A Study on Fire Risks to Firefighters in the Building with Photovoltaic System

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Abstract

Among all the available renewable energy sources, solar energy is the most abundant and is an inexhaustible source of clean energy. Moreover, photovoltaic (PV) module technology has been widely used in modern industry to directly convert solar energy into electricity to meet people's demands. The photovoltaic (PV) industry and solar cell panel installation capacity are rapidly expanding in Taiwan. In practice, many factors can cause fire hazards with PV systems, and this danger increases as such systems scale up, with high voltages of 600 to 1000 V posing a greater risk than less powerful systems. However, a limited body of knowledge and insufficient data exists for the fire service community to fully understand the risks of PV system catching fire to the extent that standard operational procedures have been developed in Taiwan. The object of this study is to document firefighter vulnerability to electrical and casualty hazards when mitigating a fire in a building involving photovoltaic system. The results of the survey would provide a technical basis for the fire service to examine their equipment, tactics, standard operating procedures and training content.

Keywords: Renewable energy, Photovoltaic, Fire risk, Firefighter path planning

Introduction

Both the PV industry and solar cell panels installation capacity are rapidly increasing in Taiwan, and the government launches many policies that aim to facilitate the development renewable energy technologies, as shown in Fig. 1. For example, the Bureau of Energy, at the Ministry of Economic Affairs, has set out a plan for "one million rooftop PVs", with an office responsible for this project opening in May 2012. The aim of this is for Taiwan's rooftop PV capacity to reach 847 MW in 2015, 2120 MW in 2020, and 6,200 MW in 2030, with the focus first being on rooftop systems, and then ground-based ones [1]. However, although BIPV systems have been developed in many countries in order to achieve zero energy buildings (ZEB) or nearly-zero energy buildings (NZEB) [2–8], the related studies seldom consider the occurrence of fires or the fire-resistance of PV systems.

In practice, many factors can cause fire hazards with PV systems, and this danger increases as such systems scale up, with high voltages of 600 to 1000 V posing a greater risk than less powerful systems fire. Fires can start due to the open circuiting of the DC circuit and bypass diodes, or because of ground faults. Moreover, the faulty installation of BIPV systems can also lead to fires. The toxic materials that are used in PV systems, such as the CdTe or CIS in thin-film modules, are another danger when fires occur, as these can cause pollution and make installing BIPV systems less attractive [9]. A number of fires have occurred with PV systems, such as a rooftop fire at the Sandia National Labs in Buerstadt, Germany [10], and at a Target store at Bakersfield, California [11-12]. A large solar PV fire occurred in May 2015, at Apple's factory in Arizona, as shown in Figure 2 [13]. The report stated that thousands of solar panels are at risk of setting roofs on fire because of an electrical fault, Dutch authorities and media warned, with 15 roof fires already reported in Europe [14]. A cause of fires may be that the connectors of the junction box create an electrical arc and overheat, generating malfunctions [14]. Broken PV modules are shown in Figure 3. In July 2016, solar panels in the Taipei Water Park caught fire. It seems that a wire of a PV module broke due to frequent movement.

While many fire-safety factors, such as the flame spread, smoke spread, toxicity, impact of fire-fighting operations, and so on, should be considered in green building codes and standards [15-16] , more work still needs to be done to both study and establish the related codes and standards for PV systems. Furthermore, Factory Mutual (FM) Global report published in 2010 indicated that the occurrence of a fire will increase the life-cycle carbon emissions of a building by ~14 %, and thus there are considerable risks to developing BIPV systems without considering how they can be fire-proofed [17-18]

In this study, we are interested in investigating the awareness of the firefighters on the PV fire.

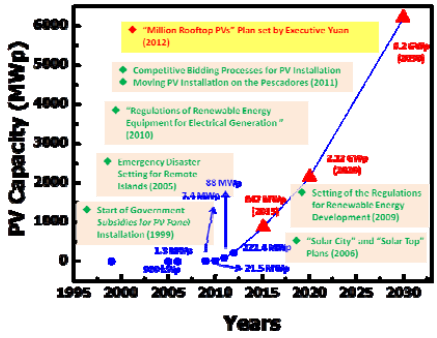

Figure 1 The installation capacity of PV systems in Taiwan

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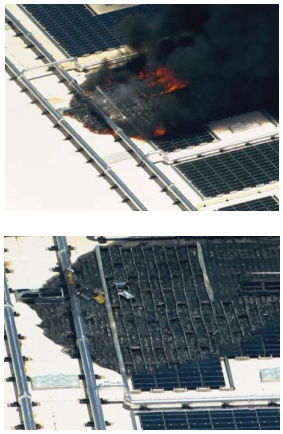

