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Summaries of Causes, Effects and Prevention of Solar Electric Fire Incidents

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ABSTRACT

Currently the number of fire incidents involving photovoltaic (PV) systems are increasing as a result of the strong increase of PV installations. These incidents are terrible and immeasurable on life and properties. It is thus very important to understand the causes, effects and how prevent the occurrence of incidents. This study aimed to summarize the causes, effects, and preventions of solar electric fire incidents. Literature review was adopted to summarize the study. The summarized and discussed result from literature found that arcing, hot spot, weather conditions, improper installations and maintenance, and systems mechanical and electrical failures are the main causes solar PV fire incidents. The effects of incidents are terrible on life and properties. The result also discussed the precautionary measures in detail on how to prevent PV systems and firefighters before and during fire incidents. Therefore, it is expected that the study is comprehensive for manufacturers, installers, professionals to build and improve understanding of causes, effects and prevention of solar electric fire incidents in residential, industrial and commercial applications.

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1. INTRODUCTION

Rising concerns about climate change, the health effects of air pollution, energy security and energy access, along with volatile oil prices in recent decades, have led to the need to produce and use alternative, low-carbon technology options such as renewables [1]. When compared to other renewable energy sources, solar electric is relatively safe, and its usage are highly welcome. Solar electric system is the system through which sunlight is directly converted to electricity. It is needed in residence to power domestic appliances and lighting purposes, in the industries to drive various machines, equipment and processes, and by commercial and institutional consumers for the provision of services and driving various devices [2]. Applications are normally smaller than other system types and are often used for small-scale projects in rural areas, as a solution in developing countries, as well as for residential households willing to disconnect from the grid (typically not the most economic or efficient option) [3]. Solar powered electricity generation is experiencing rapid growth [4]. Factors contributing to this growth are strongly considered due the safety and reliable of the PV systems. PV systems do not emit any material during their operation; however, they do generate electromagnetic fields (EMF), sometimes referred to as radiation [5]. These systems do not pose health, safety, or environmental risks under normal operating conditions if properly installed and maintained by trained personnel as required by electrical codes [6].

Despite the technological advancement in fire safety and prevention, fire disaster remains the leading cause of lives and property loss at commercial facilities worldwide and fire could lead to the premature winding up of an organization no matter how big it is [7]. The word fire refers to the natural phenomenon that occurs whenever a combustible fuel comes into contact with oxygen from the air and gives out light, heat and smoke [7]. The number of PV systems around the world is increasing and the systems are aging with little to no inspections and maintenance [8]. Accordingly, PV power plants show a set of proper causes of electrical fire ignition [9]. Various fire events involved roof housing photovoltaic plants, some with bad damage of the building roof and with the consequence of large compartment fires inside the structure, consequence of fire spread inside the building [10]. The possibility of fires resulting from or intensified by PV systems may trigger concern among the general public as well as among firefighters [5]. Among these fire risk has caught the attention of both Authorities, plant managers and any other stakeholders (such has owners of the property) due to the high number of fires involving solar plants [10]. Increase in the cases of fire incidents has been deepening over the years, recording significant losses of life and properties especially at larger systems.

