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Mitigating Environmental Hazards in the Solar Power Generation Industry

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Abstract: To meet a rapidly increasing demand for solar panel installations, employees have to work year-round in different environmental conditions (temperature, wind, precipitation and more) that pose additional levels of risk to already physically demanding work. Many safety and ergonomics training programs in the solar power generation industry utilize the guidelines of general and/or construction industry. However, none of the training programs account for hazards specific to the solar industry. This study discusses development of a new training program specifically designed for solar power generation industry employees, managers and safety professionals with an emphasis on mitigating the additional risks and hazards that are frequently posed due to the environment.

A training program specifically targeting the residential and commercial installation of solar panels was created by a team of researchers using onsite field observations, input from industry professionals and experts, and review of injury records. Injuries specifically due to environmental hazards were identified along with best practices and suggestions for avoiding those injuries. However, environment is rarely, if ever, cited as the root cause of injuries or fatalities, but considered more as contributory factors. Therefore, the contribution of environmental conditions to injuries primarily attributed to other factors (slip/trip/fall, struck by/caught between, etc.) was specifically highlighted throughout the training to emphasize the need to be aware of environmental conditions for all tasks.

The systematic process of material development and implementation is described in detail, along with explanations of hands-on activities and interactive discussions that involve the trainees to further learning and integration into their daily routines. Specific examples of steps that can be taken to mitigate the environmental hazards are provided, along with recorded incidents of best practices and observed near misses. This study further emphasized that training materials for general industry may not be appropriate for the solar power industry, and that the considered risk factors should be specific to the job. In order to properly present so called contributing factors they must be integrated throughout the training materials.

Keywords: Renewable Energy, Workplace Exposure, Safety Training, Solar Power Generation, Utilities

1. Introduction

Solar power generation has been one of the top new sources of power generation for the last 6 years (seia.org, 2019_1). The cost of installing solar systems has dramatically dropped over the years from $40K in 2010 to $18K in 2018 (seia.org, 2019_2). Solar capacity is expected to grow at an alarmingly increasing rate (seia.org, 2019_2) and in order to meet this rapidly growing demand for solar power generation, employees have to work year round in different environmental conditions (temperature, wind, precipitation, and more) that pose hazards to the workers in addition to the already physically challenging work.

To date, there are no OSHA safety standards specific to the solar power generation industry. Instead, workers employed in this industry follow a combination of Construction and General Industry standards with the underlying assumption that many of the tasks required in solar installations are similar to other work already covered by the aforementioned standards. However, there are additional concerns in solar installations that are not considered in other construction and general industry tasks (handling and installation of solar panels, working at heights, etc.). Working in diverse environmental conditions poses extra risks in terms of increasing likelihood of sustaining electric shock, being struck,

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slipping/falling from heights, and more. Employees are often facing rigorous time pressures for project completion that forces them to work in less than ideal or inclement environmental conditions (rain, high wind, cold, heat, snow, ice) which can increase the required physical demand and thereby potentially compromise the worker's safety (Azadeh-Fard et. al, 2015; Chi et. al 2005; Lipscomb et. al, 2003; Moohialdin et. al 2018). The work in extreme hot or cold conditions poses additional challenges and physical demands. Depending on the weather, numerous types of injuries such as an overexertion, slips/trips/falls, struck by/caught between, electrocution and/or electric shock are more likely to occur.

Cold, hot, windy conditions and/or precipitation can pose additional physical demands and motivate workers to complete the job faster in order to minimize the exposure duration. Given that environment has a more contributory, rather than primary, role in injury incidences, it is a common practice to focus the training of the employees on injury-specific risk factors such as overexertion due to lifting, for example, instead of the contributory factors related to the environment that led to the injury. Thus, training materials specific to environmental hazards could be rendered misleading and non-effective. For this reason, the development of training materials needs to reflect *both* the primary and contributory role environmental hazards play in the solar power generation industry.

Injury prevention and ergonomics training programs are utilized in the solar power generation industry as an injury prevention countermeasure, but these programs are generally not specific to the industry. The uniqueness of some tasks involved during the construction and installation of solar panels are not considered and thus workers are not necessarily provided training, which will directly apply to their jobs at hand. The lack of available industry-specific safety training combined with the increased demand may lead to safety being considered an afterthought in many cases. Thus, the goal of this paper is to assess the effectiveness of a newly developed training program specifically designed for solar power generation industry employees, managers and safety professionals with an emphasis on mitigating the additional risks and hazards that are frequently posed due to the worker by the environment.

