# HAZARD IDENTIFICATION AND EVALUATION IN SOLAR PHOTOVOLTAIC INSTALLATION PROCESS OF A SELECTED ENERGY SOLUTION PROVIDER COMPANY

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Field of Study: Science and Environmental Management

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**HAZARD IDENTIFICATION AND EVALUATION IN SOLAR PHOTOVOLTAIC INSTALLATION PROCESS OF A SELECTED ENERGY SOLUTION PROVIDER COMPANY**

## ABSTRACT

This research project elaborates the safety, health and environmental aspects of designing and installing solar photovoltaic (PV) in Malaysia. First, it analyzes the current safety, health, and environmental issues globally and discusses some of the national policies and the installations of solar PV on a rooftop of residential, warehouses and shopping malls in Klang Valley. Next, the general Net Energy Metering (NEM) scheme is explained, indicating its relevance in the project process flow that has been discussed in this research project. Finally, the findings from the interviews, site observation and questionnaires are presented, providing examples that have been implemented in LZ Company, as well as explaining the impact of the findings and the proposed control measures. It also analyses the impact of the proposed control measures to the solar installer in Malaysia, in terms of safety, health and environmental. It is found that many of the recommendations could potentially save lives, particularly during installing solar PV.

**Keywords**: Solar photovoltaic, Safety, Health, Environmental, HIRARC

**PENGENALAN DAN PENILAIAN HAZARD DALAM PROSES PEMASANGAN PHOTOVOLTAIC SOLAR SEMULA PRODUK SYARIKAT PENYELESAIAN TENAGA TERPILIH**

## ABSTRAK

Projek penyelidikan ini menghuraikan aspek keselamatan, kesihatan dan alam sekitar untuk mereka bentuk dan memasang photovoltaic solar (PV) di Malaysia. Pertama, ia menganalisis isu keselamatan, kesihatan dan persekitaran semasa di seluruh dunia dan membincangkan beberapa dasar kebangsaan dan pemasangan PV solar di atas bumbung kediaman, gudang dan pusat membeli-belah di Lembah Klang. Seterusnya, skim Pengukuran Tenaga Bersih umum (NEM) dijelaskan, menunjukkan perkaitannya dalam aliran proses projek yang telah dibincangkan dalam projek penyelidikan ini. Akhirnya, penemuan dari temubual, pemerhatian tapak dan soal selidik dibentangkan, memberikan contoh yang telah dilaksanakan di Syarikat LZ, serta menjelaskan kesan penemuan dan langkah kawalan yang dicadangkan. Ia juga menganalisis impak langkah-langkah kawalan yang dicadangkan kepada pemasang solar di Malaysia, dari segi keselamatan, kesihatan dan alam sekitar. Telah didapati bahawa banyak cadangan boleh berpeluang menyelamatkan nyawa, terutamanya semasa memasang PV solar.

**Kata kunci:** Solar photovoltaic, Keselamatan,Kesihatan, Alam Sekitar, HIRARC

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Regards,

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| | |
|---|---|
| OSHA 1994 | Occupational Safety and Health Act 1994 |
| EMEER 2008 | Efficient Management of Electrical Energy Regulation 2008 |
| HIRARC | Hazard Identification, Risk Assessment and Risk Control |
| ISO 9001:2015 | Quality Management System |
| KeTTHA | Ministry of Green Energy, Technology and Water |
| SEDA | Sustainable Energy Development Authority |
| MIDA | Malaysian Investment Development Authority |
| MGTC | Malaysian Green Technology Corporation |
| TNB | Tenaga Nasional Berhad |
| SESB | Sabah Electricity Sdn Bhd |
| DOSH | Department of Occupational Safety and Health |
| CIDB | Malaysian Construction Industry Development Board |
| MyHIJAU | Malaysia's official green labelling scheme |
| FiT | Feed-in-Tariff |
| NEM | Net Energy Metering |
| NEMAS | NEM Assessment Study |
| GCPV | Grid-Connected Photovoltaic |
| kWh | Kilowatt in 1 hour |
| PPE | Personal Protective Equipment |
| WhatsApp | A freeware and cross-platform messaging and Voice over IP service |
| MSB | Main Switch Board |
| Kg | Kilogram |
| DC | Direct Current |
| DB | Distribution Board |
| MV | Medium Voltage |

| | |
|---|---|
| VOCs | Volatile Organic Compounds |
| MSD | Musculoskeletal Disorders |
| Isc | Short Circuit Current |
| Voc | Open Circuit Voltage |
| DB | Distribution Board |
| ENT | Ear, Nose and Throat |
| SSS | Site Safety Supervisor |
| SHO | Safety Health Officer |
| PV | Photovoltaic |
| GHG | Green House Gas |

# CHAPTER 1

# INTRODUCTION

## 1.1 Research background

In recent decades, awareness towards global warming is increasing and hence, the number of Solar Photovoltaic (PV) systems has increased correspondingly [1]. Due to the fact these system are a great way to offset energy costs, reduce the environmental impact and provide a host of other benefits, such as supporting local businesses and contributing to energy independence, [2], many people are interested to install it at their premises' rooftop where space might be the constraint factor in the Klang Valley.

Regarding the significant demand for solar PV system, new job opportunities such as Solar PV system installer and system designer were introduced [3]. Consequently, process of installing the systems present significant unsafe behavior and service providers must ensure their designers and installers are following appropriate behavior and having a good awareness, particularly over the risk of working at height and dealing with electrical works, [4], making the need for Hazard Identification, Risk Assessment and Risk Control ( HIRARC ) control essential.

Kathy, the author of Solar Energy: Safety Risks and How to Prevent Them, said, installing solar systems is a risky business where the Occupational Safety and Health Administration (OSHA) itself requires employers to implement safety training and protection for their employees. Safety issues are common for solar installations, but proactively putting preventive measures in place can help mitigate on-the-job injuries [5].

## 1.2 Problem statement

There is a tremendous need for doing HIRARC in solar PV installation and designing process. According to the United States Department of Labor, there have been fatalities and incidents in the solar energy industry which workers in the solar energy industry are potentially exposed to a variety of serious hazards, such as arc flashes - which include arc flash burn and blast hazards -, electric shock, falls, and thermal burn hazards that can cause injury and death [6]. Unfortunately, the actual number of cases are not available.

The occupational sectors for diseases and accidents statistic as reported by Malaysia Department of Occupational Safety and Health (DOSH) were too general. Nevertheless, based on the risk and types of injuries that the workers potentially exposed to, it is safe to assume that Solar PV installation work falls under Construction and Utility sectors. Therefore, based on this assumptions, DOSH has identified 63 people were fatal and 110 people were under non-permanent disabilities in the Construction sector whiles 8 people were fatal and 67 people were under non-permanent disabilities in the Utility sector [7].

Table 1.0: Occupational Accidents by Sector until October 2017 (Ref. [7])

| Sektor | Bilangan THUK | Bilangan HUK | Bilangan Maut | Jumlah |
|---|---|---|---|---|
| Pengilangan | 1559 | 86 | 46 | 1691 |
| Pelombongan dan Penguarian | 30 | 1 | 7 | 38 |
| Pembinaan | 110 | 4 | 63 | 177 |
| Pertanian, Perhutanan dan Perikanan | 366 | 9 | 18 | 393 |
| Kemudahan Elektrik, Gas, Air dan Perkhidmatan Kebersihan | 67 | 3 | 8 | 78 |
| Pengangkutan, Penyimpanan dan Komunikasi | 58 | 0 | 9 | 67 |
| Perdagangan Borong dan Runcit | 60 | 0 | 5 | 65 |
| Hotel dan Restoran | 77 | 2 | 2 | 81 |
| Kewangan, Insurans, Harta Tanah dan Perkhidmatan Perniagaan | 104 | 2 | 7 | 113 |
| Perkhidmatan Awam dan Pihak Berkuasa Berkanun | 43 | 0 | 4 | 47 |
| Tiada Maklumat | 433 | 26 | 37 | 496 |
| **JUMLAH** | **2907** | **133** | **206** | **3246** |

To conduct HIRARC, the process involved in designing and installing the solar PV panels should be determine. Next, is to elaborate multiple regulatory authorities in Malaysia that overseeing the various segments of energy sector including the regulations and guidelines related to this topic. This report will be discussing on the needs of training and competency certification related to Solar PV offered to the Solar PV installer and system designer. Finally, this research project intended to highlights some of the studies made regarding safety, health and environmental effects of Solar PV installation process.

