Chapter 21
Exploring the OSH Scenario in Floating Solar PV Projects in India and Opportunities for Ergonomics Design Interventions

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Abstract The renewable energy industry is seeing exponential growth in India. Among the many clean energy sources, floating solar PV (FPV) projects are being preferred because of its many advantages. The installation and maintenance of FPV panels are generally been executed by an informal and inexperienced/semi-skilled workforce who are exposed to the emerging challenges, which may lead to compromising of occupational safety and health (OSH) aspects. To explore the ground scenario, field surveys were carried out to study the OSH scenario which revealed that the workers are highly exposed to different occupational hazards during installation and maintenance of FPV panels due to heavy load handling, awkward postures, inappropriate tools, lack of safety measures against the harsh working environment (hot Sun, electrocution, drowning, etc.), lack of specific training/skill-development, etc. Project managers agreed that immediate attention is required for the safety and better occupational health of the workers and felt the need for protecting the workers from the hazards especially through design interventions. This study is a maiden effort in understanding the OSH aspects in the emerging FPV sector in India and establishes an information gap, which is proposed to be addressed through suitable ergonomics design solutions.

21.1 Introduction

The power of the Sun is virtually infinite. Only 30 min of solar radiation falling on Earth can meet the annual energy demand of the world [1]. To tap this source of clean energy, countries across the world are promoting different kinds of solar PV installations. Such sources of energy are also demand-driven as concerns over climate change and sustainability are taking precedent. The growth of renewable energy in India has

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resulted from global and national policy developments (Fig. 21.1), decreasing tariffs of solar PV projects, and the vast availability of solar irradiation and potential in India most of the year [2]. In the last decade, solar PV installations in India have registered higher growth than other renewable sources of energy (Fig. 21.2). Utility-scale ground-mounted solar PV projects require large-scale land acquisition, which is a sensitive socio-economic issue. These circumstances have pushed stakeholders to explore other types of solar PV projects that are land neutral.

Globally, floating solar PV (FPV) is fast emerging as a viable option where water bodies are available. In 2007, the first floating solar project (175 kWp) in the world was installed by SPG Solar of Novato, California, and Thompson Technologies Industries (TTi), at Far Niente Winery in Napa Valley, California [3], and the first FPV project in India was installed in Kolkata, India. A study has estimated that the quantum of water surface available for FPV installation in India is 18,000 km^2, with

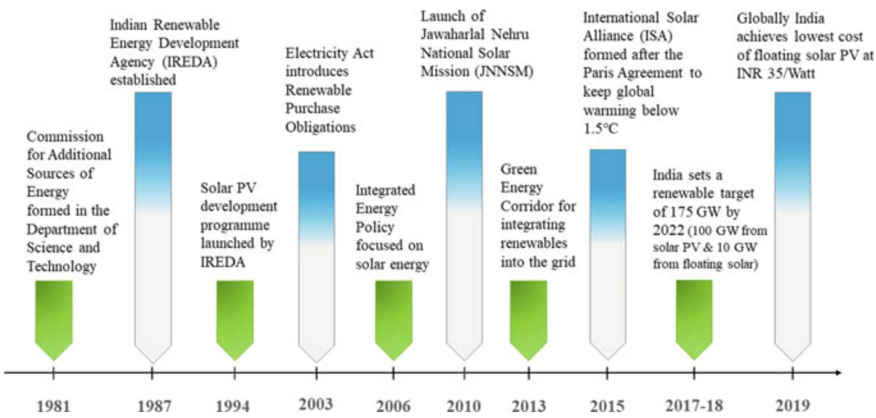

Fig. 21.1 Significant milestones in the growth of renewable energy in India (Author compilation)

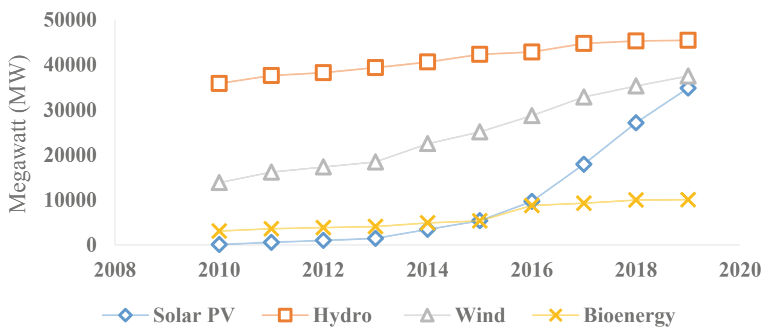

Fig. 21.2 Growth of installed capacities (in MW) of different types of renewable energy sources in India between 2010 and 2019 (Compilation by authors based International Renewable Energy Agency data)

a maximum potential of 280 GW [4] with the state of Maharashtra having the largest number of reservoirs, followed by states of Madhya Pradesh and Gujarat, indicating a vast potential. At the beginning of 2019, the global installed capacity of FPV stood at 1314 MW, and the global potential is estimated at 400 GWp [5].