In the wake of the accelerated growth of the PV industry, the reliability of PV technologies has recently caught considerable attention from researchers, manufacturers, and investors [11], which include safety. There are few reports on the incidents of fires arise directly from solar electric systems. Poor understanding of such incident may stymie its consumption. To stimulate primary knowledge and understanding of fire incident associated with solar electric system, several studies have been carryout on the safety of PV systems, that include: Wu et al. [12] conducted study on a Review for Solar Panel Fire Accident Prevention in Large-Scale PV Applications, in order to minimize the risks of fire accidents in large scale applications of solar panels, the review focuses on the latest techniques for reducing hot spot effects and DC arcs; N. C. Clean Energy [5] on health and safety impacts of solar photovoltaics; Namikawa et al. [6] conducted a study on photovoltaics and firefighter's operations: Best practices in selected countries; Neelkanth and Narendra [13] studied fire hazard and other safety concerns of photovoltaic systems; John and Sarah [14] worked on how can we make PV modules safer; Zhao et al. [15] analysed fire risk associated with photovoltaic power generation system; Yang et al. [16] carried out experimental studies on the flammability and fire hazards of photovoltaic modules; Slaughter [17] published book on fundamentals of photovoltaics for the fire service; Moskowitz and Fthenakis [18] investigated toxic materials released from photovoltaic modules during fires: Health risks; BRE [19] reviewed work on fire and solar PV systems; Johnson et al. [20] carried out research on electrical and thermal finite element of arc faults in photovoltaic bypass diodes; Dhere and S. Shiradkar [21] studied fire hazard and other safety concerns of photovoltaic systems; England [8] carried out an investigation into arc detection and fire safety aspects of PV installations; Häberlin et al. [22] assessed PV and Fire brigate safety: no panic, but realistic assessment of danger and possible countermeasures; Tammasini et al. [23] investigated the risk of electrocution during fire suppression activities involving photovoltaic systems; Tabaddor and Backstrom [24] investigated the fire performance of crack mounted PV modules on roofing assemblies; Cancelliere et al. [25] investigated the behavior of the electrical parameters of PV modules subject to a flame ignition; Fiorentini et al. [10] analysed fire risk of photovoltaic plants: A case study moving from two large fires: from accident investigation and forensic engineering to fire risk assessment for reconstruction and permitting purposes; Backstrom and Dini [26] carried out research project on firefighter safety and photovoltaic installations; Ohde and Hattier [27] published book on fire safety procedures for photovoltaic systems and battery storage; Ramali et al. [28] carried out review on safety practices for firefighters during photovoltaic (PV) fire; Hayes-White [29] published book on solar photovoltaic (PV) system safety and fire ground procedures. All the above studies are importance in improving the safety of the PV systems. Therefore, to move one step further in bridging the gap of studies, this study summarizes the causes, effects and prevention of PV systems from fire incident, with emphasized to available literature review. With the hope that this study would assist in decision making process to reduce the causes of fire incident.

2. METHODOLOGY

The method adopted in this study was to summarize and discuss the causes, effects and preventions of solar electric fire incident based on some review literature and some sought of expert opinion, with emphasized to the following subsections: Section 1. – Causes of solar electric outbreaks, Section 2. – Effects of solar electric outbreaks, Section 3. – Preventions of solar electric outbreaks.

3. DISCUSSION

3.1. Causes of Solar Electric Fire Incidents

One of the most valuable characteristics of photovoltaic (PV) technology is its high stability, with potential operational lifetimes of over 30 years [11]. As a technology deployed on residential and commercial buildings, it is critical that PV not cause damage to the buildings nor harm the occupants [9]. However, it is important to consider the cause, effect and prevention solar electric fire with respect to an overview of reviewed literature and research results as well as expert opinion on fires incident and potential strategies to minimize it, as follows:

A. Arc and Hot Spot Causes of Solar Electric Fire Incidents

In the very rare cases where the PV system was the main cause and source of the fire, the main causes relate to ground or arc faults [1]. An arc is a gas discharge existing between two electrodes in which an electrical potential difference created by ionization, which in turn lead to uninterrupted flow of current. Although, any open circuit in a series circuit or an additional ground fault in a parallel circuit can cause arcing [13]. Open circuit diodes can give rise to overheating within partially shaded modules, potentially causing fires [30]. Johnson et al. [20], describes the phenomenon and models the thermal behaviour of arcing within by-pass diodes, showing that corrosion in soldered joints can lead to arcing that results in the ignition of surrounding polymer materials within 0.1 seconds. Depending upon the materials, no matter how small the voltage and current of an electric arc is, its emits very bright light in both the visible and UV light ranges. Exposed to UV, the weather and rodents, cables, connection points and other components can degrade to the point where there is a break in the circuit and over this gap the current from the PV array can continue to flow causing an arc [8]. The direct current (DC) produced by PV systems is capable of producing a sustained arc that is more likely to trigger a fire than the alternating current (AC) that is obtained on the grid side of an inverter [6]. Mostly incident exists at voltages contact of greater than 50 VAC or 120 VDC. Arcing occurs when electrical energy flows through resistive media such as air, matching the frequencies (>60 Hz), producing non-stationary EMF, known as extremely low frequency (ELF), having less energy than commonly encountered types of non-ionizing radiation. [31] has suggested that the risk of arcing from the cell-string connector and clamp-cable connection is highest because of the moderate probability of their occurrence and highly dangerous nature due to the possibility of long-burning electrical arcs. Some aging solar panels, especially those with components not meeting their specified standards, can spontaneously ignite under high temperatures and sunlight due to chemical reactions and hot spot effects [14]. According to Johnson et al. [20], arc generates a high temperature plasma that ignites surrounding materials and subsequently spreads the fire to the building structure.

The hot spot effect and aging of PV panels were found responsible in previous fire accidents can be caused by the dust density around the PV array, the ambient temperature, and the material structure of the PV array [12] or when the PV module is partially blocked, and part of the solar cell string becomes a reverse bias and dissipates energy in the form of heat [12]. The hot spot effect occurs if the temperature exceeds 5% above the standard temperature in a period in the standard testing condition (STC, 1000 W/m2, 25 °C) [12]. The heat and electrical energy from the arc can ignite nearby materials and start a fire which could cause further damage [8]. Accordingly, fire outbreaks occur when heat or heating objects are exposed to combustible materials such as fuel, among others [32], also cause the risk of spontaneous combustion [15]. When an arc starts there is no off switch to easily cut the power from the PV array so the arcing situation can continue [8]. Henceforth, it is understood that hotspots are likely to occur in PV installation, yet it is not fully understood as to whether PID impacted PV modules' hotspots and the potential increase in their temperature [11]. [11] gives evidence that solar cells attacked by PID can develop hotspots, increasing the temperature of the cells from 25 °C to 45 °C. However, hotspots developed in the cells affected by the other two types of defects, blackout, and central breakdown area, caused an increase in the cells surfaces temperature from 25 °C to approximately 40 °C [11]. In addition, the output power losses due to blackout defects and central breakdown areas are much higher than the cracks, reasonably because more area in the cell has been damaged [11].

B. Weather Causes of Solar Electric Fire Incidents

The majority of fires involving PV systems are not caused by the PV system itself [19]. And a high quality, safe and durable PV module delivers the expected rated power (Wp) withstanding extremely wide range of environmental conditions [33]. This is because solar PV were designed to Standard Test Condition (STC), specifying that every PV module works under the nominal conditions of an irradiance value of 1000 W/m2 and a temperature of 25°C, in real operating conditions. These conditions practically never occur during normal outdoor operation as they do not take into consideration the actual geographical and meteorological conditions at the installation site [34]. To increase the reliability, safety, and the service life of PV modules one has to understand the causes of solar electric fire incidents due extreme weather conditions. At the same time, extreme weather events are clearly affecting the solar industry and are becoming the biggest cause of failure of any PV plant [1]. Despite, certain types of modules are more resilient to temperature increase than others [35]. According to Yang et al. [16], two factors pose dangers to photovoltaic systems, namely, temperature and heat flow density. Increase in temperature is one of the most weather events that causes fire incident. Al-Baghdadi et al. [36] investigates how a PV module performs throughout the year in a hot region by considering the variations in cell temperature resulting from changes in ambient temperature and solar radiation every day. Increase in temperature is accompanied by a significant increase in the solar radiation intensity, which enhances the production of the solar panel [37]. Here an inhomogeneous distribution of the solar irradiance and uneven flow of the current in the busbars would typically cause an irregular distribution of the heat across the solar cell surface [11]. Temaneh and Mukwekwe [38] concluded that the increase in PV panel temperature is most important factor that causes the increase in its power losses. Increasing the temperature of the solar panel by 1°C causes the current to rise by about 0.068%, and the voltage drop by about 0.34% which reduces the output power by 0.489% causing the electrical efficiency to deteriorate by about 0.586% [37], and its values were 10.7%, 11.3% and 11.7% at temperature 55°C, 45°C, and 35°C, respectively [37].

