Hazard Identification and Risk Assessment in Solar Manufacturing Industries

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Abstract- *Purpose of this paper is to identify and analyse the potential hazards associated with solar manufacturing industry and risk assessment of each individual hazard of each processes and systems. Hazard identification and risk assessment of different processes which are being carried out in the solar manufacturing industry and to minimize their effect in order to make the working place safe. For any industry to be successful it should meet not only the production requirements, but also maintain the highest safety standards for all concerned. The industry has to identify the hazards,assessthe associated risks and bring the risk to tolerable level on a continuous basis.*

Keywords- Hazard Identification, Risk Assessment, Safety in Solar Industries

I. INTRODUCTION

Any industry has to identify the hazards,assess the associated risks and bring the risks to tolerable level on a continuous basis. Solar manufacturing industry being a potentially-hazardous operation has considerable safety risk to the workers associated with it. Unsafe conditions and practices in the site lead to a number of accidents and causes loss and injury to human lives, damages the property, interrupt developmental aspects etc. Risk assessment is a systematic method of identifying and analyzing the hazards associated with an activity and establishing a level of risk for each hazard. The hazards cannot be completely eliminated, and thus there is a need to define and estimate an accident risk level possible to be presented either in quantitative or qualitative way. Because of the existing hazards of solar manufacturing industry and the complexity of machinery and equipment and the associated systems, procedures and methods, it is not possible to be naturally safe. Regardless of how well the machinery or methods are designed, there will always be potential for serious accidents.

II. REVIEW OF LITERATURE

Kumaravel A and Dr. Muthukumar K (2020) had concluded that Hazard identification and risk assessment were carried out in different department of the brakes India manufacturing plant. Risk has been calculated by the risk table range from 1 to 25 were consequence and frequency of occurrence rating between 1 to 5. This study was aimed to identify the potential hazards that might cause accident and risk to the workers in the workplace so that preventive action should be encounter to minimize such unpleasant accidents and events. Different control measures were submitted has a report to the Brakes India Pvt Ltd to reduce the chances of unexpected events and maintain safe workplace.

Mohamed Shahid P A1, Firoz N et. al. (2019) has found thatIndia’s growth rate is slow in the deployment of solar power projects when compared to other developing and developed countries. This study enables to identify the main risk in implementing solar energy projects and develop a guideline which could serve to reduce the risks associated with investments in solar projects. In this study, survey was conducted amongst the different players of solar power project installation and operation to identify the various risk factors and sub factors.

R Aulia and Qurtubi (2019) had discussed about hazard identification, risk assessment and risk controlling in a production line 1 in a company that focuses its production in engineering, production, installation (EPI) of concrete industry. Observation and interview are employed as the method of data collection. The analysis involves Hazard Identification and Risk Assessment. Based on hazard identification, there are 53 potential hazard occurrences that possibly could emerged in company, consist of mechanical hazards with 55%, physical hazard of 32%, chemical hazard of 9% and electrical hazard 4%. Risk potential is calculated as 53% at the high level, 34% at the moderate level, 11% at the extreme level and 2% at the low level.

Bambang Suhardi1, PringgoWidyoLaksonoet. al. (2018) had investigate the potential hazards and accidents that might occur at batik printing PT. Batik Merak Manis and recommends practical solutions to enhance safety and health at the workplace. This research adopts Hazard Identification Risk Assessment (HIRA) and Hazard and Operability Studies

(HAZOP) to perform risk identification and assessment in the workplace.

III. PROBLEM STATEMENT

1) Cell Production-The basic component of a solar cell is pure silicon, which is not pure in its natural state.Pure silicon is derived from such silicon dioxides as quartzite gravel (the purest silica) or crushed quartz. The resulting pure silicon is then doped (treated with) with phosphorous and boron to produce an excess of electrons and a deficiency of electrons respectively to make a semiconductor capable of conducting electricity. The silicon disks are shiny and require an anti-reflective coating, usually titanium dioxide. In solar cell manufacturing process various process hazards are there which may adversely affect human life and could have the potential to result in serious accidents. The various potential hazards are listed in Table 2 associated with cell manufacturing process.