21.2 Background and Need for the Study

FPV sites are new workplaces. Installation and maintenance involve new technology, new tools, new hazards, and new environments. These circumstances present new challenges to the workers engaged in such projects. Any work that is beyond the capabilities of the worker is likely to lead to serious safety and health hazards. The hazards primarily arise from the various mismatches in the interface at the workplace. The workplace transition and emergence of new hazards are represented in Fig. 21.3. The mismatches may involve physical, cognitive, and organizational factors.

Moreover, if untrained and unprotected workers are exposed to an unknown and uncertain work role or environment, the occurrence of occupational diseases becomes high. The solar PV industry in India is growing fast, and this entails that a large and temporary workforce will be engaged in this sector, exposing a larger worker population to emerging hazards. An estimate of the International Renewable Energy Agency (IRENA) says that globally 11.7 million people will be engaged in the solar PV industry by 2030 with an installed capacity of 2840 GW [6].

As is evident from Fig. 21.3, there are several mismatches between the worker and different components of a typical renewable energy workplace, which are FPV projects in this case. The workers are mostly engaged in a non-standard work arrangement and are likely to be exposed to several psychosocial hazards. These mismatches

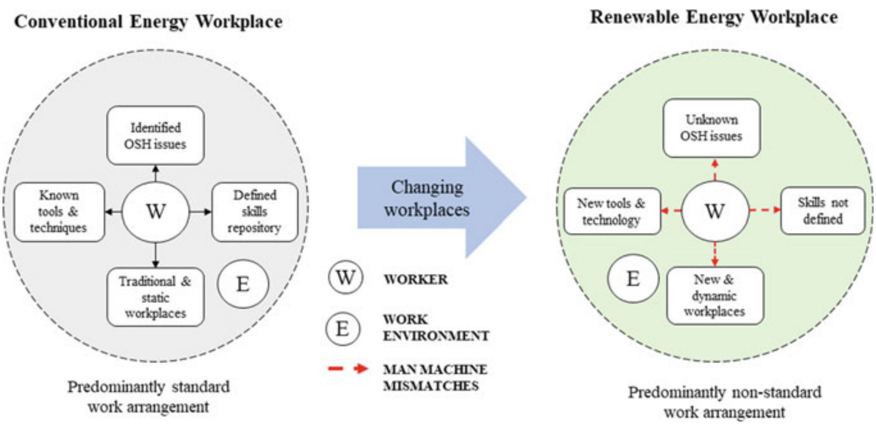

Fig. 21.3 Workplace transition from conventional energy to renewable energy workplaces (Graphic: authors)

are potential situations for the causation of several occupational diseases. An important objective of design is to provide a solution to a problem. Therefore, design solutions can be used to resolve these mismatches by controlling the risk factors and matching the interfaces with the worker to create a safe and comfortable work environment. FPV projects have a bright future in India. Thus, it is essential to address these issues through design for safety approach at the nascent stage, so that present and future workers can be protected.

21.3 Research Questions, Aims, and Objectives

The study began by formulating some research questions. They are (a) what are the occupational hazards that workers are exposed to during the installation and maintenance of floating solar PV projects? and (b) what context-specific tools, equipment, or other workplace aspects can be designed (or redesigned) to control the hazards for which solutions do not exist?

The present study investigates the ground scenario of OSH aspects of the FPV workforce and thereafter checking the possibility of improvement of OSH through innovative design interventions. The objectives are as follows:

- To identify the sources of hazards (occupational, environmental, psychosocial, skill gaps, etc.) regarding the workers engaged in FPV installation and maintenance.
- To study the existing occupational safety and health measures for the FPV sector.
- To identify the possibilities of design interventions from the OSH perspective.

21.4 Methodology

A review of the literature was carried out to identify existing research in the solar PV industry with emphasis on the FPV sector, followed by developing an OSH questionnaire to carry out the field studies.