## 1.3 Objectives

The major objective of this research project is to assist and advice LZ Company in the implementation of its safety policy and major improvement in terms of safety during Solar PV installation, particularly during installation at rooftop. The other objectives are:

1. To cooperate with Company's safety committee activity in preparing this HIRARC as part of the DOSH requirements.
2. To made as guidelines for Solar Service Providers to use for their safety training modules.

## 1.4 Scope of study

The present research is confined to study the Solar PV installation process followed at LZ Company. The scope of this study is to observe the Solar PV installation at the rooftop of three different building adopted by the company. Apart from getting an idea of the techniques and methods in the installation procedures a close look will be taken at the insight of safety culture prevailing in the organization. This would not only help to be familiar with the installer and their system designer working environment but it

would also enable to get a close look at the various levels authority responsibility relationship prevailing in the organization in terms of Safety, Health and Environmental aspects.

The scope of the project includes-

- Study of Solar PV installation at the rooftop of Industrial, Residential and Commercial buildings.
- Study of projects that applied Net Energy Metering (NEM) scheme.
- Safety, Health and Environmental impact of Solar PV in general.

## 1.5 Benefits

This report is part of the Company's safety committee references and as their guidelines in designing a control measures based on the findings. This research process has become known as the Company's safety committee activities in establishing new procedures and fulfilling new ISO 9001: 2015 that highlighted on the safety aspects.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction to Solar Photovoltaic (PV)

Growing concerns about the depletion of the world's natural resources and our future energy supply have increased the need and development of the new source of energy to replace the existing one. Energy has been part of the main contributor to our current environmental crisis where we are using the conventional energy source, which means that the sources are taken from nature like oil, gas, and coal (Figure 2.1).

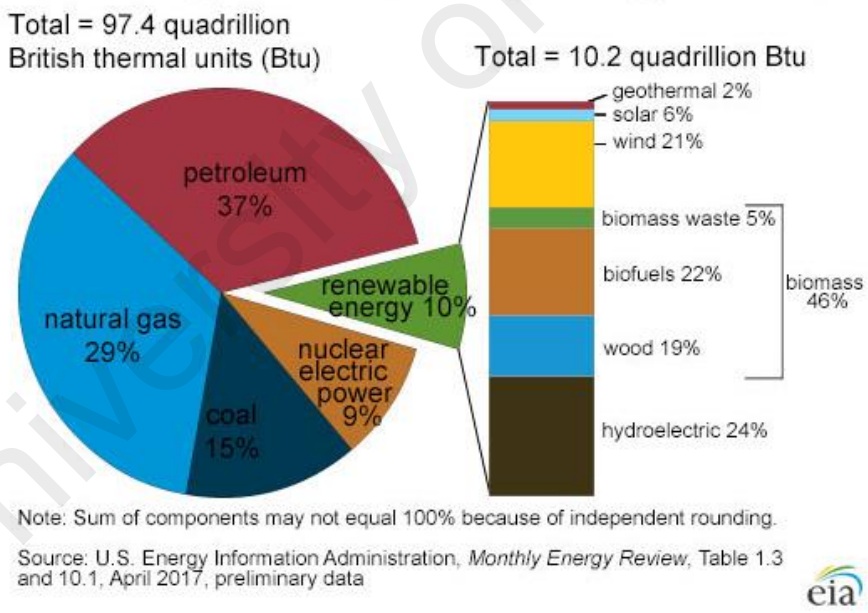


Figure 2.1: U.S energy consumption by energy source, 2016 (Ref. [23])

The idea of new energy source was first introduced to find a new land for the resources. However, this will not resolve the main concern of the depletion of the resources. Further study was conducted to find this source of energy that can be renewed,

safe and clean to the environment, health, and people. These renewable energy resources were introduced, and many were fascinated with the idea of using solar, tidal, wave and wind as the source.

The most critical advancement in the development of solar technology has been Photovoltaics, a solar energy system that uses semiconductors to directly convert solar radiation into electricity. Photovoltaic (PV) systems are composed of many cells arranged in formation on a metal frame, the entirety of which is known as a module [31]. When exposed to sunlight these cells produce a small direct current of electricity. The amount of electricity generated is dependent on several factors: the size and arrangement of the PV system, the PV module array, and the efficiency of the inverters used to covert solar energy into electricity usable by home or building [31].

Most electricity is distributed through an electrical utility provider, which is the company that produces and distributes electricity to consumers in a region or state. The electricity is distributed along the electrical grid-the utility's network of conductors, substations, and equipment that distributes electricity from its central hub to the consumer.

## 2.2 History of Accidents and Incidents Happen

According to Safe work Australia, each year about 30 Australians dies in falls from a height, and there are people electrocuted when they come into contact with power lines [26]. Both accidents happen during solar panel installation or maintenance work. Unfortunately, these events are not reported as part of work-related statistics.

| Energy Source | Death Rate (deaths per TWh) |
|---|---|
| Coal - world average | 161 (26% of world energy, 50% of electricity) |
| Coal - China | 278 |
| Coal - USA | 15 |
| Oil | 36 (36% of world energy) |
| Natural Gas | 4 (21% of world energy) |
| Biofuel/Biomass | 12 |
| Peat | 12 |
| Solar (rooftop) | 0.44 (less than 0.1% of world energy) |
| Wind | 0.15 (less than 1% of world energy) |
| Hydro | 0.10 (europe death rate, 2.2% of world energy) |
| Hydro - world including Banqiao) | 1.4 (about 2500 TWh/yr and 171,000 Banqiao dead) |
| Nuclear | 0.04 (5.9% of world energy) |

Figure 2.2: Comparing deaths/TWh for all energy sources (Ref. [24])

Fire in solar panels due to creation of hotspot solar panels may catch fire after some period. Weak mounting structure will cause damage to plant in heavy wind conditions. Other electrical accidents like damage to inverter or panel due to surge in system, lightning strikes [24]. About 1000 construction fatalities per year recorded in the US alone where 33% from working at heights.

Figure 2.3: A 1000 sq. meter warehouse housing a roof-mounted PV system. (Ref. [25])

Figure 2.4: A fire in a connection box in a ground PV system. (Ref. [25])

Figure 2.5: DC arcing effects on an external side of polyurethane (Ref. [25])

## 2.3 The rise of Solar Photovoltaic in Malaysia

The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change, which commits its Parties by setting internationally binding emission reduction targets. Recognizing that developed countries are principally responsible for the current high levels Green House Gas (GHG) emissions in the atmosphere as a result of more than 150 years of industrial activity, the Protocol places a heavier burden on developed nations under the principle of "common but differentiated responsibilities" [27]. Malaysian government signed and ratified Kyoto protocol in year 2005 and since then it formed several ministries and agencies which are working on the strategy implementation and the promotion of the industries which are leading to decrease of the GHG emissions [27].

The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius [28]. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. To reach these ambitious goals, appropriate financial flows, a new technology framework and an enhanced capacity building framework will be put in place, thus supporting action by developing countries and the most vulnerable countries, in line with their own national objectives. The Agreement also provides for enhanced transparency of action and support through a more robust transparency framework.

Malaysia ratified Paris Agreement in November 2016 and it entered into the force on December same year. As a country with many natural energy resources, possibility to develop renewable energy with specific attention to solar energy industry and place it to

the market, Malaysia is one of the most attractive countries in the world that is currently third solar panel manufacturer in the world.

