Safety and Hazard Analysis (CHE1007)

REVIEW-3

[2] Safety and security risk assessment analysis for the solar panel and application of resilience engineering concepts

Team members:

1	Rohan Allen	18BCI0247	7
1	Shraddha Manmode	18BCE2123	
3	Hrithik Ahuja	18BCE2154	
4	Medhavi Singh	18BCE2397	
5	Syed Afzal Ahammed	18BCE0038	

Abstract:

Solar energy is the most abundant form of energy on this planet, about 173,000 terawatts of solar energy strike the Earth at any given time. That's approximately ten-thousand times the total energy used on planet earth. Therefore, it is no surprise that there has been an exponential increase in efforts to harness this clean and renewable energy. However, installing solar panels is an extremely risky task. There are numerous potential hazards and safety concerns that have to be addressed, not only to safeguard the health and well-being of workers but also the environment. This paper aims to delineate the major risks associated with solar projects and establish a set of guidelines and best practices that can be followed by businesses and organisations. A Risk Analysis was conducted in order to proactively determine and evaluate risks. We also constructed a risk matrix to prioritise risk based on the two parameters of probability and risk severity, enabling organizations to focus on only the most critical issues plaguing them. Change is the only constant in this world, systems have to adapt to ever changing circumstances. In this regard, we have also suggested some resilience engineering methods to ensure that solar systems function in the event of any disruption, be it climate change or terrorism. The primary intention of this paper is to consolidate all the safety and security hazards pertaining to solar systems and to outline the required plan of action to mitigate and overcome these risks.

Introduction:

Solar energy being a clean and renewable form of energy is in high demand currently due to the adverse impacts of climate change and global warming which has only been exacerbated as the years have gone by. According to the Solar Energy Industries Association, Solar power accounted for 39% of new electricity generation capacity added in 2016, up from 4% in 2010. This trend shows how the popularity of harnessing solar energy has burgeoned, and this trend is only likely to increase exponentially as costs fall and more companies invest in solar assets. Notwithstanding all the pros of solar energy, it too comes with its fair share of problems. Installing Solar PV cells can be quite tedious and cumbersome and there are numerous risks that one must consider. Worker safety, natural disasters, electrical components, cyber-attacks are just some of the risks these solar systems must withstand and overcome so that it operates seamlessly and generates revenue. In this project we have conducted a comprehensive Risk analysis to identify certain pitfalls and have suggested safeguards and best practices which will help attenuate any potential disasters.

Objective:

- Identification of safety and security risks in solar systems and solar panels Conducting Risk Analysis to determine and evaluate risks proactively.
- Constructing a Risk Matrix to prioritise risks based on probability and severity.
- Outlining an action plan to mitigate risk
- Organising all the data in tables, diagrams, charts, etc. to enable organisations and businesses to grasp the information quickly.

Methodology:

Risk Analysis and Risk Matrix(in ppt)

We conducted a comprehensive risk analysis in which we looked at potential hazards, its consequences and some safeguards and recommendations to attenuate their detrimental effects. A risk factor was assigned based on the parameters of probability and severity. A risk matrix was made to highlight the same.

Discussion:

On reviewing the risk matrix, we had tabulated we realised that there are broadly two major risks we have to be wary of. The greatest possible risk with regards to solar plants is worker safety. They work in dangerous conditions, with electrical equipment and often at high elevations. The probability that they get injured and the consequence of that injury to the solar company is extremely high. Therefore, it is vital that the safety of workers is entrenched in the risk mitigation strategy of any company. Next comes the natural disasters like earthquakes, floods, etc. Although quite rare, the damage they can inflict on solar cells can be catastrophic. Hence the solar plant should be resilient and should be able to withstand the devastating effects of the aforementioned natural calamities.

Conclusion:

Solar systems generally have safeguards in place to ensure worker safety and resilience from natural disasters. However very few have safety mechanisms in place to prevent and mitigate cyber-attacks. Cyber crime is rapidly increasing and solar plants are sure to effected given the large role of computer operated systems. A coordinated cyber attack involving malicious code, viruses, worms and ransomware could be extremely deleterious to the functioning of solar systems. It could hinder operations, result in the loss of confidential data and lead to massive financial loses. It is therefore extremely crucial that this threat is not taken lightly and that significant action is taken. Encrypting all computers and servers, installing firewalls, anti-virus software, Intrusion Prevention/Detection Systems are some of the best practices to be followed to ensure the cyber health of the solar system. Conducting regular IT security audits will also ensure that the solar systems are well protected.

