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Michaela Zamrazilova

FIRE SAFETY OF PHOTOVOLTAIC SYSTEMS

Abstract

The segments of photovoltaic systems are tested for safety and reliability during production. These systems must also satisfy the electrical safety requirements set out in the various standards and protocols to the extent defined by the country. Based on the claims of individual manufacturers, it is possible to work with the information that photovoltaic systems don‘t pose health, safety or environmental risks under normal operating conditions, if they are properly installed and maintained by trained personnel according to the requirements of regulations and standards in individual countries. With the ever-growing global trend of photovoltaic installations and countless installation variants, from traditional installations on the roof and ground to more advanced systems integrated into building facades. It is all the more important to develop installation procedures and share equipment safety and risk mitigation information. The article presents examples of fires in photovoltaic installations in the context of the intervention of firefighters. The article further clarifies the applied approaches in the field of fire safety in the Czech Republic and in the surrounding countries.

Keywords: photovoltaic system, fire safety, fire, firefighters, solar energy

A FOTOVOLTAIKUS RENDSZEREK TŰZBIZTONSÁGA

Absztrakt

A fotovoltaikus rendszerek szegmenseinek biztonságát és megbízhatóságát a gyártás során folyamatosan tesztelik. Ezeknek a rendszereknek meg kell felelniük a különféle szabványokban és protokollokban meghatározott villamos biztonsági követelményeknek is. Az gyártók állításai alapján olyan információkkal lehet dolgozni, hogy a fotovoltaikus rendszerek normál üzemi körülmények között nem jelentenek egészségügyi, biztonsági vagy környezeti kockázatot, amennyiben a képzett személyzet megfelelően telepíti és karbantartja azokat. A fotovoltaikus installációknak számtalan beépítési változata ismert, a hagyományos tetőn és talajon történő beépítéstől kezdve az épület homlokzatába integrált fejlettebb rendszerekig. Ennek megfelelően fontos a különböző telepítési eljárások kidolgozása, valamint a berendezések biztonságával és a kockázatcsökkentéssel kapcsolatos információk megosztása. A cikk példákon keresztül mutatja be a fotovoltaikus létesítményekben bekövetkezett egyes tűzeseteket. A szerző emellett pontosítja a Cseh Köztársaságban és a környező országokban alkalmazott tűzbiztonsági megközelítéseket.

Kulcsszavak: fotovoltaikus rendszer, tűzbiztonság, tűz, tűzoltók, napenergia

1. INTRODUCTION

In case of a fire on the photovoltaic system, it is necessary to adapt the fire extinguishing to take account of the installed photovoltaic equipment and the associated potential hazards. Dangers for firefighters include electric shock, slipping and falling from roofs, roof collapse, and fire hazards of other materials in the area. Research and analysis are available in each country to protect firefighters and mitigate the risks of intervention, such as the 2018 British Research Group Building Research Establishment (BRE) [1] or the 2013 analysis published by TÜV Rheinland in Germany. Energie und Umwelt GmbH [2], which provide information on how to proceed during and after fire fighting. This article aims to summarize the approach to fire safety in the installation of photovoltaic systems in selected countries such as the Czech Republic, Germany, Austria and Slovakia and to highlight best practices.

At the same time, the article identifies the potential dangers associated with the intervention, which could help knows what is what both users and stakeholders in the field of solar energy, from the perspective of firefighters and serve to support measures that could minimize these risks and aren‘t implemented in the country.

2. PRINCIPLE OF PHOTOVOLTAIC POWER PLANT

The principle of a photovoltaic power plant is based on the photovoltaic phenomenon. The phenomenon occurs *"when a photon with sufficient energy releases an electron from the valence band into the conduction band. The "missing electron" will remain in the valence band, a.k.a. hole, which can be considered as an elementary positive charge "*[3]. The primary material for photovoltaic cells is silicon. To produce electricity, it is necessary to add impurities to the crystal lattice of silicon, in the form of phosphorus (type N - one excess electron) or boron (type P - one hole). When connecting N and P type layers, the PN junction occurs, which creates a small area of spatial charge and an electric field [4].