In past several years, Malaysian government has been investing large effort to support development of renewable energy technology through it official institutions, by delegating Ministry of green energy, technology and water (KeTTHA) which founded two Agencies Sustainable Energy Development Authority (SEDA) and Malaysian Green Technology Corporation (MGTC) as well as the common standardized Green Mark that is unifying all of the green products available on Malaysian Market under one logo, called MYHijau [8].

Taking Malaysia as an example, government has launched Feed-in-Tariff in year 2011 where they were paying over RM 1 per produced kilowatt hour (kWh) to the ones who decided to use their roof top as a platform for small solar systems installation. The projection and the price of the technology at that point was giving a possibility to people to invest into the small solar farms they would place on their roof tops and count on return of investment in following four to five years [32]. Everything after that would generate the pure profit as the Feed-in Contracts last for 21 year. By Malaysian green plan, each year the price per produced kWh would be decreased for 10% where in 2016 the complete system was shut down. At that point the interest for solar industry was almost completely lost as people didn't see other than financial interest to invest into the solar industry [32].

At the beginning of 2017 Malaysian government introduced the Net Energy Metering scheme which is operating on a different principle. House owners are still able to invest in solar systems that they will place on their roof tops, but this time, they will have a chance to use all of the electricity that their micro solar farms would produce [3]. That would give them an opportunity not to be so dependent on the electricity price rise and general grid system in the country. Whatever energy they would over produced, would be

sold back to Tenaga Nasional Berhad (TNB) and decreased from their next electricity bill. NEM in that sense sounds like a great opportunity where people could actually use the energy they produce, but unfortunately as the produced kWh price went down from over RM 1 to RM 0.31. The Return of the Investment period went 3 times up [3].

## 2.4 Acts and Regulations Involved in Malaysia

Guidelines for Solar Photovoltaic Installation on Net Energy Metering Scheme was introduced by the Energy Commission as part of their contribution as the commission for Solar PV technology [21]. This guideline was taken parts from the Electricity Supply Act 1990. NEM can be installed in Peninsular Malaysia and Sabah, where have different legislations, are as follows [8]:

- Electricity Supply Act 1990
- Renewable Energy Act 2011
- Environmental Quality Act 1974
- Occupational Safety and Health Act 1994
- Factories and Machinery Act 1967

The legislation listed above also requires compliance with the regulations, orders, rules and other sub-legislation made thereunder. Some of the more relevant ones are listed below [8]:

- Electricity Regulations 1994
- Licensee Supply Regulations 1990
- Renewable Energy (Feed-In Approval and Feed-in Tariff) Rules 2011
- Renewable Energy (Renewable Energy Power Purchase Agreement) Rules 2011
- Renewable Energy (Technical and Operational Requirements) Rules 2011

The Energy Commission of Malaysia (the Commission) is the primary regulator of the energy and gas supply in Peninsular Malaysia and Sabah. They are responsible:

- To advise the Minister of Energy, Green Technology and Water (Minister) on all matters concerning national policy objectives for energy supply activities;
- To advise the Minister on all matters relating to the generation, production, transmission, distribution, supply and use of electricity as provided under the electricity supply laws and the supply of gas through pipelines and the use of gas as provided under the gas supply laws [33]
- To promote and safeguard competition and fair and efficient market conduct or, in the absence of a competitive market, to prevent the misuse of monopoly or market power in respect of the generation, production, transmission, distribution and supply of electricity and the supply of gas through pipelines [33]
- To promote the use of renewable energy and the conservation of non-renewable energy [33]
- To promote research into, and the development and the use of, new techniques relating to [33]
    - The generation, production, transmission, distribution, supply and use of electricity; and
    - The supply of gas through pipelines and the use of gas supplied through pipelines.

The Commission reports to the Malaysian Ministry of Energy, Green Technology and Water (KeTTHA) and is responsible for the oversight of all elements of the industry

from tariffs and licensing to consumer safety. The Commission works in close cooperation with the Sustainable Energy Development Authority of Malaysia (SEDA), which is a statutory body formed under the Sustainable Energy Development Authority Act 2011 to administer and manage the implementation of the feed-in tariff mechanism under the Renewable Energy Act 2011.

## 2.5 Hazard Identification and Risk Assessment

Hazard is a source or a situation with a potential for harm in terms of human injury or ill health, damage to property, damage to the environment or a combination of these. Hazard identification is a process of identifying the hazard. It can be implemented at everywhere but mostly the application can be found at the workplace [18].

Risk means a combination of the likelihood of an occurrence of a hazardous event with specified period or in specified circumstances and the severity of injury or damage to the health of people, property, environment or any combination of these caused by the event. Risk assessment is the process of understanding the risk and take control to minimizing or eliminate the risk. In short, risk can be presented in mathematical statement as below:

**Risk = Likelihood x Severity**

Hazard Identification, Risk Assessment and Risk Control (HIRARC) is a method introduced by the Department of Occupational Safety and Health (DOSH) as a guideline for the Company to refer for managing the hazard and risk exposure to their workers during working period [18].


Figure 2.6: Flowchart of HIRARC process (Ref. [18])

Here are some important tables to conduct HIRARC.

Table 2.1: HIRARC likelihood rating (Ref. [18])

| LIKELIHOOD (L) | EXAMPLE | RATING |
|---|---|---|
| **Most likely** | The most likely result of the hazard / event being realized | 5 |
| **Possible** | Has a good chance of occurring and is not unusual | 4 |
| **Conceivable** | Might be occur at sometime in future | 3 |
| **Remote** | Has not been known to occur after many years | 2 |
| **Inconceivable** | Is practically impossible and has never occurred | 1 |

Table 2.2: HIRARC level of severity (Ref. [18])

| SEVERITY (S) | EXAMPLE | RATING |
|---|---|---|
| **Catastrophic** | Numerous fatalities, irrecoverable property damage and productivity | 5 |
| **Fatal** | Approximately one single fatality major property damage if hazard is realized | 4 |
| **Serious** | Non-fatal injury, permanent disability | 3 |
| **Minor** | Disabling but not permanent injury | 2 |
| **Negligible** | Minor abrasions, bruises, cuts, first aid type injury | 1 |

Table 2.3: HIRARC risk matrix (Ref. [18])

| | Severity (S) | | | | |
|---|---|---|---|---|---|
| Likelihood (L) | 1 | 2 | 3 | 4 | 5 |
| 5 | 5 | 10 | 15 | 20 | 25 |
| 4 | 4 | 8 | 12 | 16 | 20 |
| 3 | 3 | 6 | 9 | 12 | 15 |
| 2 | 2 | 4 | 6 | 8 | 10 |
| 1 | 1 | 2 | 3 | 4 | 5 |

Table 2.4: HIRARC indication of the severity (Ref. [18])

| RISK | DESCRIPTION | ACTION |
|---|---|---|
| 15 - 25 | HIGH | A HIGH risk requires **immediate** action to control the hazard as detailed in the hierarchy of control. Actions taken must be documented on the risk assessment form including date for completion. |
| 5 - 12 | MEDIUM | A MEDIUM risk requires a planned approach to controlling the hazard and applies temporary measure if required. Actions taken must be documented on the risk assessment form including date for completion. |
| 1 - 4 | LOW | A risk identified as LOW may be considered as acceptable and further reduction may not be necessary. However, if the risk can be resolved quickly and efficiently, control measures should be implemented and recorded. |

There are 4 types of controls that can be done based on the suitability of the working situation. These are only as guidelines and sometimes are not applicable at area which can incurred higher risk to the workers if implemented. Risk can be control at the source of the hazard where it can either be eliminated or can be substitute to something that are less risky. Another way to control risk is by engineering control where it involves in redesign, isolation, automation, barriers, absorption and dilution of certain chemical to reduce the hazard effect. Administrative control such as safe work procedures, supervision and training, job rotations, housekeeping, repair and maintenance programs and hygiene are also ways to control risk. Finally, is the personal protective equipment (PPE) and clothing is used when other controls measures are not feasible and where additional protection is needed. This controls will be explain further in Chapter 4: Results and Discussion.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

The research project methodology framework consisted of four approaches. This chapter provides a description of the project task, including the methodology used to perform them.