2. Methods

New training materials were proposed by the CARGI at UWM team, with an emphasis on hazards and risk factors present in tasks performed during the solar panel installation and maintenance phases. A new training curricular scope and content was created using a combination of onsite field observations, ergonomics analysis, interviews with industry personnel and review of injury records

Development of training materials included creation of a new workbook for the training session and a set of identical pre- and post- test questions specific to the materials covered in the training. The pre- and post-training assessments are essential for the baseline and post-training knowledge evaluation on a given topic.

2.1 Data collection and analysis

Five small to midsize utility companies and/or contractors that are involved with solar panel installation or maintenance processes were recruited for this study. Onsite field observations took place during diverse weather conditions at various locations across the Midwestern United States by a team of two or three ergonomists per location. During the visits the team performed: i) observations of the workers performing various tasks, ii) informal interviews with employees and management, and iii) review of injury records. Video recordings, photos and written notes were collected during the field visits. Examples of tasks observed by the team of ergonomics and safety experts included installing brace posts and junction boxes, pulling cables and moving spools, working at heights with power tools, lifting and carrying solar panels, and much more. Video recordings and photos that were collected during the team field observations were analyzed using ergonomic assessment tools such as NIOSH, Reba, Liberty Mutual tables for lifting and carrying, OSHA checklist, etc. A separate analysis was performed on the record of injuries addressing each situation and potential contributing root-cause(s). The most frequent causes of previous injuries were selected for further investigation. Follow up conversations took place with the safety teams and managers regarding each injury case that was selected by the team of experts.

Current practices and various levels of mitigation techniques to combat hazards due to weather or environmental conditions were gathered and analyzed. The analysis revealed that environmental hazards are systematically present during the solar panel installation and maintenance phases and can be contributory to injuries, the causes of which are traditionally attributed a variety of commonly recognized risk factors such as slips and falls, struck by, electrocution or overexertion.

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2.2 Development of Curriculum

Training material development began with identification of sections required for the curricula. This was achieved by first analyzing the injury records and then combining the cause(s) of injuries with the outcomes of analysis from the interviews and task observations. For each risk factor, a set of "Good Practices" and "Avoid" lists was generated. Power point slides were created for each section. Currently implemented strategies intended to help combat environmental hazards, gathered by interviews, current published sources such as the OSHA, and NIOSH websites, were incorporated into the training materials. The hazards that could be posed by poor weather or environmental conditions were identified for each section of the training. Examples of interactive exercises for the training were developed based on the visual information gathered and risk factors identified during the analysis. Different environmental conditions and mitigation scenarios were also incorporated into the training curricula and materials.

3. Results

New training materials were developed and stratified by the risk factors that resulted in the most number of injuries for the solar power generation industry such as overexertion, slips/trips/falls, and struck by/caught between, as well as other hazards observed in the field that could result in injuries such as noise, environment, electric shock/electrocution, and arc flash. Each section began with the definition of the identified risk factor and contained variations of scientific principles, injury cases, definitions, demonstrations and/or interactive exercises to help emphasize the knowledge to be learned by the trainees. Detailed descriptions of each section of the novel training materials are presented below.

3.1 Training materials: Environment

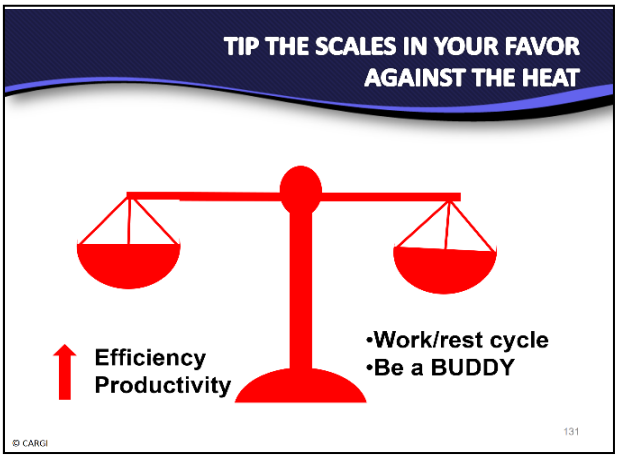

Figure 1. Solutions proposed to combat against heat

This section specifically targeted working in the heat, cold, and different types of precipitation. Trainees were informed about the dangers of working in the heat and cold, the different contributors to the injuries, and the types of injuries. Emphasis was placed on employees recognizing symptoms because recorded injury cases and fatalities involving the environment (heat in particular) would arise in workers after the work was completed (up to 48 hours later).

Solutions to help mitigate the environmental hazards in order to increase efficiency and productivity (Figure 1) were provided and included getting acclimated to the particular working environment, work-rest cycles based on temperature and physical exertion required to complete a task, clothing, and more. Trainees were also given information for readily available resources via the OSHA website and different applications available for download.

