FIREFIGHTING INTERVENTIONS IN FIRES INVOLVING PHOTOVOLTAIC SYSTEMS AND BUILDINGS WITH SOLAR PANELS

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ABSTRACT

The development and increasing use of photovoltaic systems on residential, public and industrial buildings create new challenges in the field of fire protection and firefighting interventions. The aim of this paper is to analyse the specific characteristics of fires involving buildings equipped with solar panels, identify the main risks faced by firefighters during interventions, and present basic safety procedures and preventive measures that contribute to more efficient and safer fire suppression. The purpose of the paper is to emphasise the importance of professional firefighter training and proper design of photovoltaic systems in order to reduce the risk of fire occurrence and spread. The paper will use a review and analysis of available scientific and professional literature. The literature analysis shows that fires in photovoltaic systems most commonly occur due to electrical faults, improper installations, inadequate maintenance, and arc faults. Fires involving buildings equipped with solar panels require a specific approach by firefighting units due to particular electrical and structural risks.

Keywords: photovoltaic systems, fire, firefighting interventions, solar panels, fire protection

INTRODUCTION

The use of renewable energy sources has experienced significant growth worldwide in recent years, with photovoltaic (PV) systems occupying a particularly important position among them. The development of solar technology has enabled the widespread installation of solar panels on residential, commercial, industrial, and public buildings. In addition to numerous benefits, such as reducing greenhouse gas emissions and improving energy efficiency, the increasing number of installed photovoltaic systems has introduced new challenges in the field of fire protection and firefighter safety.
Fires involving buildings equipped with solar panels differ from conventional fires due to the presence of electrical energy generated by photovoltaic modules as long as they are exposed to sunlight. As a result, certain parts of the system may remain energised even after the main power supply of the building has been disconnected, increasing the risk of electric shock during firefighting operations (Piantedosi et al., 2016). Such circumstances require a specialised approach by fire departments and the implementation of specific safety procedures.

In Bosnia and Herzegovina, the solar energy sector has experienced rapid development in recent years. An increasing number of households and businesses are investing in photovoltaic systems, which raises the likelihood that firefighters will encounter buildings equipped with solar panels during emergency interventions.

RESEARCH PROBLEM AND OBJECTIVE

The research problem addressed in this paper concerns the specific hazards that arise during firefighting operations involving buildings equipped with photovoltaic systems. Unlike conventional electrical installations, solar panels represent a continuous source of electrical energy during daylight hours, which may endanger firefighter safety and complicate firefighting activities.

The aim of this paper is to analyse the most common causes of fires in photovoltaic systems, identify the risks faced by firefighters during interventions, and present recommended protective measures and safety procedures. A particular objective is to emphasise the importance of firefighter training and the application of modern technical solutions to reduce the risk of injuries and material losses.

RESEARCH METHODOLOGY

This study applies a literature review and analysis methodology focusing on scientific and professional publications related to photovoltaic system fires and firefighter safety. International reports, firefighter training manuals, scientific articles, and technical guidelines issued by relevant fire protection organisations were analysed.

Special attention was given to documents published by the International Energy Agency Photovoltaic Power Systems Programme (IEA-PVPS), research concerning the safety of building-integrated photovoltaic systems, and professional guidelines intended for fire services. Through content analysis, the most common causes of fires, characteristic intervention risks, and recommended preventive measures were identified.

RESULTS AND DISCUSSION

The analysis of available scientific and professional literature indicates that photovoltaic systems, although considered a reliable and environmentally friendly source of energy, introduce specific fire safety challenges that may influence both fire occurrence and firefighting operations. The reviewed studies show that most fires associated with photovoltaic systems are not caused by the solar panels themselves but rather by electrical failures, improper installation practices, inadequate maintenance, and damage to electrical components.