ANNEXURE

LITERATURE REVIEW

[1] Upholding Safety in Future Energy Systems: The Need for Systemic Risk Assessment

This paper showcases that energy systems are becoming more complex, and it shows how the already existing transition to renewable energy sources has resulted in the emergence of new types of hazards. It demonstrates that the energy sector heavily relies on analytic risk assessment approaches, and that systematic methods provide valuable additional insights. A comparison of the hazard and operability study (HAZOP, analytic) with the system-theoretic process analysis (STPA) in the Dutch gas sector demonstrates this. It emphasises the importance of researching the organisation of protection in energy transitions. The researchers conclude that proper risk management for future energy systems requires both a quantitative and qualitative approach.

[2] A framework for conceptualizing and assessing the resilience of essential services produced by socio-technical systems

Complex adaptive socio-technical processes generate essential resources like electricity. Continuous structural shifts, such as urbanisation and the rise in the frequency of severe weather, necessitate the resilience of critical services. The paper emphasises the importance of having a dependable and resilient technological infrastructure. The researchers propose a conceptual framework based on a complex adaptive systems perspective that identifies four key domains where investment is needed to strengthen critical services resilience. This structure takes into account both the technological and social aspects of the socio-technical frameworks that provide essential services, as well as specific and broad resilience concerns.

[3] Adapting the theory of resilience to energy systems

Resilience has gained in importance among the sector of analytic thinking in recent years and has additionally become more and more vital within the thought for energy systems. However, there's no uniform understanding within the literature and therefore the applications dissent.

One reason for this is often that their square measure styles of resilience: engineering resilience, wherever systems square measure placed close to a stable purpose and invariably come back to that when a pause, and ecological resilience, where it's assumed that the system into consideration doesn't rest in associate degree equilibrium however is unendingly in motion. additionally, this kind of resilience assumes many basins of attraction between that associate degree unsustainable system switches, whereas a property system remains in one basin.

[4] Principles and criteria for assessing urban energy resilience

The framework and criteria introduced during this may be used as a vital preliminary step for development of tools for assessing urban energy resilience. Assessment tools are helpful for informing higher cognitive process by native authorities. Such tools may be used for 3 main purposes: to capture the complexness and effectively change the route to resiliency; to benchmark and live resilience and track action of goals. A point of trade-off between the standards is inevitable and this could be adequately informed. it's hoped that the results of this preliminary work offer helpful steering to increase the scope of the study on assessment of urban energy resilience. Future analysis can have a special concentrate on providing a rather complete understanding of co-benefits and trade-offs between the standards introduced during this study.

[5] Project risk analysis of solar energy project delays in India

The current strong reliance of the humanity on fossil fuels is seen as a contributing factor to climate change and increasing challenges in meeting renewable energy goals. The use of renewable energy has been proposed as a potential solution to the aforementioned problems. The primary cause of the deficiencies is a lack of risk-mitigation techniques. The effective mitigation of project-related hazards is a critical factor in completing projects on schedule, and it is well within reach.

[6] An integrated management approach of the project and project risk

Rodney proposes modelling, simulating, and evaluating project risks in terms of efficiency, delay, and expense, with the goal of reproducing the project's behaviour, evaluating its results, and anticipating its likely drifts while valuing the following requirements relevant to the entire risk management method.

[7] Health and safety impacts of solar Photovoltaics

The motive of this paper is to work on public health and safety for utility-scale solar Panels.

The problem was divided in Toxicity, Electromagnetic Fields, Electric Shock and Arc Flash, Fire. In all of this part the problems were shown in very less amount, the negative health and safety impacts of utility-scale PV development were shown to be non-existing , the public health and safety benefits of these facilities are significant and much better than any other resource

[8] The application study in solar energy technology for highway service area:A case study of West Lushan highway low-carbon service area in China

This paper shows the subject of highway and solar energy in a sun based innovation application for highways. This paper has done an investigation on West Lushan parkway lowcarbon administration zone in Jiangxi area of China. The paper demonstrates a decrease of cost on power by the utilization of solar energy. This paper considers solar based traffic signals, sun oriented streetlights, etc. The region powers the utilization of sustainable energy for a low carbon impression on the climate as well as to improve the productivity and efficiency.