2) Module Production-The solar module consists of the silicon semiconductor surrounded by protective material in a metal frame. The protective material consists of an encapsulant of transparent silicon rubber or butyryl plastic (commonly used in automobile windshields) bonded around the cells, which are then embedded in ethylene vinyl acetate. A polyester film (such as mylar or tedlar) makes up the backing. A glass cover is found on terrestrial arrays, a lightweight plastic cover on satellite arrays. The electronic parts are standard and consist mostly of copper. The frame is either steel or aluminum. Silicon is used as the cement to put it all together. Module manufacturing is a complex method and poses a variety of potentials hazards. These hazards are found in module production processes and tabulated in Table 3.

IV. METHODOLOGY

The Hazard identification and Risk assessment (HIRA) is the structured multidisciplinary hazard identification, risk assessment and methodology that provides detail review of hazard, risk and control of the construction activities. The review is facilitated by the relevant construction personnel in the brainstorming session.

This tool covers the following steps in a systematic approach as follows in Figure 1.

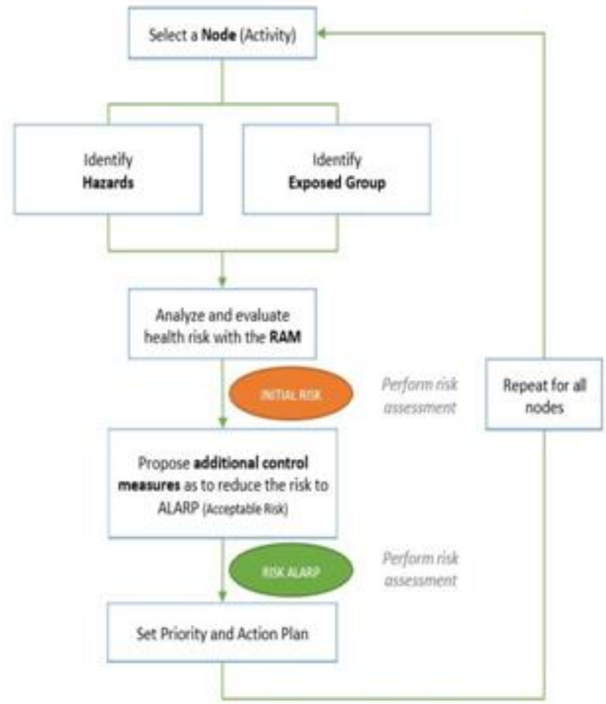

Figure 1: Overview of HIRA Methodology

Steps of HIRA is summarised as follows:

1. Classify work/assessment units or work activities during construction phase (based on Work Method Statement).
2. Identify the hazards associated with work activities.
3. List out the Consequence of the hazard involved in the activity.
4. Assess and score the risk (i.e. probability X severity) using the Risk Matrix as per Risk Assessment Matrix (refer to Table 1).
5. List out present controls (preventive and recovery).
6. Assess the risk based on present controls.
7. Reassess the medium and high risk to bring it down to acceptable risk.
8. Verify compliance to regional Regulation, Project Specifications, and applicable international codes and standards.

V. RISK ASSESSMENT

Risk Assessment Matrix- For each of the identified hazard, the level of risk is assessed based on the Risk Assessment Matrix (refer Table 1) during HIRA review. Risk ranking is firstly performed based on the unmitigated risk for each hazard, and then the level of risk is re- evaluated after taking into consideration of the existing prevention/mitigation measures and controls.

If the risk is in the Green region on the Risk Assessment Matrix, this is broadly acceptable and no further action is required. If the risk is in the Yellow region on the Risk Assessment Matrix, this is in the tolerable regions and needs to be demonstrated to be as low as reasonably achievable (ALARP) by recommending further action. If the Risk is still in the Red region, this is not acceptable and action definitely needs to be taken.

HIRA Review team shall discuss the proposed actions, where applicable, to address the hazard that isascribed with a medium to high-risk rating.

Control Measures- Controls are required to be separated into preventive and recovery. Controls are required to be categorized using the hierarchy of controls (eliminate, substitute, isolate, engineering, administrative, and PPE). It allows review of controls to ensure the principle of inherently safer construction is being applied.