21.4.1 Literature Review

To understand the available literature in this research area, online databases of Scopus, Google Scholar, ScienceDirect, and Web of Science were accessed. The period of the search was chosen between 1965 and 2020. Only articles published in English were shortlisted. Search terms included "solar/floating solar PV," "ergonomics design interventions," and "occupational safety and health" and their keyword combinations. The existing literature revealed several occupational health and safety hazards, such as chemical (toxic gases), thermal, and physical hazards [7] associated with the manufacturing of photovoltaic energy systems. Studies showed that with large-scale solar PV increasing in number, the focus shifted to studying the hazards related to the installation of PV systems. These include falls, injury from objects, electric shock, traffic accidents, thermal burns, awkward postures, handling heavy loads, and wounds [8]. Such hazards can lead to work-related musculoskeletal disorders (WMSDs), which can cause permanent damage to the workers' health. Fire hazards were identified in grid-connected PV systems [9]. Sources of health effects on workers/employees during PV system installation and maintenance includes heat, non-ionizing radiation, electricity, flora, and hailstorms [10]. The workers are also exposed to hazards from various components of the PV system such as solar panels, batteries, and inverters [11].

To understand the existing design interventions for ensuring the OSH of the workers in the solar PV industry (with emphasis on floating solar), literature was reviewed. Most of the papers concentrated on design considerations related to PV system design in terms of cost and efficiency, ecological design of solar PV system, roof design for PV system efficiency, aesthetic impact, and designing for consumer preference for residential solar panels [10, 12–15]. Only three studies were found which used a design approach for ensuring the safety and health of the workers. One study reports on the floating solar PV system's grounding design, thus ensuring electrical safety [16]. Another research suggests the use of multiple inverters (small) to prevent fire hazard [9]. A comprehensive OSH study on the roof-top solar installations was carried by a group of researchers who have used the prevention through design (PtD) approach to ensure workers' safety by developing a PtD protocol [17]. No studies on training/skill up-gradation, psychosocial aspects, or design interventions specific to the floating solar PV sector were found. This establishes a knowledge gap that this present paper attempts to explore.

Questionnaire development for the study: A literature survey was carried out to explore the existence of OSH related questionnaires specific to the solar PV industry/FPV sector. Only one OSH checklist on roof-top solar was found [18]. Drawing inferences from the OSH checklist on roof-top solar, views of the project managers, and observations during the field studies, a questionnaire was constructed. The questionnaire contains eight sections, namely (a) general information about location, type, and size of the project, type and skill level of workers, etc.; (b) training, safety, and work organization aspects; (c) hazards of working on water, slips, trips, falls, etc.; (d) use of personal-protective equipment (PPE); (e) electricity-related hazards; (f) hazards that may lead to musculoskeletal disorders (MSDs); (g) specific sources of OSH hazards, and (h) suggestions for design/redesign of FPV system components. Photographs were taken of the installation process to understand the workflow and functioning of a floating solar PV system and the workers' interface.

The study included an analysis of the workflow; a survey of the tools and techniques used, and identification of occupational hazards faced by the workers ($n = 22$) using observational methods and unstructured questionnaire seeking views of the project managers ($n = 4$) engaged in the installation and maintenance of two

Table 21.1 Overview of the FPV sites considered for the study

Parameters	Mejia TPS (DVC)	Kawas (NTPC)
Location	The water reservoir of a thermal power station	The water reservoir of a gas-based power station
Capacity	25 kWp	1 MW
Design of FPV	Floating structure type	All in one buoyancy type
Number of workers engaged	06	16
Direct normal irradiation (DNI)*	1187 kWh/m2 per year	1614 kWh/m2 per year
Peak months*	March and April	March, April and May
Power output for 1000 kWp*	1.297 GWh per year	1.478 GWh per year

* *Source* Global solar atlas

FPV projects in India. The findings from the field studies were compared with the findings of the literature review to derive opportunities and future scope for design interventions from the OSH perspective.

21.5 Case Studies

To understand the OSH scenario of the FPV projects in India, two sites where the installation was underway were visited. The first site was a 25 kW FPV project at Mejia Thermal Power Station of Damodar Valley Corporation (DVC) in the state of West Bengal, and the second site was a 1 MW FPV installation at the Kawas Gas-based Power Station of National Thermal Power Corporation (NTPC) in the state of Gujarat. An overview of the two locations is given in Table 21.1.

21.6 Results

The project managers completed the questionnaires related to the two sites using online software during the period September–October 2019. The responses are summarized in Table 21.2.