## 3.2 1st Approach : To do Site Observation

The first approach focused on observing how solar PV installation process was conducted from the beginning of the project awarded towards the end of testing and commissioning stage. Understanding their methods and best practices, the project fused these practice into a coherent framework that showed the connection of each process flow with related to Safety, Health and Environmental issues. As described above, this methodology observed several criteria that showed the potential risk of injuries and fatalities which have been translated into a checklist as shown in Appendix A.

## 3.3 2nd Approach : Working Checklist

The second approach focused on understanding how the system was designed and what information was needed to ensure that the design able to operate safely. The system designer required to conduct a feasibility study and gathered as much as information as shown in Appendix B.

### 3.4 3rd Approach : Questionnaires

Questionnaires are an important methodological element of the study. Technical staffs that were clustered to Operation and Maintenance, Projects and Designers section were interviewed, with these interviews focusing on their general knowledge of work exposure – working experience in Solar PV related, opinions of their workplace, etc. - , their safety awareness and management support. This includes accidents or incidents happen to them or within their knowledge. The questionnaires consisted of open-end, fixed-response and multiple choices questions where it was distributed to the staff in link form through WhatsApp messenger - a freeware and cross-platform messaging and Voice over IP service. The questionnaires can be found at Appendix C.

### 3.5 4th Approach : Interviews

The final approach for this research project was through interviewing two peoples that are responsible to overview current process and procedures implemented by LZ Company. The interviewees were the Manager of Engineering Department and the Group leader of Operation and Maintenance Group. The selection of the interviewees was based on their more than 3 years' experience in their field and their influence in making the decision in their sub-ordinates working procedure. The list of questions asked can be seen at Appendix D.

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 Introduction

This chapter discusses the results of gathered from the Methodology explained in Chapter 3 and interprets the findings. The chapter is organized as follows: Section 4.2 presents the site observation of the Solar PV installation process on the rooftop of three different buildings. Section 4.3 reports on the Hazard Identification, Risk Assessment & Risk Control (HIRARC) analysis of the installation process as per observed earlier. Section 4.4 discusses the results of the questionnaires analysis. Section 4.5 presents the results of several interviews done and finally Section 4.6 concludes this chapter.

## 4.2 Site Observation of Solar PV Installation Process

Site observation is the best way to understand a certain process especially for people with no technical background of the topic. LZ Company Engineering Department was given the responsibility to conduct a feasibility study of a potential building for Solar PV system. The objective of this feasibility study was to ensure that the building utilities, structure and space are suitable for Net Energy Metering (NEM) installation. The study was prepared by two engineers – working in pairs has been their safety practice during working at height. - Working at heights is where any person is required to work at a place from which he will be liable to fall a distance of more than ten feet, means shall be provided to ensure his safety and such means shall where practicable include the use of safety belt or ropes. (Reg. 12, [9])

Next, the project team carried out load study or NEM Assessment Study (NEMAS) to verify the total energy consumptions of the premises for Grid-connected Photovoltaic (GCPV) Competent person to design the most beneficial system to the Client. Load study is performed on premises that are installing less than 12kWp while NEMAS is for premises that are installing 12kWp and more. NEMAS report is required prior to NEM application to SEDA Malaysia. The study was coordinated by the relevant distribution licensee (TNB or SESB) [11].

Upon confirmation order from the Client, next, was to install the system. Project completion period varied based on its system capacity. LZ Company never failed to conduct the safety briefing and checked attendance for the installers and the Client every day before work. From the observation, first aid kit and fire extinguisher were available at each of their on-going installation sites as part of their precautionary plan.

Figure 4.1: Loading and unloading of the Solar Panels at a Commercial building

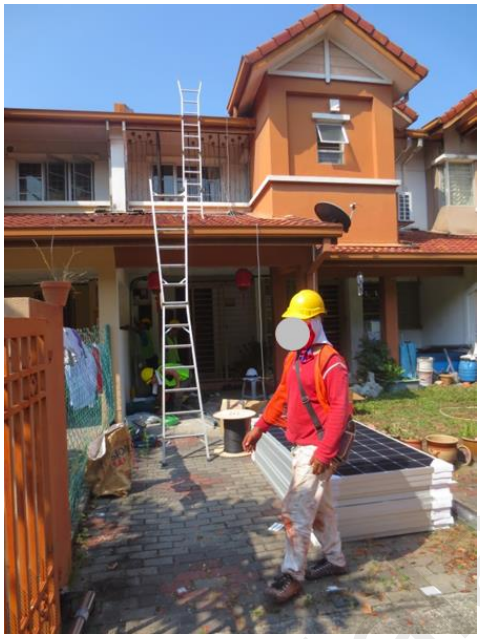

Figure 4.2: Solar panel relocation process at Residential building

Figure 4.1 and 4.2 were the methods of transferring the solar PV panels for different height of the building. The panels were delivered in a paper box on top of wooden pallets with an estimated weight of each pallet was 480kg. In both situations, the package is at risk of falling and can cause death or serious injury to the workers or surveillance that was on the perimeter.

Figure 4.3: Installer were unwrapping the solar panel boxes

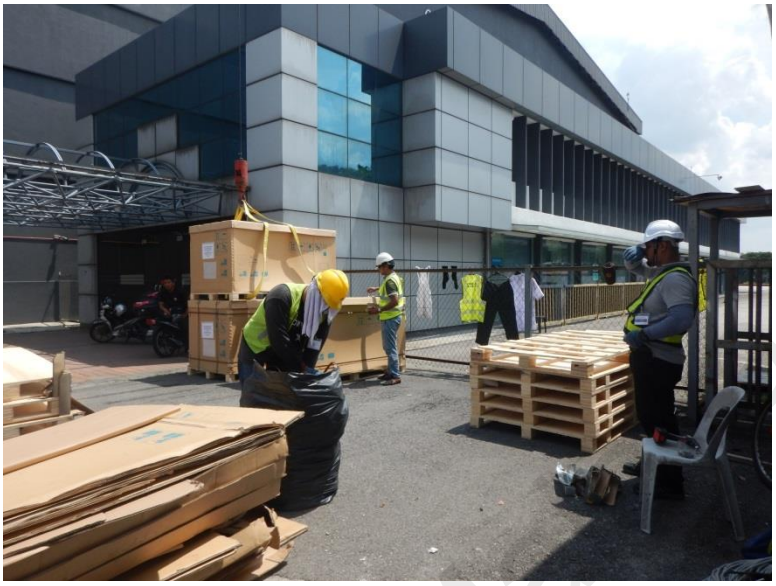

Figure 4.4: Waste management at Solar PV installation site

The packages that were unwrapped and the empty pallets and boxes were transferred back to the ground for disposed of. Loading and unloading panels from trucks and onto roofs can cause strains, sprains, muscle pulls and back injuries as well as cumulative trauma that stress the spine [5]. The panels can also heat up quickly when exposed to sunlight, causing burns if not handled safely [5]. Noticed also that the employees were wearing full body cover where they're covered their face using a shirt due to hot temperature. Working at high temperature can cause dehydration, heat exhaustion and fainting which are not fatal as heat stroke but can interfere with a person's ability to work [10].

Figure 4.5: Workers were installing the scaffolding as the main access to the rooftop

Some buildings have built-in access to the rooftop. If no, scaffolding shall be installed as the main access to the rooftop or ladders are stack as Figure 4.2. The scaffolding was inspected by their Site Safety Supervisor (SSS) for its condition and stability for the worker's safety (Reg.25, [9]).

Figure 4.6: Worker was grinding the cable tray

Grinding considered as Hot Work - Hot work is any work that involves burning, welding, using fire- or spark-producing tools, or that produces a source of ignition. Welding and cutting operations are common to drilling and servicing operations [12] - where the worker have to display their Work Hot Permit and follows the correct safety procedure related to hot work. Unfortunately, the workers were not wearing any safety glasses or goggles, or a face shield to protect against flying particles during grinding the cable tray as shown in Figure 4.8.