The heat transfers between the PV panel and the surrounding environment is driven by a global heat transfer coefficient, which describes the radiative and convective exchange processes [39]. Poor heat transfer causes additional module temperature increase about 10°C [40]. PV modules installed at rooftop may also affected by heat flow. According to [15], if roof temperature and heat flow density are high, the photovoltaic systems on the roof are at great risk. Moreover, potential-induced degradation (PID) of photovoltaic (PV) modules is one of the most severe types of degradation in modern modules, where power losses depend on the strength of the electric field, the temperature and relative humidity, and the PV module materials [11]. In fact, the chemical reactions that cause degradation of solar modules double for every 10°C increase above ambient temperature (around 25°C) causing their lifetime, as well as their voltage output, to shrink [16]. Therefore, increase in PV module temperature, heat flow between PV and environment and potential-induced degradation (PID) of photovoltaic (PV) modules are the main causes of fire incident due to the effects weather.

C. Electrical and Mechanical Causes of Solar Electric Fire Incidents

Solar power systems are complex electro-mechanical systems with numerous individual components. It is an electrical device that combines mechanical and electronic circuitry in changing or converting DC (fed in from the solar panels) to AC [41]. Normally they are relatively independent and safe, but they can become risk when exposed to fire. Heat from a small flame is not adequate to ignite a PV panel, but heat from a more intense fire or energy from an electrical fault can ignite a PV panel [16]. Electrical fires may involve combustible metals - especially alkali metals like lithium and potassium, alkaline earth metals such as magnesium, and group 4 elements such as titanium and zirconium [42]. In principle, there is a risk of toxic materials evaporating into the air in case of CdTe or CIS thin-film modules affected by fire [13]. Likewise, polymer content, like plugs, clamp connectors, fan, capacitors, housing, surge arresters/varistors, connectors, switches, cable inlets and outlets, cable penetration holes, cable trenches, and cable trench interfaces, occur inside an inverter, along with passive, electronic and power-electronic components, etc are combustible and may pose a "normal" fire risk. Tabaddor and Backstrom, [24] strongly suggests that the presence of a rack mounted PV module on a roof could adversely affect the fire performance of the roofing system. The high operating temperatures designed PV systems could result to the fire incident.

Other causes of fire incident include:

- Scratches, dents and cell or glass fractures on PV module might cause fire incident during usage.
- Battery overcharge typically cause fire incident, because it's plastic casings and spilled electrolyte can react with other metals to cause combustion process, toxic fumes, as well as existing flammable or explosive gas.
- overload, for example, refrigerators, washing machines and dishwashers are usually not capable of working over 24-hour scheme because solar electric system always work around limit. Overworking it might cause fire incident.
- High DC input voltage. The dependency of the inverter efficiency on the DC input voltage is very complex phenomenon that still lacks a full physical explanation [20]. Inverter strongly rely on the DC input voltage as well high input voltage might lead to its damage thereby causing fire incident.

D. Installation and Maintenance Causes of Solar Electric Fire Incidents

Photovoltaic arrays of photovoltaic power generation systems are mainly installed on the roof of a building, which can be threatened by building fire [15]. Rooftop solar PV reduce the cost of getting permission, financing, zoning, net metering, maintenance and interconnection processes for residential, industrial and commercial installations. Although, PV modules voltage are not that high than other sources electricity. The tendency towards increasing large PV systems has led to the enrichment of DC voltages of 1,500 V and even more. Many of the PV systems on buildings are of sufficiently high voltage (300 to 600 Volts dc) to present potential hazards [43]. Consequently, whenever sufficient voltage is developed by a number of PV modules in series, there is a risk of electric shocks [25]. Due to that, installing a PV system on a building worsens the pre-existent fire risk level and increases fire severity compared to a building without a PV system [44]; [28].

