaži, market, školi, svuda gde su ljudi i njihove aktivnosti. Požar se takođe može pojaviti i kao prirodna katastrofa. Jedan od načina kako se boriti protiv požara je detektovanje požara u ranoj fazi., što je brže moguće. Za tu svrhu, projektovani su detektori požara. Ovaj rad je napisan da pokaže upotrebu linijskih detektora požara u zaštiti od požara, njihov raspored u objektu u odnosu na različite standard i komjutersku simulaciju linijskih detektora u slučaju parking garaže.

Ključne reči: *požar, linijski, simulacija, garaža, standard*