Based on the above principle, a photovoltaic system converts solar energy directly into electrical energy using several solar modules (chains) electrically connected in series. In the case of a grid-connected photovoltaic system, the inverters help to convert the direct current generated in the solar modules into alternating current, which can then be fed into the grid via transformers. The system is shown in Figure 1.

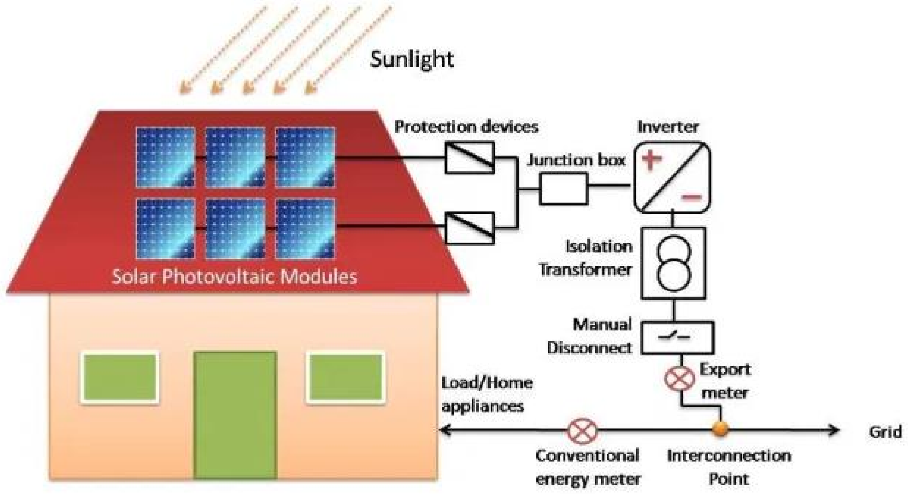

Figure 1- The plan of photovoltaic system. Source: Green Clean Guide, 2013 [5].

When installing in detached houses, often only modular chains are used, so they can be connected directly to the inverter and the above-mentioned generator junction box is omitted. In the case of larger systems, generator junction boxes are used for parallel connections. Very large systems and systems with many separate inverters use junction boxes that connect multiple lines of generator junction boxes. The generator connection box contains connection terminals and disconnection points, or chain fuses and chain diodes. Generator junction boxes often include integrated surge arresters to conduct surges to ground. The equipotential bonding or earthing conductors therefore lead to the generator distribution boxes [2].

The individual solar panels can be connected in series, in parallel or by a combination of serial and parallel connections. Serial connection (connection of positive and negative poles), increases the output voltage of the power plant and is used in systems supplying electricity to the distribution network. On the contrary, for local use (a.k.a. isolated systems) with a possible backup of energy in accumulators, a parallel connection is used (interconnection of positive and negative poles, cells or entire panels). This connection increases the generated electrical power even at low output voltage [6].

The required output direct current (DC) voltage or even alternating current (AC) voltage is corrected by semiconductor converters or inverters. They convert DC voltage to other

DC voltage (e.g. rechargeable batteries), or DC voltage to AC voltage (to classic 230 V AC voltage). Another component is a possible backup device consisting of batteries, which is charged in the event that the photovoltaic system produces more energy than is consumed and is discharged in the event of higher consumption. To redistribute energy between the panel, batteries and appliances, a.k.a. charge controller is used, which is used for controlled charging and protection against overcharging [6].

Cabling is an significant part of photovoltaic systems. It must meet several conditions, namely long-term stability of electrical and mechanical parameters, resistance to temperature, ultraviolet radiation, ozone, wind, hydrolysis [6].

3. EXAMPLES OF FIRES ASSOCIATED WITH PHOTOVOLTAIC SYSTEMS

In the Czech Republic, the Fire and Rescue Brigade of the Czech Republic registered 15 fires connected with photovoltaic systems in 2019. It was primarily a fire from a switchboard, inverter or batteries and a subsequent fire in the roof location, but there was also a spread of fires to the entire family house or business building. However, in only one case did the damage to property exceed 10 million crowns (EUR 400,000) and there were no casualties.