In most cases the PV systems are safe and reliable, but incorrectly specified or installed isolators can cause fires, damage the reputation of the solar power industry, or worse, cause loss of life [45]. [46] posited that improper electrical fittings, use of substandard electrical materials, defective generators, power fluctuations resulting from frequent power outages and illegal tapping from the national grid are some of the possible causes of fire outbreak. According to BRE [19], causes of fires initiated by PV systems: Design errors; Installation errors; Product defects; Inadequate Operation and Maintenance (O&M). Also according to [47], the causes of such fires include erratic power surges, illegal electrical connections, improper electrical fittings, substandard electrical materials, and use of indoor generators. Other the causes of fire incidents been identified by researchers include bush/waste burning [48], use of faulty electrical appliances, use of sub-standard electrical materials and bad workmanship [7], child fire play [49], faulty electrical outlets and old, outdated appliances [50], electrical fault/wiring, political reasons, negligence among others are the causes of fire disaster in the area with electrical fault/wiring [51], careless in the handling electrical equipment, storage of chemicals and flammable substances [32].

3.2. Effects of Solar Electric Incidents

In an attempt to boost growth of solar electric system, the effect fire incident has to be considered. Researchers do not generally believe these risks to be substantial given the short duration of fires and the relatively high melting point of the materials present in the solar modules [52]. However, with frequent occurrence of faulty, system components can affect the sustained interest of end-users to use solar PV systems [53]. The possibility of fires resulting from or intensified by PV systems may trigger concern in buildings. When the solar panels catch a fire, it not only results in power generation reduction but also causes secondary damage such as toxic gas emission [12], electric shock, burn injury, building's structure collapse, bursting and splintering of the glass, injury from electric arcs, light and air pollution. Research indicates that smoke inhalation is the most common fire related cause of death [54], during a fire or explosion, the frame of PV modules releases cadmium telluride, gallium arsenide, phosphorus fumes, and boron gases [27]; [28], explosive release of energy causes a flash of heat and a shockwave, both of which can cause serious injury or death [5], toxic substances, such as cadmium, are chemically bound into PV materials and release to the environment is thought to be unlikely, even if modules are destroyed by fire [55]; [56], arc hazard can potentially burn skin when in contact and aids in spreading fire [28]. Yang et zl. [16], observed that exposing the materials to high heat fluxes would be very dangerous. According to BRE [19], potential effects of fires caused by PV systems: Damage to, or loss of, PV system, and associated loss of income; Damage to building covering or structure; Complete loss of building; Injury or loss of life; Reputational damage to the industry. According to [17], variables affecting the physiological impact include amount of current flowing through the body; length of contact time; travel path through the body; area of contact; pressure of contact; moisture of contact; body size and shape; and type of skin.

3.3. Preventions of Solar Electric Incidents

3.3.1 Preventive measures before Solar Electric Fire incidents

Though fire is useful, precautionary measures have to be taken to avert its occurrence in our homes, offices, marketplace and environment, because the level of destruction occasioned by fire outbreak can be mind-boggling [32]; [57]. Protection measure against fire is an important element in disaster risk reduction and it encompasses adequate awareness and readiness to render appropriate responses [58]; [59]. Various warning labels and markings are found on PV components, such as main electrical service panels, distribution boards, utility meters, PV modules, cables, electrical conduits, DC and AC disconnects. The purpose of PV labeling is to indicate the presence of a solar PV system on or supplying the building with solar power [29]. It also addresses currently known major safety requirements during PV servicing and repair, including the proper use of lockout/tagout procedures, the use of personal protective equipment, procedures for safely disconnecting live circuits, and appropriate observation of and compliance with all PV-specific system signage and warnings [60].