Figure 4.7: Worker was painting the inverter room

Painting operations should be carried out in a manner that will minimize dispersal of paint mist and solvent vapors in public areas [15]. Figure 4.11 show the painter was painting the inverter room without proper PPE which exposed him to the risk of accidentally ingest pigments due to eating, drinking or smoking while working, inadvertent hand to mouth contact, or pointing the paintbrush with the lips. The painter may also

experience eye, nose and throat irritation from the ammonia. Environmental impact from paints is the release of volatile organic compounds (VOCs) during the drying process after the coating is applied. VOCs participate in the formation of ozone. In the presence of nitrogen oxides (NOx) and sunlight, VOCs react with oxygen in the air to produce ozone, the most toxic component of the form of pollution commonly known as smog. Ozone attacks lung tissue, and is very injurious, even in very low concentrations [14].

Figure 4.8: Workers were installing the solar PV brackets on the rooftop under sunny day

Figure 4.9: Worker arranging the Solar PV panel at residential rooftop

Figure 4.13 shows the workers were bending repeatedly to arrange the metal deck brackets. Each panel weighted 26 kg was lifted by two workers to arrange it to fit the brackets. This process required them to squat repeatedly which might be a good exercise but not under the uncomfortable cloth and hot temperature. Ergonomically says, working in awkward body postures and performing the same tasks repetitively will expose them to Musculoskeletal disorders (MSDs) which increases their risk of injury [16] and the risk becoming higher if the workers work alone as Figure 4.15. Other than that, lifting heavy items at the uneven surface will significantly contribute to tripping and falling from the rooftop.

Finally, the cables were laid and pulled on the cable tray. Once everything was at its place, the interconnection between modules and the inverters was ready to be tested as shown in Figure 4.17. Solar electric systems include several components that conduct electricity: the PV solar array, an inverter that converts the panel's direct current to alternating current, and other essential system parts. When any of these components are

"live" with electricity generated by the sun's energy, they can cause injuries associated with electric shock and arc-flash. Even low-light conditions can create sufficient voltage to cause injury [5].

### 4.3 Hazard Identification and Risk Assessment (HIRARC)

HIRARC is the list of activities done which each activities hazard shall be analysis and to be evaluated based on its likelihood and severity. Then from the likelihood and severity value, the multiplication of this value will give us the risk rating. The risk rating can be categorized to low risk (L), medium risk (M) and high risk (H) [18].

Referring from Table 2.1, the risk assessment rating for likelihood were between two to four – two is an accident has not been known to occur after many years, three is an accident that might be occur at sometimes in future and 4 is an accident that has good chance of occurring and is not unusual. - The highest Risk analysis as shown in Appendice E was during the work activities done on the rooftop.

The level of severity of a certain task can be categories as per Table 2.2. Based on the HIRARC that has been done, the highest severity was for painting activities. Painting was not only affected the painter but due to the chemical presence in the paint itself and the process of painting can contribute to environmental issue that also affecting the surrounding air. Therefore, proper waste managements are much recommended while painting to avoid this kind of catastrophic.

There are 3 activities that falls in the high risk matrix – During feasibility study where the designer need to climb and study the rooftop, during installers were installing the solar panel brackets on the rooftop and during painting activities. - This three activities required immediate control measures such as the enforcement of wearing full body harness

while working at height, install safety net, barricade the area that can caused danger and have a comprehensive waste management plan for the waste and spillage.

From the HIRARC shown in Appendice E, four activities were under medium categories – electrical work, grinding which related to hot work, hacking and during installation of scaffolding.- Medium risk does not required immediate control measures, it is sufficient if the SSS able to provide temporary action that can minimize the risk such as taking rest every one hour. All safety measures must be documented for further improvement.

Finally, there are two activities that show low risk and were acceptable where no improvement is required. However, this activity must be monitored closely as it might cause serious injury and death if the task were done perfunctory.

## 4.4 Questionnaire Analysis

This analysis is based on 10 responses – 8 mans and 2 women- of Engineering Department staff in LZ Company - 5 were from one to two years of experiences, 3 were from less than one year experience and 2 were from more than four years experiences in Solar PV industries (Figure 4.18) – which are Malaysian citizen between age of twenty to forty years old. The majority of the staffs are working eight to twelve hours per day (9 responses, 90%), while other works less than 8 hours per day (1 response, 10%) – 8 were working during weekdays and 2 were working six to seven days per week. They were the suitable candidate for this survey as describe in Figure 4.19, the job scope involved were in working at height during system design and installation on the rooftop including electrical works.

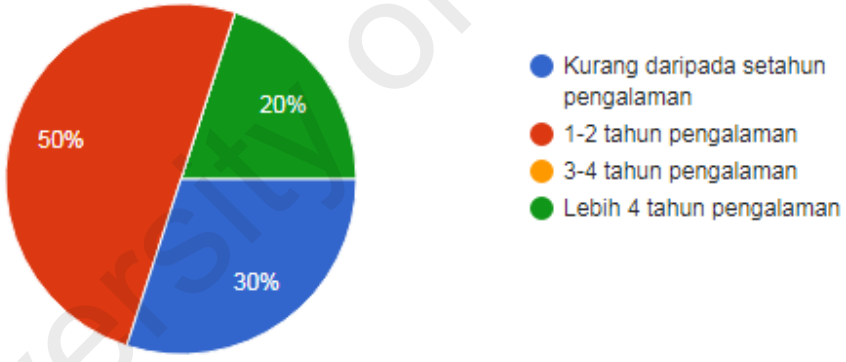


Figure 4.10: Percentage of workers working experience in solar industries

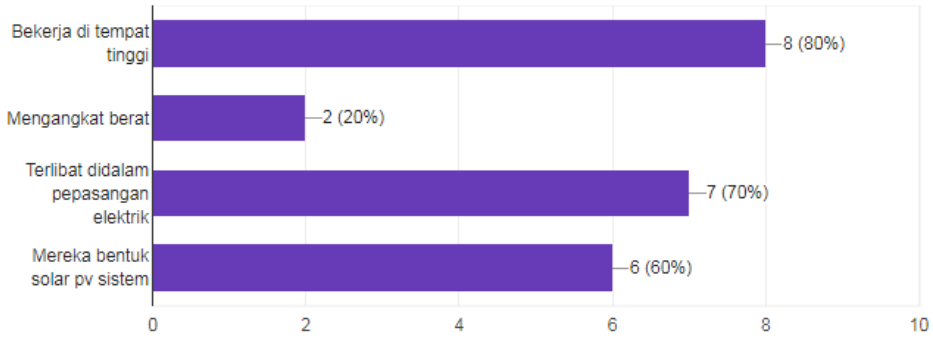


Figure 4.11: List of job scope of the workers in LZ Company

### 4.4.1 Work Exposure

When they were asked about their workplace condition, the results shows difference opinions of the best practice for their workplace (Figure 4.20) which although majority of them (6 responses, 60%) agreed that their workplace have minimum risk, 30% felt that it is safe and only 10% felt that his workplace was very risky and need for safety improvement. Safer workplace does not only focus on the big accident or incident that might occurred but also include the health and environmental effect of having a bad working space e.g. in terms of ergonomic work station and the airflow at the area. LZ Company should educate their employees on the bigger picture of best practices for their workplace.