Figure 2 Case of PV Module Fire at Apple Facility in Mesa

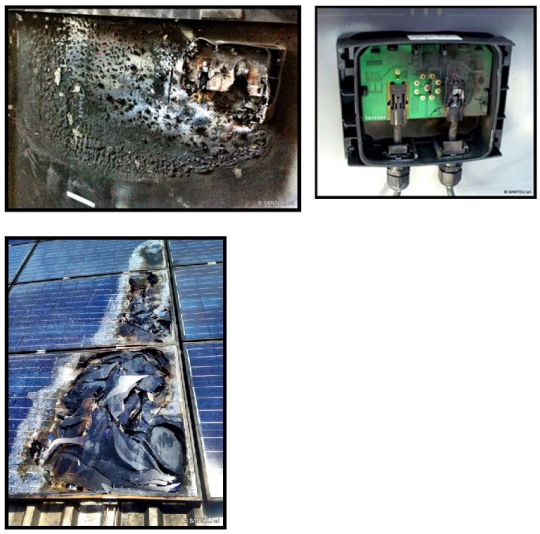

Figure 3 Case of PV Module Fire at Scheuten Solar in Netherlands

Survey

The survey was designed to investigate the awareness of the firefighters on the PV fire. The following parameters were investigated for the PV fires: origin, cause, and risk of PV fire, safety knowledge and demand of training program.

280 firefighters were chosen in this study and the questionnaires with 15 questions were given via personal visit. 280 valid samples were collected. Figs. 4 and 5 show the characteristics of the respondents in this survey. The average working experience of respondents was 10.5 years (all with firefighting background). Fig. 5 show that most of the respondents (60.3%) held a college degree, 22.8% held a bachelor's degree, 10.7% held a master's degree, and 6.7% held a senior high school degree.

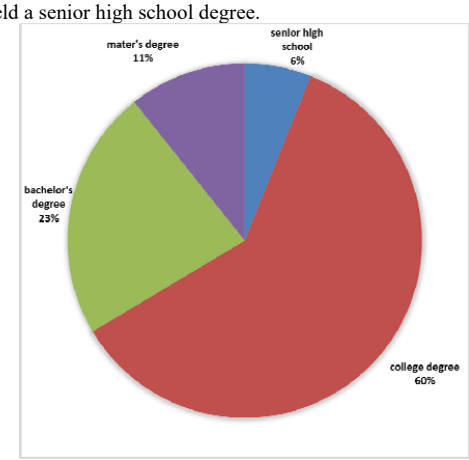

Figure 4 Percentage breakdown of respondents' education group

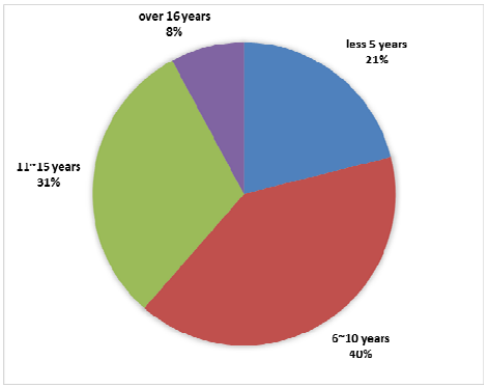

Figure 5 Percentage breakdown of respondents' working age group

Results and discussion

The survey results indicated that only 26% of the respondents had the experience of participating in the fire-fighting on the PV fire. Figure 6 shows that only 70% of the respondents agreed that the occurrence probability of PV fire is high. However, for the risk of PV fire accident survey, it was found that 91% of the respondents felt that there is a significant risk in the PV fire accident, and only 1% felt that the risk of PV fire accident is very low (as shown in Figure 7).

Figure 8 shows the possible origins of PV fire accidents; fire accidents occurred most frequently at the circuit, at a rate of about 39%, much more than at PV panel (32%) and inverter (23%) laboratories. Figure 9 shows details of the ignition factors causing PV fires based on the views of respondents, where high current overheated (44%) and junction-box fault (35%) are the most.

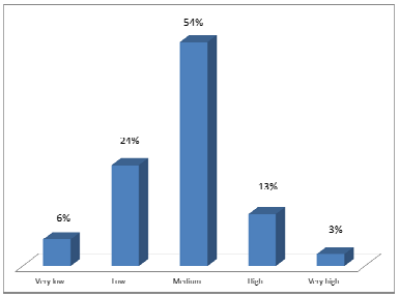

Figure 6 Percentage breakdown of the views of respondents' on the occurrence probability of the PV fire accident.