To protect the firefighter and to respect the environment, consideration should be given to the type of fumes and gases that are released into the environment during a PV-related fire [61]. This is because, combustion products from burning PV components on a roof or facade interfere with the smoke and the ventilation systems, which causes fire spread to evolve outside or throughout a building [10]; [28]. In order to prevent the initiation of fire on the roof, the roof and the module must be certified for fire safety and additionally, the installation must be safe [13]. For instance, guidance on installation to reduce the incidence of fires and shocks (e.g. ground-fault circuit interrupters [GFCIs] and arc-fault circuit interrupters [AFCIs]) [6]. According to Häberlin et al. [22], marking all houses with PV plants with a special identification plate and by special training for officers of the fire brigade, an appropriate assessment of the effective danger and an appropriate fight against the fire should be possible.

A common preventive measure during the operation of PV systems is early detection of faults in PV modules. A number of systems have been developed to detect faults in order to identify and eliminate early stage of incident. One of these devices was tested to determine if it was effective in detecting arcs [8]. Recent survey on preventive maintenance strategies including replacement actions [62], to keep system running smoothly, usually required after 10 years to last as long as 25 to 30 years. This implies that the incident can be avoidable and reduced by replacing old components with new one. For instance, Lithium ion batteries currently dominate the world utility-scale battery market, which are not very toxic [5]; [16], can replace toxic batteries that are likely not safe to use.

Heat from a small flame is not adequate to ignite a PV panel, but heat from a more intense fire or energy from an electrical fault can ignite a PV panel [5], when the PV module is partially blocked, and part of the solar cell string becomes a reverse bias and dissipates energy in the form of heat [12]. However, bypass diodes are used to avoid accidental application of high reverse voltages to individual cells within series connected strings of PV modules, similarly blocking diodes are used in PV module arrays to avoid accidental application of forward voltage bias to individual series connected strings of PV modules that are in parallel to the rest of the system [13]. By-pass diodes, which are normally incorporated into modules, are important in the context of reducing fire risks [21]; [19], it eliminate the hot-spots within PV modules caused by the increased resistance of shaded cells [19]. Other techniques include the use of water, which has been widely researched but less successfully applied as an effective PV coolant around the world, because while water can be extremely effective in maintaining the equilibrium of solar panels, incorporating water-based systems into module manufacturing or installation adds cost and complexity [63].

Since there is no specific fire prevention code for photovoltaic buildings [15], and separation gap between the roof and PV panel have been identified as a potential parameter that could affect fire spread [64]. A completely incombustible roof could be a good solution to limit the risk [10]. PV modules should be mount in well ventilated areas and far away from combustibles materials.

3.3.2 Preventive measures during fighting Solar Electric Fire incidents

Basic knowledge of how solar PV systems work will help firefighters understand where the potential hazards exist and how to reduce injuries. According to experts, fire safety is considered to be dependent on: How individuals behave, how organizations behave, the vulnerability of the people exposed to the fire, the fire properties of products, the technical fire safety in the building, the fire service's ability to respond to a fire [65]. Many people have faulted the responsiveness of fire services and emergency first responders in the country, who have been reputed to always arrive late and without sufficient equipment to the scene of fire incidents [65], and few people have ever doubted the need for government to provide at least some fire safety regulation [66].

PV modules power generation systems are mainly installed on the rooftop, which can be threatened to fire incident. If its catches by fire, care should be taken in fighting the fire, and it should not respond similar to others conventional sources of electricity. At the same time, electrical fire may be fought in the same way as an ordinary combustible fire, but water, foam, and other conductive agents are not to be used [67]; [50]. This is because, there is a real danger of electric shock to anyone entering any of the electrical cabinets such as combiner boxes, disconnect switches, inverters, or transformers; or otherwise coming in contact with voltages over 50 Volts [68]. Contact with any components and subcomponents of a system is the first step in establishing a preventive measure to solar electric system fire incident. When the human body comes in contact with energized components, the current path is established through hand-to-hand, hand-to-foot, or foot-to-foot [26]; [28]. Consequently, firefighters become vulnerable to electric shock hazards due to severing energized PV components or cutting through raceways containing live conductors [26]; [28].