Table 21.2 Summary of responses received from project managers

Query overview	Site 1 (NTPC)	Site 2 (DVC)
Skill level of the workers	Semi-skilled	Semi-skilled
Mode of safety training	Lectures in local language	Demonstration
Cooperation, communication, occupational check-up, and worker feedback for workplace safety	✓	✓
Consideration of needs of workers of different types, gender, and ages	✓	✓
Platforms/scaffolding/rails/barriers/safety nets for work near water	✓	✓
Inspection of all parts of the floating solar PV system	✓	✓
Type of tools used	Tools used in other solar PV projects	General hand tools
PPE (life jackets, etc.) and life preservers	✓	✓
Safety signs, fire extinguishers, first aid, and emergency plan	✓	✓
Precautions to prevent electricity-related hazards such as grounding and dry inverter area	✓	✓
Design of work and layout to reduce manual material handling and ergonomic hazards	×	×
Specific hazards from solar PV panels	Sharp edges, the weight of panels, and lack of proper grips	Sharp edges, lack of grips, electrical hazards, and difficulties in replacement
Specific sources of hazards from floating structures/pontoons	Instability of the floating structure	Falls into water and gaps in the walkways
Specific sources of hazards from tools	Difficulty in use during installation	Difficulties in use during installation and tools may fall into the water
Specific sources of hazards from cables/inverters/batteries	Electrical shocks and carrying cables/wires	Electrical shocks, fire, and chemical hazards from batteries
Environmental hazards	Humidity and hailstorms	Rain and extreme sunlight
Design/redesign required	Scaffolds/walkways/shoes	Solar panels, floaters, personal-protective equipment (PPE), tools, and work methods

21.6.1 Other Inputs from Project Managers and General Observations

- The hazards of workers engaged in FPV projects are different from those of other types of solar PV projects. The additional hazards include unstable floaters working on/near the water. The avoidance of using slippery shoes was emphasized.
- Sometimes workers are casual with the use of PPE, which are monitored and corrected by supervisors. Standardized equipment and items for floating solar projects will help in interchangeability. Need for standards for work procedure, skill sets, etc.
- Site conditions not conducive to the use of mechanized material handling equipment. Instability of floating platforms during strong winds. Possibilities of sunstroke, dehydration, and other heat illnesses.
- A requirement of an OSH checklist and design standards. Training and motivation of workers for skill development, safety consciousness, and alertness during work.
- Workers are exposed to a work environment where both electricity and water are present.

The field surveys revealed that the workers are highly exposed to different occupational hazards (Fig. 21.4) during installation and maintenance of FPV panels. The hazards arise due to heavy load handling, awkward posture, inappropriate tools, lack of safety measures against the harsh working environment (hot Sun, glare, electrocution, drowning, etc.), lack of context-specific training/skill-development, etc. It

Fig. 21.4 **a** A multitude of ergonomic hazards during installation; **b** work near water exposes the workers to a combination of hazards; **c** sharp edges and presence of electricity are occupational hazards, and; **d** work on unstable floaters presents additional hazards

was also noticed that the slippery and unstable working surfaces and unavailability of appropriate tools presented unique challenges for the workers engaged in FPV projects, which are different from other traditional workplaces. Project managers agreed that immediate attention is required for the safety and better occupational health of the workers. They also suggested the need for design/redesign of several aspects from the OSH perspective.

21.7 Discussion and Conclusion

This exploratory study revealed that FPV workers face multifarious OSH hazards on both land and water. The hazards mainly arise due to the mismatches between the workers and FPV system components. The study was designed in such a way so as to collect views of project managers on OSH hazards and their views on the need for addressing them through design interventions in specific areas. The results of the case studies were compared to existing literature available wrt design interventions in the FPV sector (Sect. 21.4.1) from an OSH standpoint, which elicited several research gaps. The identified gaps for design/redesign for ensuring OSH include (a) scaffolds around the walkways: (b) walkway platforms; (c) solar panels; (d) floaters/pontoons; (e) PPE; (f) tools; (g) shoes, and (h) work methods. Apart from this, design interventions toward ensuring training/skilling needs, protecting workers from psychosocial hazards and environmental factors can also be explored.

The protection of the environment is an important human goal, and tomorrow's energy needs are likely to be completely met by clean energy sources. At the same time, the protection of the workers in the renewable energy industries must also be an important priority. Design can serve as a powerful tool to attain this objective. The preliminary field surveys were intended for "problem defining" [19] from the OSH dimension in the FPV sector in the Indian context. The hazards in floating solar PV projects are different from other kinds of solar PV installations. One project manager suggested that "*Floating Solar Technology, still in an evolving stage, needs specific design of equipment, tools, and accessories suitable for Floating installation.*" These findings call for a particular focus on designing different workplace aspects, so that workers have a safe and comfortable work experience. This study has identified some possible design interventions in that direction. Future studies include a detailed analysis of the specific occupational hazards using ergonomic assessments and the development of sustainable design solutions from a human-centered design (HCD) perspective. This paper's novelty is that this is a maiden study to explore the OSH scenario of these new workplaces and identify opportunities for design interventions.

21.8 Limitations of the Study

The present exploratory study was based on a small sample size of workers ($n = 22$) and project managers ($n = 4$) from only two sites limited to the Indian population. This is because very few sites are available for investigation in this emerging sector. The parameters of the work environment and psychosocial factors were not measured.

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