[9] Design of ”Risk and Resilience” Focused Courses for Undergraduate Engineering Education Towards a Hazard-Resilient Built Environment

Since India is growing in the department of infrastructure and hence the intensity and frequency of the hazards like natural non biodegradable are increasing it’s important to report the problem that being faced by environmental so this paper worked on rational object and content of following challenges

The following paper work on following 3 challenges

1. Information about RISK AND RESILIENCY
2. Optimization and reliability

Sensing and data analytics for infrastructure systems

[10]Towards climate resilient urban energy systems

This paper gives an understanding into the advancement that can be accomplished in the energy field to the rising environmental issues and centres around environmental flexibility of metropolitan energy frameworks. The paper defines climate resilience as "an upcoming concept that is used to represent the durability and stable performance of energy systems against extreme climate events". This paper studies and shows a significant disadvantage in the environmental change variation strategies. It also presents the limitations which may occur while connecting the effects of environmental change to different models that attempt to improve it. It provides an insight to the complexity of resilience within the energy system.

RISK ANALYSIS

Hazard	Consequence	Top Event	Safeguard	Recommendation	Risk Factor
Working at roof tops	Falling from roof top	Trauma, Broken Bones, Death.	Install scaffolding with stair access and guard rails around the roof top.To prevent a potential fall, deploy safety netting or supply each employee with a body harness that is fastened to the rooftop.	Install ground mounted solar systems avoiding the need to work in an area of high elevation.	High
Working with ladders	Falling from ladders. Electrocution	Trauma, Broken Bones, Death.	Secure the ladder to the ground or rooftop on dry, flat ground away from walkways and entrances, and at least 10 feet away from electrical lines. When working near electricity sources, use a fiberglass ladder with non-conductive side rails.	Install ground mounted solar systems avoiding the need to work in an area of high elevation.	High

Hazard	Consequence	Top Event	Safeguard	Recommendation	Risk Factor
Lifting and handling solar panels	Can cause strains, sprains, muscle pulls and back injuries	Paralysation, Death.	Using mobile carts or a forklift, transport solar panels onto and around the job site. Climbing ladders while lugging solar panels is never a good idea. Use professionally inspected cranes, hoists, or ladder-based winch devices to install solar panels on rooftops.	Install ground mounted solar systems avoiding the need to work in an area of high elevation. Lift each solar panel with at least two people while applying safe lifting techniques.	High
Working with Solar electric systems.	Short circuit, Electric Shocks, electrocution Arc flash, burns	Paralysation, Death.	Wear arc-rated clothes from the neck to the wrists to the ankles with a minimum ATPV of 4calm2.Wear safety glasses, gloves, and rubber boots.	To “turn off” the sun's light, cover the solar array with an opaque sheet. Before working on any circuits, use a meter or a circuit test equipment to confirm that they are all de-energized. Technicians must be properly educated.	High

Hazard	Consequence	Top Event	Safeguard	Recommendation	Risk Factor
Working outdoors.	Exposure to the sun	Exhaustion, fatigue, heat stress . Sun burn, skin cancer	Wear protective gear, apply SPF 30+ sunscreen, slap on a hat, and put on sunglasses.Make sure you get lots of water.	Whenever possible, rearrange work schedules so that outdoor duties are completed before 10 a.m. and after 3 p.m.Tasks that require direct sun exposure should be rotated.Use gazebos to increase the amount of shade provided.	High
Working in ceiling spaces	Exposure to poor air quality such as fiberglass, coal dust, lead dust and other harmful substances Exposure to loose-fill asbestos	Respiratory diseases, Cancer, Mesothelioma, asbestosis	When working in dusty ceiling spaces, use suitable, well-maintained, and properly-fitted personal protection equipment, such as a respirator.To avoid eye irritation, wear a head covering and goggles.	Do not proceed with job until asbestos-containing material removed by licence contractors . Install ground mounted solar systems avoiding the need to work in a ceiling space	Medi um

Hazard	Consequence	Top Event	Safeguard	Recommendation	Risk Factor
Earthquake.	Damage of installation	Death, Serious Injury, Massive Financial losses	Solar panels should be protected with tempered glass. Ethylene-vinyl acetate (EVA) is a material that is often used to encapsulate cells and increase their robustness.	Don’t construct solar plants in areas of great seismic activity. Insure against any damage from natural calamities.	Low
Lightning strike	Panels would be destroyed or melted if struck directly. Indirect strikes would introduce high voltages into the system, causing conductors and PV panels to fail, as well as dangerous sparking that might burn flammable	Death, Serious Injury, Massive Financial losses.	Install air terminals for ground-mounted panels that are interlinked and hooked into a grounding ring electrode system, allowing the lightning current to safely dissipate into the earth. Surge protection devices (SPDs), which restrict lightning-induced high voltages to ground and prevent	Insure against any damage from natural calamities. Don’t install solar panels in areas of high lightning flash intensity.	Low