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3.2 Considerations of Environment

Throughout each section of training, trainees were made aware of the additional difficulty the weather-related elements (wind, rain, heat, snow, cold, and more) added in task completion and the resulting increase in hazard level. For example, in the electric shock and electrocution section employees discussed different conductors and insulators (Figure 2a), emphasizing how dry skin has more electrical resistance than moist/wet skin and how the body can become more of a conductor when working in the rain or sweating while working in the heat. Similarly, trainees were asked to identify the slipping risks from ice and present potential solutions to avoid incurring a slip (Figure 2b).

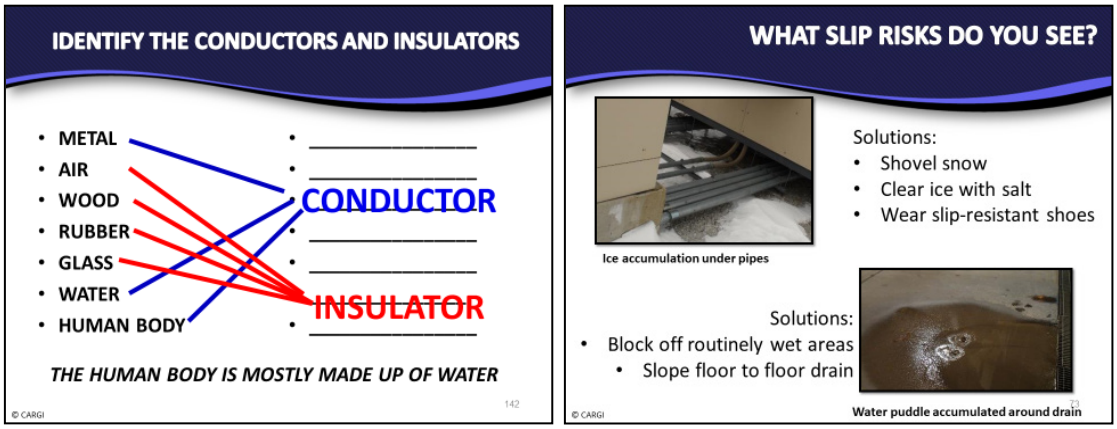

Figure 2. Example of interactive exercises incorporated into non-environment sections of the training to raise trainee's awareness of the additional hazards posed to the worker by the environment to (a) electric shock and electrocution and (b) slip risks

3.2.1 Additional Hazards in Overexertion

Contributors to overexertion injuries are discussed via different observed tasks included pulling cables, working with power tools, lifting cable spools, installing posts, digging, cutting cables, lifting solar panels, and various other manual material handling tasks. An example of how the additional hazard posed by the environment to the worker was incorporated into the training was illustrated during the lifting solar panel task section. The average size panel weighs 25-35 pounds and the large rectangular dimensions pose challenges when carrying the panels to the intended location. Solar panels are considered awkward loads due to their size (31.5" x 62") and absence of handles. Workers have to create a wide base of support to maintain good balance while carrying or positioning the panels and it becomes more difficult to maneuver the panel in the wind. For other manual material handling tasks such as lifting spools, digging, or pulling cables, trainees are asked to consider the extra physical effort due to environmental conditions that could be required to complete these already physically demanding tasks, which in turn could lead a worker to reach fatigue sooner thereby making one more susceptible to injury.

3.2.2. Additional Hazards in Slips/Trips/Falls

Trainees first learn the difference between slips, trips, and falls and are taught the different hazards present for each injury type. The relationship between slipping risk and friction is discussed and how in wet conditions friction is decreased.

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Figure 3. Example of potential near miss sustained in cold

Understanding how these extra hazards contribute to these types of injuries allows workers to pick more appropriate personal protective equipment, such as shoe selection and consideration of shoe tread depth. Additional precautions would need to be taken when working at heights, such as on roofs. In wind and rain the fall hazards are increased, leading to situations such as described in Figure 3. Wind ice, snow, and rain increase slip and fall risks when walking, digging, or working on inclined surfaces. For example, a team was scheduled to perform maintenance work on a rooftop installation at a location 3-hours away from their home base. Upon arrival to the jobsite, it was evident that the roof was covered with a thin layer of ice. Had the team known earlier, the job would have been rescheduled. However, since it was a 3-hour commute each way the team decided to complete the job. While on the roof of the residential site, one of the workers accidentally slipped and became suspended on the fall protection harness for an extended time while waiting for rescue (Figure 3). While the fall protection harness was protective of the employee, it also caused some harm due to blood restriction to the lower extremities leading to bruising and temporary numbness as well as an inability to walk. When prompted during discussion companies would note that the majority of the maintenance work, especially at residential sites, is caused by severe weather conditions and requires a fast response from the team. Environment related circumstances leading to an injury and/or near misses were incorporated into all sections of the training materials to raise the trainee's awareness of the additional hazards and the difficulty the environment poses when attempting to complete a task.