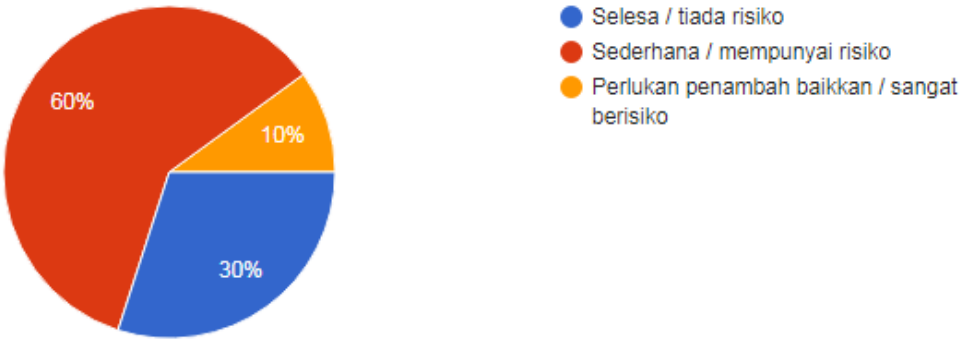


Figure 4.12: Percentage of workers opinion of their workplace

Solar PVs were installed at an unsheltered space where the panels shall have direct exposure to the solar radiance for the system to generate energy. Therefore, the conditions of the weather are important for the workers to complete their task as per schedule. This statement supports the results shown in Figure 4.21 - 80% felt that this should be improved especially during raining season. The best weather for installing Solar PV system is a clear day. Working in the rain puts the installers at a greater risk of falling because wet roof are slippery. For that reason, it is advisable for LZ Company to keep a close eye on the weather forecast when setting their schedule for Solar PV installation. But weather forecasts aren't always accurate. If the forecast on the day should be clear skies, but unfortunately it is dark clouds instead, the installation must be rescheduled.

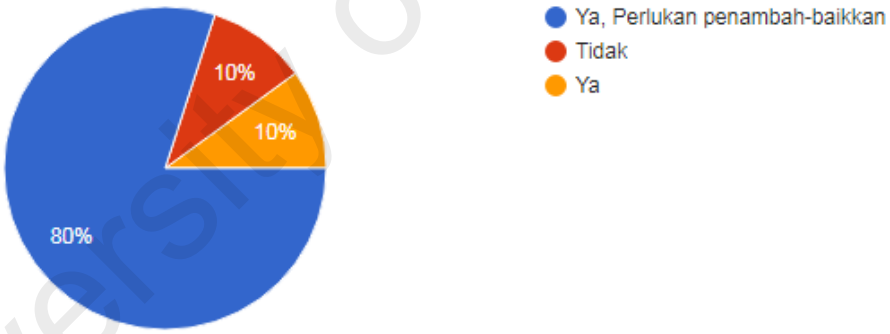


Figure 4.13: Percentage of workers opinion of weather influence in their task

### 4.4.2 Safety Awareness

This section discussed on the importance of housekeeping where effective housekeeping can eliminate some workplace hazards and help get a job done safely and properly as agreed by the respondents (Figure 4.23). Poor housekeeping can frequently contribute to accidents by hiding hazards that cause injuries [19]. Housekeeping is not just cleanliness. It is an ongoing operation which can be summarize as practicing the 5-S

approach – Seiri as for sort, clearing, classify; Seiton as for straighten, simplify, set in order, configure; Seiso as for sweep, shine, scrub, clean and check; Seiketsu as for standardize, stabilize, conformity; and finally Shitsuke as for sustain, self-discipline, custom and practice [20]. The frequency of practicing the 5-S should be done daily as agreed by half of the respondents while the other half felt that it is sufficient to do housekeeping once a week (Figure 4.22).

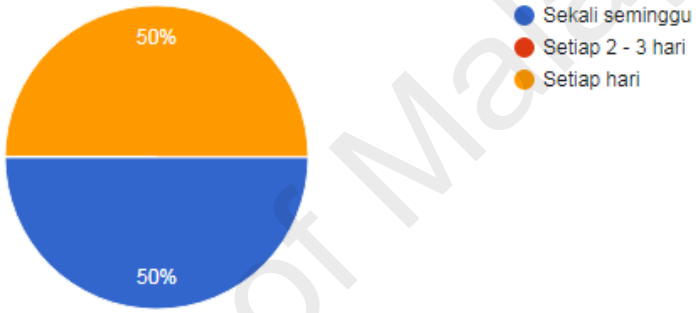


Figure 4.14: Workers opinions about the housekeeping practice at workplace


Figure 4.15: Workers opinions regarding the effectiveness of housekeeping in safety

### 4.4.3 Management Support

LZ Company is a professional service provider which believes safety practices are important during Solar PV installation. All of their employees received proper safety training (Figure 4.25) and were given their own PPE that were inspected to be in good condition (Figure 4.26) – PPE given to them were the basic type such as safety shoes and safety helmet (Figure 4.27) . Although most of them understand their job scope (9 response, 90%), there was 1 employee that was not brief on his job scope (Figure 4.24). This might be due to that the employee was new at this company and have not yet received an introduction training arranged by the Human Resource Department.

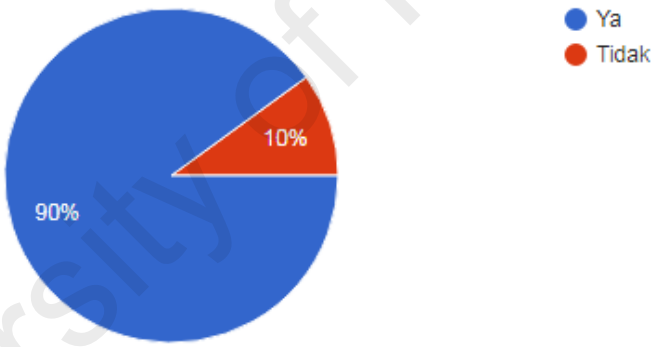


Figure 4.16: Percentage of workers feedback on the effectiveness training given regarding their job scope

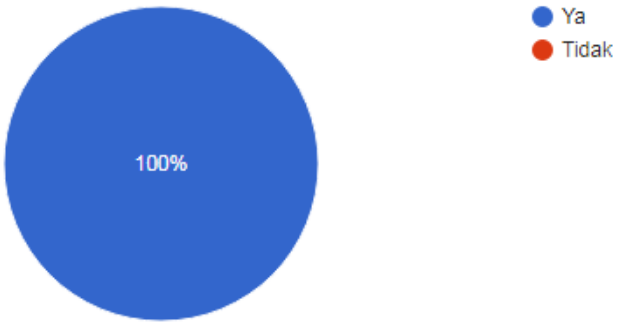


Figure 4.17: Workers feedback on the safety training received by them

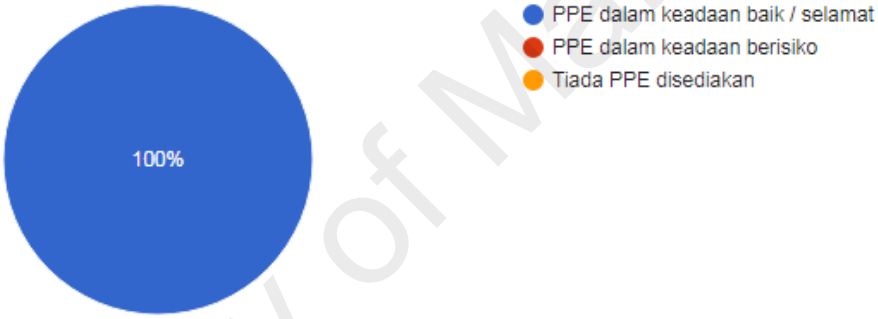


Figure 4.18: Percentage of PPE condition based on workers opinion

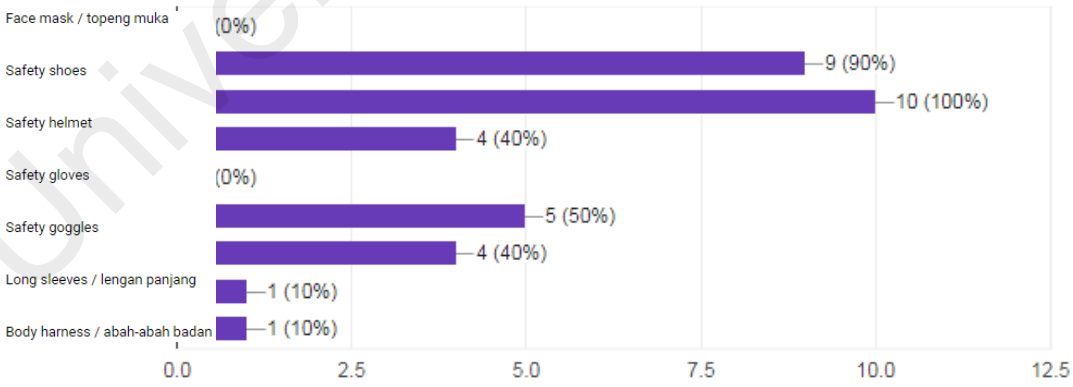


Figure 4.19: List of PPE received by the workers that involved in installation

### 4.4.4 Accident / incident

There were no reports of the accident and near misses recorded happen at the site in LZ Company. However, when they were asked for the normal duration of medical leave taken by them, 90% response that the longest medical leave taken was one to two days only. In Occupational Safety and Health Act 1994, an employer shall notify any accident which has occurred or is likely to occur at the place of work whereas in Factories and Machinery Act 1967, any accident must be notified if the accident prevents the person from following his normal occupation for more than 4 days. However, when an accident occurs and medical leave is given even for less than 4 days it still needs to be reported under Occupational Safety and Health Act 1994 [21].