Hazard	Consequence	Top Event	Safeguard	Recommendation	Risk Facto r
Heavy Winds	Damage of installation	Death, Serious Injury, Massive Financial losses.	Install Wind deflectors, stow or return to flat position quickly.	Insure against any damage from natural calamities. Wind tunnel testing so that it is resistant to high speeds.	Medi um
Fire	Parts of the solar panel that are flammable, such as the thin polymer wraps that surround the PV cells, will catch fire.	Death, Serious Injury, Massive Financial losses	Non-combustible materials between the panels and the roof will act as a slight buffer, and coupling connections must be firmly closed to prevent the fire from spreading quickly.	Insure against any damage from natural calamities. install a shut-off switch to disconnect the solar panels from the electrical system	Medi um

Hazard	Consequence	Top Event	Safeguard	Recommendation	Risk Factor
Floods	Damage of installation. There's a good probability of a power outage and a short circuit, as well as electrocution and burns.	Death, Serious Injury, Massive Financial losses.	PET (polyester) is used for backsheets because of its thermal and moisture barrier qualities.Wires and cables of good grade are also resistant to water absorption.Turn off the mains power.	High ground clearance for sensitive components such as inverters or data gathering equipment.It is not recommended that the system be turned back on until it has been tested by a clean energy council accredited installation or a professional electrician.	Medium
Sand storm	Sand particles and dirt accumulate on the solar panels	Efficiency of solar panels decreases and power output drops	Use automated cleaning system with brush to remove sand. This will improve efficiency.	Insure against any damage from natural calamities.	Low

Hazard	Consequence	Top Event	Safeguard	Recommendation	Risk Factor
Volcano	Clouds of ash and smoke cover the sky blocking sunlight to solar panels and reducing solar PV power output	Death, Serious Injury, Massive Financial losses. Volcanic ash is corrosive and can also damage solar panels and reduce their efficiency.	Use automated cleaning system with brush and cleaning agent to remove volcanic ash which is toxic and jagged. This will improve efficiency.	Insure against any damage from natural calamities. Don’t install panels in volcano prone regions	Very Low
Terrorism	Damage of installation, Delay or stop of completion, loss of revenue or project	Death, Serious Injury, Massive Financial losses Loss of credibility	Use of stringent security protection measures, political guarantee. Fences, biometric authentication, metal detectors, in house SWAT team.	Insure against any damage. Access to "high-value" components like inverters should be restricted. Set up physical barriers around the solar modules.	Low

Hazard	Consequence	Top Event	Safeguard	Recommendation	Risk Factor
Corrosion	Rust can disrupt the crucial electronic connections within the panels, causing degradation.	Reduce the efficiency and the amount of electricity a solar panel can reduce resulting in Massive Financial losses.	Between two layers of plastic, PV panels are protected from air and moisture. The ethylene-vinyl acetate (EVA) material is extensively used for cell encapsulation.	Install good quality solar panels and replace them after 25 years as corrosion due to environmental conditions is inevitable.	High
Lead contained in PV cells	During the service life of a PV panel, lead can be released into the environment.	Lead is extremely poisonous to the brain and central nervous system, resulting in unconsciousness, convulsions, and even death.	its internal components, including lead, must be sealed from any moisture.	amount of lead in the panels should be below the RoHS thresholds. Discard solar panels after 25 years as there is a higher chance of leeching of lead.	Very Low

Hazard	Consequence	Top Event	Safeguard	Recommendation	Risk Factor
Unacceptable environmental impacts	Encroaching on Protected territory, endangered species, etc	Loss of habitat and life of endangered species. Court case, massive fines	Full Environmental and Social Impact Assessment should be performed to prevent any unfortunate incidents.	Stringent environmental procedures to be followed at construction and operations in accordance to existing laws.	Medium
Theft	loss of highly expensive systems like solar modules, inverters, etc.	Massive Financial losses Loss of credibility	Proactive system monitoring will help identify theft quickly.	Create raised solar arrays that are at least 8 feet above the rooftop.Using locking bolts, physically connect the components.	Medium