Table 1: Risk Assessment Matrix

Likelihood / Probability	**SEVERITY / CONSEQUENCE**				
	Insignificant 1	**Minor 2**	**Moderate 3**	**Major 4**	**Catastrophe 5**
	No loss of work ,short time discomfort no visible ill health and injury	Cuts/abrasions, short time discomfort with no loss of work.	Loss of work, reversible damage to body parts, and short time illness exceeding 48 hours	Irreversible/ reversible Loss of Body parts, Loss of work beyond 2 weeks.	Fatality / Multiple fatalities, Massive Damage, Permanent disability leading to loss of work.
Almost impossible [1] (Neither can be perceived or occurred anywhere.	L (1)	L(2)	L(3)	L(4)	M(5)
Unlikely [2] (Not/ Never occurred.	L(2)	L (4)	M(6)	M(8)	M(10)
Unusual / but Possible [3] (Not Known to have occurred or has Occurred in similar Operations)	L (3)	M(6)	M(9)	M(12)	M(15)
Quite Possible (Likely) [4] (Known to have occurred or has while performing similar tasks.	L(4)	M(8)	M(12)	H(16)	H(20)
Almost Certain [5]	M(5)	M(10)	M(15)	H(20)	H(25)

(Always known to have occurred while such tasks are carried out)					

Table 2: Hazard Identification and Risk Assessment (Cell Production)

Sr. No.	Activity	Hazards	Existing Risk Controls			Risk rating			Risk Level	Qualitative				Risk level
			Engineering Controls	Administrative controls	PPE	Consequence	Likelihood	RPN		LC	BC	IPC	E	
1	Wafer Unpacking and Placing the wafers from Pallet to magazine.	• Fall of packing/wafers • Cut against the tool used for unpacking • Hit against the work table during handling • Finger-cut against the broken wafers.		People are made aware of hazards and safe work practices. SOPs made available Provision of First Aid and medical facility	• Surgical Gloves. • Safety Goggles. • Face shield • Cut-resistive gloves. • Clean Room Garments	2	2	4	LR	N	N	Y	N	MR
2	In-line Texturing - Collection of rejections/ breakages from the texturing machine	• Cuts against the broken wafer. • Wafer jammed inside Wetbench. • Finger trapping in the belt conveyor. • Chemical exposure due to overlapped wafers	Emergency Stop to shut down the equipment in safe mode, Enclosed operation. Sash door with alarm- visual and sound, Emergency stops for draining HF/ HNO3/ KOH / HCL to secondary tank, DM water gun for rinsing wafers which have residual acids	People are made aware of hazards and safe work practices. Trained and Authorised Operators SOPs made available Provision of First Aid and medical facility	• Disposable Nitrile Gloves • Safety Goggles. • Face shield • Clean Room Garments	3	4	12	MR	N	N	Y	N	MR
3	Wet bench Bath change/drain	Chemical leakage and Drain Pump failure resulting in exposure to chemicals- Skin contact	Doors with Safety interlock, Provision of Leakage sensors, Provision of Fume extraction system with scrubber, Electrochemical sensors -HF with alarm and interlocking with Local exhaust ventilation	People are made aware of hazards and safe work practices, Users confirm critical controls operating correctly prior to start operation , Safe Operating Procedure, Provision of First Aid and medical facility, Hazard warning signs, GHS Labelling, Safety Data Sheets, spection and Preventive, aintenance of critical to EHS equipment (sensors, LEV, alarms, interlock relays etc.) MOC for any changes in the installation	Full face piece air respirator Minimum 60 min permeation resistance and excellent degradation resistance rating –Butyl rubber or neoprene hand gloves and sleeves, full body suit	3	4	12	MR	Y	N	Y	N	MR
4	Clean Rollers/bath as per requirement	Chemical splashing on body.	Doors with Safety interlock, Provision of Leakage sensors, Provision of Fume extraction system with scrubber, Electrochemical sensors -HF with alarm and interlocking with Local exhaust ventilation	Display of Safety signages Display of MSDS, People are made aware of hazards and safe work practices. SOPs made available Provision of First Aid and medical facility	• Chemical Resistive Gloves • Chemical Resistive Suit • Chemical Respiratory Mask • Chemical Resistive boots • Face Shield	3	4	12	MR	Y	N	Y	N	MR
5	Makeup new bath	• Chemical overflow. • Chemical fumes can spread outside. • Pump failure.	Doors with Safety interlock Provision of Leakage sensors Provision of Fume extraction system with scrubber	Display of Safety signages Display of MSDS, People are made aware of hazards and safe work practices. SOPs made available Provision of First Aid and medical facility	• Chemical Resistive Gloves • Chemical Resistive Suit • Chemical Respiratory Mask • Chemical Resistive boots • Face Shield	3	4	12	MR	Y	N	Y	N	MR
6	POCl3 bubbler changing - Movement of POCl3 bubbler from its storage to diffusion room as packed	• Fall of POCL3 bubbler package resulting in chemical contact and fumes • Hit against doors/trolley	POCL3 bubbler is packed in a over pack container	People are made aware of hazards and safe work practices. SOPs made available. Provision of First Aid and medical facility	• Chemical Resistive Gloves • Chemical Resistive Suit • Chemical Respirator with cartidge Mask • Chemical Resistive boots • Face Shield	5	4	20	HR	Y	N	Y	N	MR