In the United Kingdom, the BRE Scientific Group analyzed over 50 firefighting interventions in 2017. According to the BRE report, 36 % of fires were caused by incorrect installation, 12 % by defective products and 5 % by incorrect installation design [7]. One example is the fire of a new apartment building in East London (Figure 2) with damage of more than one million pounds (EUR 1.1 million), which occurred in 2017. The fire was extinguished by 80 firefighters who had 12 fire trucks at their disposal and two helicopters. The fire was localized by the units in 3 hours [8].

Figure 2 - Fire in Bow Wharf. Source: Stoker, 2017 [7].

In Germany, an analysis was published in 2015 by TÜV Rheinland Energie und Umwelt GmbH, which analyzes interventions in 2013. From the beginning of the installations until January 2013, approximately 1.3 million photovoltaic systems with a total output of over 30 GW were installed in Germany. 430 cases of fires in photovoltaic systems were analyzed, of which 85 fires were caused by incorrect installation or product defect [2]. An example is the hall fire in Walldorf in 2014 (Figure 3). The photovoltaic panels ignited together with the plastic roofing. Incorrect installation and improper selection of the roofing led to a fire.

Figure 3 - Fire on the roof of the hall in Walldorf. Source: wiwa-lokal.de, 2017 [9].

4. RISKS ASSOCIATED WITH EXTINGUISHING

A fire caused by or in the vicinity of a photovoltaic system can bring various risks to firefighters, whether there is a risk of falls, electric shocks, collapse of the roof structure or total collapse of the roof structure. Due to these dangers, in the Czech Republic, the incident commander - a officer of the Fire and Rescue Brigade - is entitled to interrupt or terminate the intervention if the life of the intervening firefighters would be immediately endangered.

In addition to the direct risk of fire from the aforementioned defective photovoltaic system, the presence of a photovoltaic system on the structure can complicate firefighting for other reasons, for example the weight of the photovoltaic system can lead to a faster collapse of the roof on a burning structure. On a sloping roof, there is a risk of slipping on the glass surface of the solar panel, which can lead to a fall from the roof. It should also be borne in mind that if photovoltaic systems are exposed to the sun, they remain energized, even after the building's mains connection has been deactivated. If live wires are exposed due to improper installation or damage, an electric shock may result [10].

Complications in extinguishing can also bring a place of intervention, the main points include the following points:

- panels of photovoltaic systems are not visible from the ground (these are primarily straight roofs);
- in the neighborhood of the building there are no suitable boarding areas for high-altitude firefighting equipment;
- it is not possible to transport the fire extinguisher to the entire fire area in the required intensity;
- the presence of other technological equipment on the building (e.g. lightning conductors, ventilation, skylights, heat and smoke removal equipment, antennas) in which there may be electrical voltage;
- the location of the control (disconnection) elements of the photovoltaic system is not known to the firefighters;
- endangerment of animals placed in the area of the photovoltaic power plant;
- the possibility of fire equipment getting stuck on an unsuitable access road;
- burning of grassland in times of drought [11].

5. IMPLEMENTATION OF FIRE SAFETY ELEMENTS IN THE CZECH REPUBLIC AND SELECTED COUNTRIES

Fire safety elements can give firefighters better control over the risks associated with photovoltaic systems. Fire safety elements can include, for example, circuit breakers and disconnect switches. Circuit breakers can reduce the occurrence of fires and electric shocks from live conductors. Disconnect switches can reduce the number of wires that remain energized from illuminated photovoltaic panels. Requirements for the installation of these elements vary from country to country.

In the Czech Republic, there is support in normative legal acts [12, 13, 14], which is followed by approximately 11 technical standards dedicated to the installation of photovoltaic systems. What is possible to tackle with in the Czech Republic in the field of state fire supervision is the fact that for installations with an output of up to 20 kW (corresponds to installations and consumption for a family house), it isn‘t necessary to solve a building permit or notification to the building authority. [15] Therefore, the Fire and Rescue Brigade of the Czech Republic is not informed about these performed installations, and therefore it isn‘t possible to prepare firefighters for this situation to intervene on objects with a photovoltaic system installed.