Hazard	Consequence	Top Event	Safeguard	Recommendation	Risk Facto r
Cyber Attack	Compromise all the software systems leading to delay of service, shutdown of plant.	Massive Financial losses Loss of credibility	Install IPS sytems, firewalls, antivirus, etc.	Insure against cyber attacks. Conduct a thorough cyber security audit.	High

RISK MATRIX

Severity

Likelihood

1	2	3	4	5
LOW 1	LOW 2	LOW 3	MEDIUM 4	MEDIUM 5
LOW 2	MEDIUM 4	MEDIUM 6	HIGH 8	HIGH 10
LOW 3	MEDIUM 6	HIGH 9	HIGH 12	EXTREME 15
MEDIUM 4	HIGH 8	HIGH 12	HIGH 16	EXTREME 20
MEDIUM 5	HIGH 10	EXTREME 15	EXTREME 20	EXTREME 25

RISK DESCRIPTION	RISK SEVERITY	RISK LIKELIHOOD	IMPACT
Working at roof tops	High (4)	Likely(4)	EXTREME
Working with ladders	High (4)	Likely(4)	EXTREME
Lifting and handling solar panels	High (4)	Likely(4)	EXTREME
Working with Solar electric systems.	High (4)	Likely(4)	EXTREME

RISK DESCRIPTION	RISK SEVERITY	RISK LIKELIHOOD	IMPACT
Working outdoors.	High (4)	Likely (4)	EXTREME
Working in ceiling spaces	High (4)	Likely (4)	EXTREME
Earthquake	Catastrophic (5)	Unikely (2)	HIGH
Lightning strike	Catastrophic (5)	Unlikely (2)	HIGH

RISK DESCRIPTION	RISK SEVERITY	RISK LIKELIHOOD	IMPACT
Heavy Winds	High (4)	Likely(4)	EXTREME
Fire	High (4)	Likely(4)	EXTREME
Floods	High (4)	Possible(3)	HIGH
Sand storm	Moderate(3)	Unlikely(2)	MEDIUM

RISK DESCRIPTION	RISK SEVERITY	RISK LIKELIHOOD	IMPACT
Volcano	High (4)	Very Unlikely (1)	LOW
Terrorism	Catastrophic (5)	Unlikely (2)	HIGH
Corrosion	High (4)	Possible(3)	HIGH
Lead contained in PV cells	High (4)	Very Unlikely (1)	LOW

RISK DESCRIPTION	RISK SEVERITY	RISK LIKELIHOOD	IMPACT
Unacceptable environment al impacts	High(4)	Possible(3)	HIGH
Thefts	High (4)	Possible (3)	HIGH
Cyber Attacks	Catastrophic (5)	Possible (3)	EXTREME

REFERENCES

[1]. IEA. Getting Wind and Sun onto the Grid—A Manual for Policy Makers. 2017. Available online: https://www.iea.org/reports/getting-wind-and-solar-onto-the-grid (accessed on 9 December 2020).

[2]. Allenby, B. R., and D. Sarewitz. 2011. The techno-human condition. MIT Press, Cambridge, Massachusetts, USA.

[3]. resalliance.org, 2017. https://www.resalliance.org/about. (Accessed 23 Oct 2017)

[4]. S.L. Cutter, L. Barnes, M. Berry, C. Burton, E. Evans, E. Tate, *et al.*

A place-based model for understanding community resilience to natural disasters

Global Environ Chang, 18 (2008), pp. 598-606

[5]. Siddarthgaurav, Nicolas Chileshe, Tony MA (2011), Project risk analysis of solar energy project delays in India, 49thAuSES Annual Conference

[6]. Rodney E, Ducq, Breysse D, Ledoux Y (2015), An integrated management approach of the project and project risk, IFAC- Paperonline-48-3(2015)535-540

[7]. A. T. Bahill., Design and Testing of an Illuminance Management System, The ITEA Journal 31(1) (2010), 63-89.

[8]. American Society for Civil Engineers (2007). The New Orleans Hurricane Protection System: What Went Wrong and Why. Reston, VA: ASCE.

[9]. **Vahid M Nik, A T D Perera, Deliang Chen, Towards climate resilient urban energy systems: a review, *National Science Review*, 2020;, nwaa134, https://doi.org/10.1093/nsr/nwaa134**