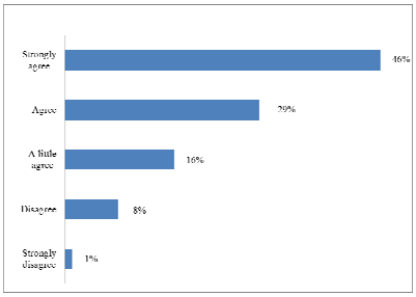

Figure 7 Percentage breakdown of the views of respondents' on the significant risk in the PV fire

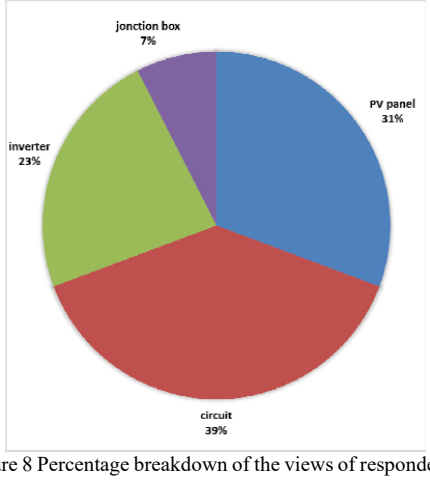

Figure 8 Percentage breakdown of the views of respondents' on the origins of PV fire

Regarding the fire safety performance of PV system, nearly 97% of respondents felt that current PV system had room for improvement and only 1% felt that there was no need (as shown in Fig. 10). It is implied that the issues related to the fire-resistant characteristics of BIPV system should be an important consideration for BIPV system can be widely used in the building. Fig. 11 indicated that only 30% of the respondents understand the exact standard operation procedures during the PV fire rescue. In terms of whether PV fire safety training should be included into regular firefighter training program, Fig. 12 indicated that over 97% of respondents thought that it should be included, yet presently few of them have it. These results indicate that most training programs need improvement, especially for safety skills training curricula in PV fire.

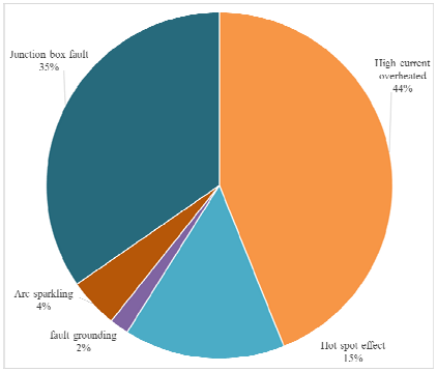

Figure 9 Percentage breakdown of the views of respondents' on the ignition factor of the PV fire.

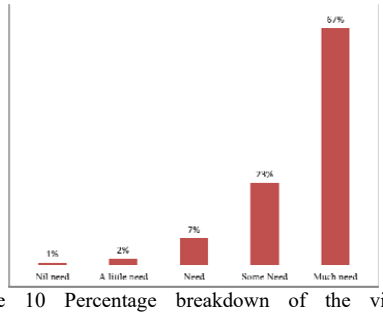

Figure 10 Percentage breakdown of the views of respondents' on the necessity of improving the fire safety function of the PV system.

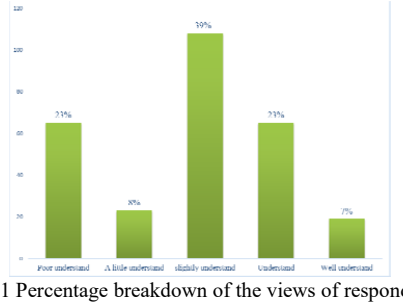

Figure 11 Percentage breakdown of the views of respondents' on whether they understand the SOP during a PV fire rescue.

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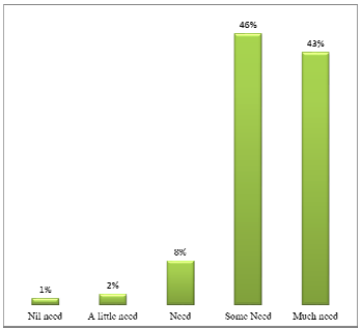

Figure 12 Percentage breakdown of the views of respondents' on the necessity of introducing the PV fire safety training into the regular fire fighter training program.

Conclusion

With the increasing of PV installation capacity, the fire risk assessment of the PV system becomes the focus on the fire workers. A survey to investigate the fire risk of the PV fire and to examine their equipment, tactics, standard operating procedures and training content from the views of the firefighters was conducted in this study. The survey results indicated that only 26% of the respondents had the experience of participating in the fire-fighting on the PV fire. Over 90% of the respondents indicated that there is a significant risk in the PV fire accident. The survey also revealed that only 30% of the respondents understand the exact standard operation procedures during the PV fire rescue and PV fire safety training should be included into regular firefighter training program.

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