The respondents have heard and were informed of the accidents happen at another site from other installers such as shown in Figure 4.29 where the most frequent accidents happen were tripping, electrocution and fall from height. These were the same incident that normally reported as near misses (Figure 4.30).

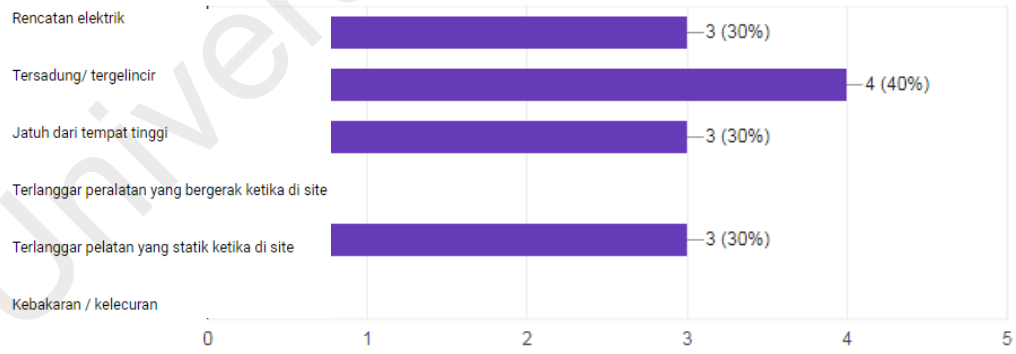


Figure 4.20: Types of accident occurred during installation based on workers experiences

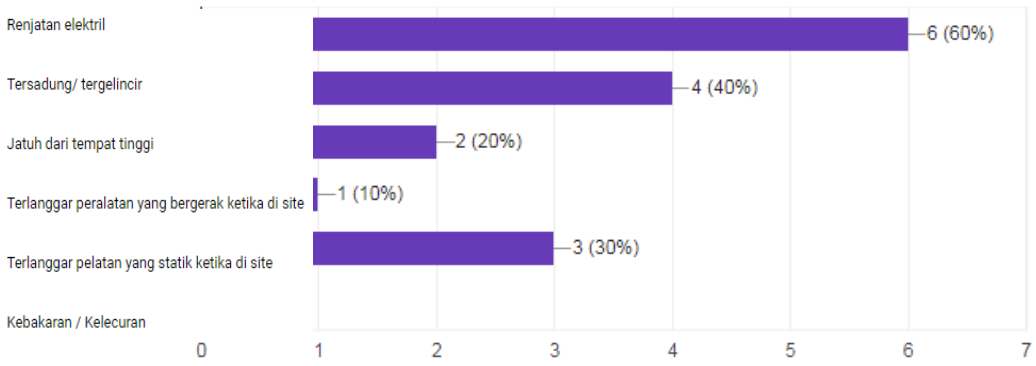


Figure 4.21: List of near misses happen during installation based on the workers knowledge

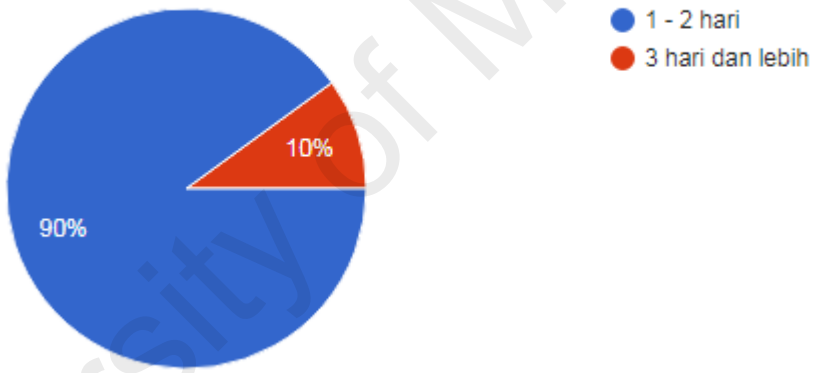


Figure 4.22: Numbers of days of medical leave taken by the workers

## 4.5 Interview Analysis

Two peoples that are responsible to overview current process and procedures implemented by LZ Company - Manager of Engineering Department and the Group leader of Operation and Maintenance Group - were interviewed.

They were asked to describe the overall process of design stage and they explained that they followed the NEM guidelines either the design falls under HT or LV system. If it is an HT system, their design capacity will only take 75% of the electricity maximum

demand consumption. whiles if it is an LV system, their design will be 60% of the CT rating or 60% of the fuse rating, depending on the types of a meter - 60% of fuse rating taken for an OPC meter which the highest fuse rating can be is 100A or 60% of CT rating from an LPC meter which normally has more than 100A CT rates.

Next, they were asked if they have been involved or heard any accident that happens during the service in this field. One of them said that once there was a serious injury happen due to falling from height about two or three years before. It was reported that the victim was confused by the color of the rooftop and the skylight. The accident happens during the victim was in the middle to grab some tools when he accidentally steps on the skylight. After the accident reported, the engineering team immediately requested to barricade each of the skylights that available between their working areas. When they were asked why they were not wearing body harness until today during installation, the manager said that he does not advise his team to wear it as it might increase the risk of tripping and slow down the installation process. However, body harness can be implemented based on the recent technology of falls protection for Solar PV installer [22].

Next question was about the hot weather effect on the installation and are there any health issues due to this. Both of them said that there were cases where the installer was not feeling well but only for one or two days of medical leave. Since the fall from height accident, the installers were given permission to rest for every one hour as part of improvement.

Is there any accident due to electrical work during the installation? They said that there were two cases -first was when the factories' rooftop was minor burned due to an injured cable that caused arching. Secondly was during installation, where the system required for a design improvement, the installer accidentally touches the bus bar and burned 30% of his hand -. It’s important to recognize that with PV systems, electricity comes from

two sources: the utility company and the solar array that is absorbing the sun's light. Even when a building's main breaker is shut off, the PV system will continue to produce power. This makes isolating the power source more difficult and requires extra caution on the part of the solar worker [5]. What improvement has been done to avoid these types of accidents from happening again? They said that all electrical works shall be done only with the right PPE and only when the main supply, DC and AC, were confirmed switch off and have no supply.

Do the installers update their health status and is it necessary? As mentioned in their safety briefing, they were advised to not proceed with their work if they are not fit for work and they will replace with another installer. If they were found working not in good health, they were advised to leave the site immediately.

Does this solar PV contribute to environmental effect? Yes. The effect can be seen in the coming 21 years where the system will no longer able to perform where it has not been decided on how to manage the Solar PV panels when even now the solar panel that is not used were kept at the site. This caused space wastage. Can we return the damaged panel to the manufacturer? They would not accept it since it is no longer fit.

Does this company have done any HIRARC before? Yes but no enforcement since LZ Company previous Safety Health Officer (SHO) resigned.