Table 3: Hazard Identification and Risk Assessment (Module Production)

Activity	Hazards	Risks	Existing Risk Controls			Risks rating			Risk Level	Qualitative				Risk level
			Engineering Controls	Administrative controls	PPE	Consequence	Likelihood	RPN		LC	BC	IPC	E	
Switching on the Machine at the Main Electrical Panel and operating panel	Damaged or open cables. Arc Flash, Short-circuit, Over load, Fumes	Fatal, Sever Injury, Burn Injury, Property damage, Fire, Explosion, Lungs damage	RCBO provided, Approved electrical panels.	Safe Operating Procedure, Deployment of trained and qualified persons, Access Control Provision of rubber mat. Cautionary signages displayed on the electrical panel.	Electrical Arc Flash Suits during Live energized electrical work , Electrical Insulated Gloves	5	4	20	HR	Y	N	N	N	MR
Loading of cells	Pinch points or nip points , moving parts or rotating parts –rotating silver ribbon spool, Heat due to high temperature of furnace, oven or heater, sharp edge of the cells	Cut entanglement, abrasion, amputation, Thermal Burn, Heat stress	Enclosed operation with interlocks, physical fencing, sensors etc. Emergency Stop to shut down the equipment in safe mode.	Trained and Authorized Operators Safe Operating Procedure	Safety Shoes Surgical Gloves Apron for clean environment	2	4	8	MR	Y	N	N	N	MR
Loading of flux	Flammable Chemicals, Spillage of Chemical, Contact of body parts with Hazardous Chemicals, Harmful Vapour during loading	Fire, Explosion, Burn Injury, Property Damage, Contamination of soil or ground, Skin Irritation, Eye Injury	FM/UL approved storage cabinet, dispenser and plunger cans, paint coated floor	GHS Label, Safety Data Sheets, Safe Operating Procedure, Storage of limited quantity.	Safety Goggles, Safety shoes	5	4	20	HR	Y	N	N	N	MR
Loading of Ribbon Bobbins	Pinch points or nip points , moving parts or rotating parts –rotating silver ribbon spool, Heat due to high temperature of furnace, oven or heater	Cut entanglement, abrasion, amputation, Thermal Burn ,Heat stress	Enclosed operation with interlocks, physical fencing, sensors etc. Emergency Stop to shut down the equipment in safe mode.	Trained and Authorized Operators Safe Operating Procedure	Safety Shoes Surgical Gloves Apron for clean environment	3	4	12	MR	Y	N	N	N	MR
Machine operation	Pinch points or nip points , moving parts or rotating parts –rotating silver ribbon spool, Heat due to high temperature of furnace, oven or heater	Cut entanglement, abrasion, amputation, Thermal Burn ,Heat stress	Enclosed operation with interlocks, physical fencing, sensors etc. Emergency Stop to shut down the equipment in safe mode.	Trained and Authorized Operators Safe Operating Procedure	Safety Shoes Surgical Gloves Apron for clean environment	5	4	20	HR	Y	N	N	N	MR
Reversing the cell and module	Pinch points or nip points , moving parts –Pneumatic lifting device	Hit, abrasion, crush, amputation etc.	Electronic protective safety curtain	Trained and Authorized Operators Safe Operating Procedure	Safety Shoes Apron for clean environment	4	4	16	HR	N	N	Y	N	MR

VI. CONCLUSION

During our visit to the plant we have noticed few safety measures have been taken however there is scope for improving in the area mentioned in Table 2 and Table 3 in red and yellow colour. We were astonished to see the workers participation and eagerness to adopt safe practices. This type of Safety culture is only possible by management's commitment and motivation towards safety. some improvements brought out in the HIRA study may be considered for implementation.

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