Causes of Fires in Photovoltaic Systems

According to Romosios, Vasilikou, and Choulakis (2018), the most common causes of fires in photovoltaic systems are faulty electrical connections, poorly executed installations, inverter malfunctions, and electrical arc faults. Arc faults represent one of the most dangerous phenomena in photovoltaic systems because they generate extremely high temperatures that can reach several thousand degrees Celsius, which is sufficient to ignite surrounding combustible materials. Buildings where solar panels are installed on roofs constructed from combustible materials or equipped with heat-sensitive insulation are particularly vulnerable.

Zamrazilova (2024) points out that an additional challenge is posed by Building Integrated Photovoltaic (BIPV) systems, where photovoltaic modules simultaneously function as building components and electricity generators. In the event of a fire, such systems may accelerate fire spread through roof and façade structures, thereby increasing risks to building occupants and emergency responders.

Research further indicates that improper system installation significantly increases the likelihood of fire occurrence. Poorly executed electrical connections, low-quality connectors, damaged cables, and inadequate surge protection are among the most common technical deficiencies leading to overheating and fire development. Meacham et al. (2012) emphasise that the growing number of photovoltaic installations requires continuous improvement of fire safety standards in order to reduce the risk of incidents.

Risks to Firefighters During Interventions

The reviewed literature confirms that fires involving photovoltaic systems present unique challenges for firefighting units. The primary hazard arises from the fact that solar panels continue generating electricity whenever exposed to sunlight. Unlike conventional electrical installations, where disconnecting the power supply eliminates the risk of electric shock, components of photovoltaic systems may remain energised even after the building's main power switch has been turned off.

According to the IEA-PVPS report (Namikawa, 2017), the most significant risks to firefighters include electric shock, arc flash incidents, falls from rooftops, restricted movement on buildings, and structural collapse caused by fire damage. A particular challenge is that solar panels are often installed on rooftops, where they may obstruct firefighter access and complicate roof ventilation procedures.

An additional hazard is the high direct current (DC) voltage generated by photovoltaic systems. According to firefighter safety guidelines, some systems can produce up to 1,500 V DC, representing a serious threat to the life and health of emergency responders. Even when current levels are limited, such voltages can result in severe injuries or fatalities due to electric shock.

Piantedosi et al. (2016) emphasise that special attention should be given to cables and connection

points between photovoltaic modules, as these locations are most susceptible to damage and arc fault occurrence. During firefighting operations, all conductors should be assumed to be energised until proven otherwise.

In addition to electrical hazards, firefighters are exposed to chemical risks. During the combustion of photovoltaic modules, harmful substances may be released, posing potential respiratory hazards. Therefore, international guidelines recommend the mandatory use of a self-contained breathing apparatus (SCBA) during interventions involving solar panel installations.

Safety Procedures and Preventive Measures

The reviewed literature indicates that risks during firefighting operations can be significantly reduced through the implementation of appropriate safety procedures. The first step involves promptly identifying the presence of a photovoltaic system on the affected building. Consequently, international standards recommend clear labelling of buildings, electrical cabinets, and major system components to ensure that firefighters are immediately aware of the additional hazards upon arrival.

Namikawa (2017) states that access corridors between rows of rooftop panels should be provided to allow firefighters safe access to fire locations. The installation of rapid shutdown systems is also recommended, as these systems reduce voltage levels in certain parts of the installation and thereby improve intervention safety.

When extinguishing fires, the use of fog or spray water streams is recommended while maintaining prescribed safety distances from electrical components. Direct solid water streams may increase the risk of electric shock and are therefore not recommended near energised system components.

Regular maintenance also plays a crucial role in fire prevention. Periodic inspections of electrical connections, cable conditions, protective devices, and thermal imaging assessments can help identify faults at an early stage and prevent fire occurrence.

Situation and Challenges in Bosnia and Herzegovina

The solar energy sector in Bosnia and Herzegovina has experienced considerable growth in recent years. Rising electricity prices, improved technology availability, and renewable energy policies have contributed to the increasing number of photovoltaic systems installed on residential, commercial, and industrial buildings.