3.2.3. Additional Hazards in Struck by/Caught Between

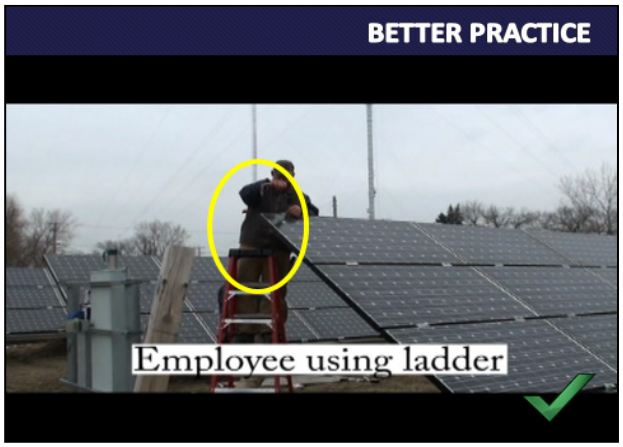

Figure 4. Example discussing how a better practice can be advantageous during non-ideal environmental conditions

Trainees learn how one could sustain these types of injuries and consider how wind could increase the likelihood of sustaining a struck by injury, as for example when lifting and passing solar panels on rooftops during windy conditions. For this same task, wet conditions lead to low visibility and once again the likelihood of sustaining a struck by injury is increased. The advantages of better practices during non-ideal environmental conditions are also discussed. For example, Figure 4 shows an example of how the employee secures his drill in the ladder. This practice prevents the tool from falling from height and striking another worker. During windy or wet conditions, this practice provides extra security and is a way to mitigate the additional hazard brought upon by the environment.

3.2.4. Additional Hazards in Electric Shock/Electrocution and Arc Flash

An electrick shock, electrocution, or arc flash injury risk can be increased when working in differnet environments. Trainees were taught how wet conditions can decrease an object's electrical resistance which makes it more likely that one can be shocked (Figure 2a). Additional precautions would need to be taken when handling power equipment in the rain or snow. Even with the increased risks, work was observed to occur during these conditions due to stringent deadlines, exposing the workers to even more hazardous conditions.

4. Discussion and Conclusions

This paper investigates the development of a new training curriculum specifically focusing, in part, on mitigating the additional hazards frequently posed to the worker due to the environment in the solar power generation sector. Training material was developed based on observed tasks in the field. However, environment is rarely, if ever, cited as the root cause of injuries or fatalities, but considered more as contributory factors (Azadeh-Fard et. al 2015; Chi et. al, 2005; Liao et. al, 2008; Moohialdin et. al, 2018; Taylor et. al, 2002). Researchers also cite the increase of occupational accidents during certain inclement weather conditions (Liao et. al, 2008; Moohialdin et. al, 2018; Taylor et. al, 2002), but not as the sole cause of those injuries.

Conversations with industry personnel reveal that companies attempt to mitigate the additional hazards posed by the environment to the worker with elimination and/or administrative controls, but workers need to be reminded of the additional hazards posed to them when working in the field. Given the lack of direct connection between environmental conditions and injuries, emphasis on the additional hazards posed by the environment to the worker was reiterated throughout all sections of the training materials. Trainees were asked to consider how the environment could make tasks more physically demanding, take longer to complete, and/or increase the likelihood of sustaining an injury or a fatality.

Many companies implement administrative policies such as alternating work schedules to cooler parts of the day during hot months and warmer parts of the day for colder months, incorporating mandatory breaks into the work schedule, requiring coolers with water on every truck during summer months, using lift devices to lift panels to the roof when in windy conditions, etc. These policies tend to make the work safer. However, the downfall with some of these policies is that workers may still adopt work practices that could be perceived as haphazard to complete the jobs as quickly as possible, and in whatever environmental conditions are present. Training may not always be the first line of defense to mitigate inclement weather conditions, but refresher courses should be given to (1) raise the employee's awareness of the extra hazards posed by the environmental conditions and (2) remind employees that injuries are multifactorial in nature and the environment can increase one's likelihood of sustaining various types of injuries given the high physical demands required and rigorous time schedules. This study emphasized that training materials for general industry may not be appropriate for the solar power industry, and that the considered risk factors should be specific to the job. In order to properly present so called contributing factors they must be integrated throughout the training materials.

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