How do you select your contractor? Is it based on their competency? Do you have your own skill evaluation? No, normally we selected our installers based on an interview session with them and most likely based on their experience in the task.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

This research report revealed the process taken from design stage to the end of testing and commissioning stage where there are many safety improvements can be done in LZ Company. Although the visibility of HIRARC was real, unfortunately, it was not referred as main documents. LZ Company took safety seriously as shown in their effort to conduct safety awareness training once in every two weeks for their staff. This training was part of their key performance index requirement. Other than that, the establishment of safety committee and their continuous effort in sharing safety awareness thread through emails represented the commitment of LZ Company towards safer, healthier and environmentally cautious company. Their dedication in improving each of their near misses and safety procedure were also visible as an example of what had happen to one of the installer that was fall from the skylight earlier in the report. Due to this accident, LZ Company enforced of barricaded and installed safety net at each skylight immediately before any installation team proceed with their work.

There are many authorities that involve in the implementation of Net Energy Metering (NEM) scheme. Some of them are Sustainable Energy Development Authority (SEDA) and Malaysian Investment Development Authority (MIDA). The commission for this scheme is the Energy Commission and reports to the Malaysian Ministry of Energy, Green Technology and Water (KeTTHA) who is responsible for the oversight of all elements of the industry from tariffs and licensing to consumer safety. Solar PV installation also involved authority from Malaysian Construction Industry Development

Board (CIDB) to oversee the construction aspect and Department of Occupational Safety and Health (DOSH) to supervise the occupational safety practice during the installation.

Basically, there are a lot of legislation and guidelines for Solar PV. Since the system generated electricity, therefore it falls under Electricity Supply Act 1990 and Renewable Energy Act 2011, just to name few of it.

Most of the installers were selected based on experienced and some without proper training. Nevertheless, the number of injuries happen in LZ Company is nil, probably due to the effectiveness of safety briefing and control measure taken by them. Contrarily, the system designer must be a competent Grid-connected photovoltaic certified by SEDA. Charge man and wireman are other requirements for solar PV installation.

Finally, although they are several articles that share their opinion toward safety, health and environmental effects of Solar PV installation process, none of it was found to be part of a research project. This shows that despite the popularity of this system, many are more interested to know the safety, health and environmental effects of Solar PV during the manufacturing stage which can be found easily on the web.

To summarize this conclusion, the risk presence during Solar PV installation process has similarities to the risk of a roofer and electrical workers. It is supported by the accident index from the DOSH where solar PV installer was not listed but was part of the construction and electrical occupational hazard. However, proactive safety planning and its successful implementation on the job can help ensure that accidents don't happen. HIRARC should be updated and be the main reference for each process taken during design and installation stage. LZ Company should not focused on the awareness and basic safety process but to manage the risk and hazard comprehensively by hiring a Safety Health Office (SHO) or trained somebody that is suitable for this position. A SHO shall

not be responsible of other task that are not related to SHO job scope so that the enforcement and activities plan can be done smoothly.

## 5.2 Recommendation of Control Measures

The introduction of risk controls should follow the principle of hierarchy of control, that is, in the following priority order: Firstly – Elimination, Secondly – Substitution, Thirdly – Engineering control, fourthly – Administrative control and Lastly – Provision and use of suitable Personal Protective Equipment (Figure 4.32).

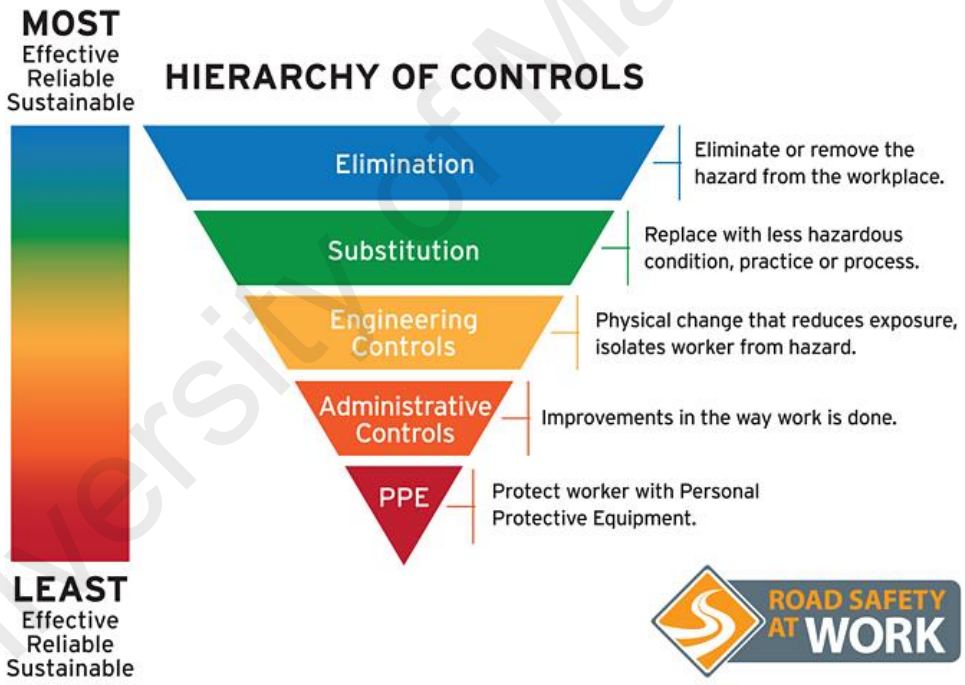


Figure 5.1: HIRARC hierarchy of controls (Ref. [18])

Lifting solar panels to rooftop are heavy and it is awkward to carry especially when climbing the ladders while carrying solar panels. To get solar panels onto rooftops, use properly inspected cranes, hoists or ladder-based winch systems (***Engineering control***). Therefore, to minimize the risk of falling, each solar panel must be lifted with at least two

people while applying safe lifting techniques (***Administrative control***). Loading and unloading panels can cause pain at the lower back area. Once unpackaged, cover panels with an opaque sheet to prevent heat buildup and must always wear gloves when handling panels (***Elimination***).

Solar construction often involves working on roofs and from ladders. Choosing the right ladder and using it properly are essential. Therefore select the ladder that best suits the need for access – whether a stepladder, straight ladder or extension ladder. Straight or extension ladders should extend a minimum of three feet above the rung that the worker will stand upon (***Engineering control***). Choose the right ladder material to eliminate serious hazard near power lines or electrical work. Always place the ladder on dry, level ground.

Rooftops solar installations are especially hazardous because the work space diminishes as more panels are installed, increasing the risk of falls. Practicing a good housekeeping such as keeping all work areas dry and clear of obstructions must become workers habit to avoid tripping (***Administrative control***). Fall from height will cause serious injuries or death. Therefore, holes on rooftops were covered, including skylights, and on ground-level work surfaces. For fall distances of six feet or more, take one of three protective measures: install guardrails around ledges, sunroofs or skylights; use safety nets; or provide each employee with a body harness that is anchored to the rooftop to arrest a potential fall (***Engineering control***).

Solar electric systems include several components that conduct electricity: the PV solar array, an inverter that converts the panel's direct current to alternating current, and other essential system parts. When any of these components are "live" with electricity generated by the sun's energy, they can cause injuries associated with electric shock and arc-flash. Even low-light conditions can create sufficient voltage to cause injury.

The best way to stop the current flow is by covering the solar array with an opaque sheet to "turn off" the sun's light (***Elimination***). Treat the wiring coming from a solar PV array with the same caution as a utility power line. Always ensure that all circuits are de-energized by using a meter or circuit test device before working on them. Practice Lock out Tag out (LOTO) while dealing with power on systems that can be locked out (***Elimination***). Tag all circuits you're working on at points where that equipment or circuit can be energized.

Personal Protective Equipment is an essential part of every solar installation. It's the employer's job to assess the workplace for hazards and provide the ***PPE*** deemed necessary for the employee's safety. Safety helmet, gloves and safety shoes with rubber soles are among the commonly required PPE for solar projects. Employees are in turn responsible for using PPE in accordance with their employer's instructions, maintaining it in a safe and reliable condition and requesting replacements when necessary.

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