However, the analysis of available literature and professional practice indicates that the development of photovoltaic systems has not been fully accompanied by the development of specialised firefighting procedures. Most fire departments in Bosnia and Herzegovina still lack dedicated operational guidelines for fires involving solar panel installations. Furthermore, specialised training programmes in this field remain limited.

Considering the anticipated growth of solar power installations, firefighters are expected to encounter photovoltaic systems more frequently during future interventions. Therefore, it is necessary to develop national guidelines based on international best practices, improve firefighter training programmes, and strengthen cooperation between system designers, electrical engineers, installers, and fire protection services.

The findings of this analysis confirm that proper system design, regular maintenance, the implementation of modern protective technologies, and continuous firefighter education are key factors in reducing fire risks and improving the safety of firefighting operations involving photovoltaic systems.

CONCLUSION

Fires involving photovoltaic systems represent a specific challenge for firefighting units due to the presence of electrical energy, the risk of electric shock, and restricted access to fire locations. Unlike conventional electrical installations, photovoltaic systems can continue generating electricity when exposed to sunlight, even after the main power supply has been disconnected. This characteristic significantly increases operational risks and requires firefighters to apply specialised tactics and safety procedures during emergency interventions.

The literature review revealed that the most common causes of fires in photovoltaic systems are electrical faults, improper installation practices, damaged electrical connections, inadequate maintenance, inverter failures, and arc fault occurrences. These factors can lead to overheating of system components and ignition of surrounding combustible materials, particularly in rooftop installations and building-integrated photovoltaic systems. The findings also indicate that the growing number of photovoltaic installations worldwide is accompanied by an increased need for effective fire prevention strategies and improved operational preparedness.

The analysis also highlights the importance of continuous firefighter education and specialised training programmes focused on photovoltaic technologies. As solar energy systems become more common, fire departments must adapt their operational procedures and develop the necessary technical knowledge to respond safely

and effectively to such incidents. Cooperation between firefighters, engineers, installers, and regulatory authorities is essential for improving overall fire safety standards.

Given the increasing number of photovoltaic systems in Bosnia and Herzegovina, additional efforts are needed to strengthen the regulatory framework, develop national operational guidelines, and expand firefighter training programmes. Future activities should focus on harmonising local regulations with international best practices, promoting preventive maintenance, and improving awareness of photovoltaic fire risks among both professionals and system owners. Such measures would contribute to a higher level of safety, reduce potential fire losses, and ensure effective protection of people, property, and the environment in the context of the growing use of renewable energy technologies.

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VATROGASNE INTERVENCIJE KOD POŽARA NA FOTONAPONSKIM SISTEMIMA I OBJEKTIMA SA SOLARNIM PANELIMA

SAŽETAK

Razvoj i sve šira primjena fotonaponskih sistema na stambenim, javnim i industrijskim objektima donosi nove izazove u oblasti zaštite od požara i vatrogasnih intervencija. Cilj rada je analizirati specifičnosti požara na objektima sa solarnim panelima, identifikovati glavne rizike za vatrogasce tokom intervencije te prikazati osnovne sigurnosne procedure i preventivne mjere koje doprinose efikasnijem i sigurnijem gašenju požara. Svrha rada je ukazati na značaj stručne obuke vatrogasaca i pravilnog projektovanja fotonaponskih sistema radi smanjenja opasnosti od nastanka i širenja požara. U radu će biti korištena metoda pregleda i analize dostupne naučne i stručne literature. Analiza literature pokazuje da požari na fotonaponskim sistemima najčešće nastaju usljed električnih kvarova, neispravnih instalacija, lošeg održavanja i pojave lučnih kvarova. Požari na objektima sa solarnim panelima zahtijevaju poseban pristup vatrogasnih jedinica zbog specifičnih električnih i konstrukcijskih rizika.

Ključne riječi: fotonaponski sistemi, požar, vatrogasne intervencije, solarni paneli, zaštita od požara

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