When fire is severe, it can be difficult to discern whether an electrical appliance started the fire or if a poorly wired plug was the case [50]. Any time Firefighters engaged in fire ground operations observe metallic electrical conduit, hard wall or flex, on the interior of a building, caution should be used and safety procedures followed to avoid serious injury or death from accidental electrical shock [29]. According to BRE [19], Perceived additional risks faced by firefighters, whether or not the fire was caused by a PV system: Risk of electrocution; Risk of re-ignition due to arcing cables and connections; Falling glass; Tripping over cables on roofs; Emission of noxious gases; Risk of PV accelerating structural collapse; Impeded access to building. It is recommended to utilize stairway access to the roof as one of the safety requirements [44].

Water, which is the conventional firefighting medium, cannot be used to extinguishfires in photovoltaic buildings [69]- [71]; [15], as electricity may be conducted from the fire, through water, to the firefighter's body, and then earth [50]. If necessarily to use water. During water application, attention must be paid to fire-damaged components that remain energized, contributing to the potential shock hazard [26]; [28]. In addition, during a rescue operation, where a part of a component or conductor has to be pulled apart, the current can continue to flow in an air space creating an arc between separated conductors [44], also, caution should be exercised during the deployment of tarps on damaged equipment as a wet tarp may become energized and conduct hazardous current if it contacts live equipment [26]; [28], especially inverter which usually store a charge for some minutes. Hence, firefighting activities regarding buildings normally require electric power to be disconnected before a water jet is used, in order to minimize the risk of electrocution [23], with expectations that they are far away from burning PV systems, before applying water.

During fire incident, it is mandatory first for firefighter to look for labeling and marking especially rapid shutdown function, checking electrical connections, shutdown the power system, removing all electrical appliances that could pose a risk to human health and others physical damages, earth/ground all metal tools to electric shock, avoid all scene of lighting when incident occur at night time because it produces dangerous voltage from lighting, isolate the photovoltaic system from inverter and spray water in a fog pattern on top of PV module with critical care before fighting fire. To abide worsening the existing level of fire incident, firefighters should never walk, climb, place ladder, break, cut, remove solar PV accessories interfered with incident without wearing electrical resistance tools such as gloves, boots/shoes and destruction implements. According to [18], emergency responders are required to wear full respiratory protection (e.g., self-contained breathing apparatus) for any atmosphere that is possibly IDLH (immediately dangerous to life or health), and this should be the case when handling damaged solar modules involved in fire unless proven otherwise. Moreover, capabilities for preventing and controlling fires of photovoltaic systems should be strengthened by providing professional training to the firefighting staff [15].

4. CONCLUSION

Solar electric is highly considered reliable, require a small degree of maintenance, have least operational costs, environmental friendly, self-dependence and provision of flexible and adaptable power supply. The causes, effects and preventions of solar electric fire incident to the user, in some cases, are not known, but understanding them is important to obtain a valuable solar power. The purpose of this study is to provide brief and easy overview of the literature explaining the causes, effect and prevention of solar electric fire incident based on literature review. The study found that arcing, hot spot, weather conditions, improper installations and maintenance, and systems mechanical and electrical failures are the main causes solar PV fire incidents. Most of these incidents are resulting to the great threats to health and properties. The result also discussed the precautionary measures in detail on how to prevent PV systems and firefighters before and during fire incidents. Therefore, it is expected that this study would help solar PV installers to take precautionary measures against fire and natural hazards during the design, installation, and maintenance.

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