For larger installations of photovoltaic systems, a safety element in the form of a "CENTRAL STOP" button is installed. This button doesn‘t completely turn off the power flow because the wiring sections from the panels to the drive remain energized. The flow is interrupted only if the panels are mechanically damaged. Despite the risk of permanent equipment under voltage, a button is needed and facilitates the intervention of firefighters. One of the contacted private companies installing photovoltaic systems on the roofs of detached houses confirmed the author of the article that it is already introducing the installation of the "CENTRAL STOP" button for installations in detached houses. This situation can be described as positive and beneficial and approaching the standards in countries such as Austria or Germany.

It is in Austria that the rules for installation are the same regardless of the installed capacity. Since 2013, the ÖVE Directive R11-1 [16] on fire protection requirements has been in force in this country. For example, the installation of performance optimizers is limited by this directive, and the switching control must operate on the principle of fail-safe. It also introduces a switching device that monitors the voltage, if the network is turned off, the DC voltage in the house is also turned off. Switching is also possible by the network operator or the firefighters remotely. Furthermore, the obligation to place markings in the entrance area of the house is introduced, which is shown in Figure 4 [17].

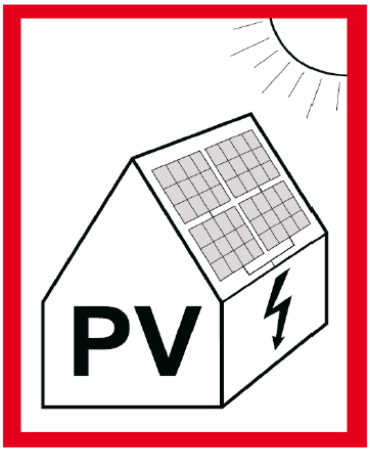

Figure 4 - Designation of a house with a photovoltaic system Source: Becker, 2014 [17].

In Germany, guidelines on fire protection for the installation of photovoltaic systems are given in a document of the German Solar Industry Association entitled "Planning, construction and maintenance of photovoltaic systems, focusing on fire protection" [18]. This document is a set of recommendations, it also contains individual provisions that are mandatory. Mandatory elements include the designation of the installation of the photovoltaic system (the mark is similar to that in Austria), which is located in the main power supply box and main distribution panels, there is also a schematic drawing of the photovoltaic system [18].

It is also mandatory to install a fire protection DC voltage line on the outside of the building, only AC voltage lines are allowed inside the building, the inverter itself is located outside the building. A remote DC voltage switch for firefighters is also installed in the main fuse box in the building [18].

In Slovakia, since January 2013, on the basis of the standard, STN 92 0203 Fire safety of buildings - Continuous supply of electricity in the event of a fire [19], it is required to ensure safe shutdown of electricity supply. It can be deduced from this standard that the switch-off must take place directly at the solar panels. This can be realized by means of a mandatory switch of the photovoltaic device, which is to be located close to the main switch. [20]

6. CONCLUSION

As the installation of photovoltaic systems has become commonplace, it is necessary for the executive and legislative authorities to cooperate with fire brigades and corporate to install photovoltaic systems for the preparation of mandatory document. This publication should serve not only to address potential risks to firefighters, but also installation procedures. In addition, a document should be created containing information for future and current users of these systems.

Installation procedures, firefighting instructions for firefighters and fire safety equipment that can reduce the risk of fire and / or injury are now used in some countries, such as Germany or Austria. Differences in implementations over time and country provide information to identify best practices for minimizing risks in firefighting operations. In the future, preventive measures of cooperation between experts, firefighters and representatives of the legislature will be essential for the further development.

Education of the non-expert audience plays an important role. It is at the outset in the Czech Republic and isn‘t overemphasized at the expense of the benefits of installing photovoltaic systems, obtaining grants and quantifying savings. Awareness is one of the basic pillars of fire prevention.

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Michaela Zamrazilova
Department of Military Science Theory,
Faculty of Military Leadership, University of Defence
E-mail: mzamrazilova@gmail.com
ORCID: 0000-0001-9060-7508