Avrupa Bilim ve Teknoloji Dergisi
Sayı 23, S. 497-511, Nisan2021

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
No. 23, pp. 497-511, April 2021

Research Article

Determination of Hazards and Risks in a Solar Power Plant Using the Matrix Risk Analysis

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(First received 16 February 2021 and in final form 5 April 2021)

(**DOI:** 10.31590/ejosat.881614)

ATIF/REFERENCE: Gür, B, Yavuz, Ş., Çakır, A. D. & Köse, D. A. (2021). Determination of Hazards and Risks in a Solar Power Plant Using the Matrix Risk Analysis. *European Journal of Science and Technology*, (23), 497-511.

Abstract

Electric power generation from renewable energy sources such as solar energy, wind energy and geothermal energy is an alternative option to energy generation from fosil flues. Renewable energy sources are more advantageous when we consider the environmental damage caused by fossil flues during energy generation. Our country is rich in terms of renewable energy resources with its location. When we consider the daily sunshine duration and the wind force in the flat plains, the number of power plants that generate electrical energy without harming the environment with solar panels and wind turbines is increasing day by day. In this study , as a result of field observations of a power plant that converts solar energy into electrical energy with solar panels in Çorum by instructors who have class B OHS certificate and field experince, the risk score was calculated by determining the hazards and risks by 5x5 L-type Matrix Risk analysis which is a qualitative risk assessment. According to the calculated risk score, twenty-four risks which include four high level risks, fifteen medium-level risks, and five low-level risks were identified and recommendations were made. We think that this study will make a positive contribution to the power plants to be established and to the actively onoing plants in terms of occupational health and safety.

Keywords: Solar energy, Occupational health and safety, Risk analysis, Matrix Method

Güneş Enerjisi Santralinde Matris Risk Analiz Yöntemiyle Tehlike ve Risklerin Belirlenmesi

Öz

Güneş enerjisi, rüzgâr enerjisi ve jeotermal enerji gibi yenilene bilinir enerji kaynaklarından elektrik enerjisi üretimi fosil yakıtlardan enerji üretimine alternatif seçenek olmaktadır. Fosil yakıtların enerji üretimi sırasında çevreye verdiği zararları dikkate aldığımızda yenilenebilir enerji kaynakları daha avantajlıdır. Ülkemiz sahip olduğu konumu ile yenilenebilir enerji kaynakları bakımından zengindir. Günlük güneşlenme süresi ve düzlük ovalardaki rüzgâr şiddetini dikkate aldığımızda güneş panelleri ve rüzgâr gülleri ile çevreye zarar vermeden elektrik enerjisi üreten santrallerin her geçen gün sayısı artmaktadır. Bu çalışmada, B sınıfı İSG belgesine sahip, saha tecrübesi olan öğretim elemanları tarafından Çorum ilinde güneş panelleriyle güneş enerjisini elektrik enerjisine çeviren bir santralin saha gözlemleri sonucu, tehlike ve riskler kalitatif bir risk değerlendirmesi olan 5x5 L tipi Matris Risk analizi ile belirlenerek risk skoru hesaplanmıştır. Hesaplanan risk skoruna göre dört tane yüksek düzeyde risk, on beş tane orta düzeyde risk ve beş tane düşük düzeyde risk olmak üzere yirmi dört tane risk tespit edilerek önerilerde bulunulmuştur. Yapılan bu çalışma ile bundan sonraki kurulacak santrallere ve aktif olarak devam eden santrallere iş sağlığı ve güvenliği yönünden olumlu katkı sağlayacağını düşünmekteyiz.

Anahtar Kelimeler: Güneş enerjisi, İş sağlığı ve güvenliği, Risk analizi, Matris Yöntemi

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1. Introduction

Solar energy is one of the world's renewable energy sources, alternative to fossil fuels and not harming nature in terms of waste. The occurrence of formations in nature, the flow of matter and energy are due to solar energy [1,2]. Due to the location of our country, solar energy potential is high. Therefore, energy generation plants consisting of solar panels have been established in many of our provinces to generate electrical energy from solar energy [3].

It is very important to examine the hazards and risks caused by dangerous movement and situations in terms of occupational health and safety by using the heat and light effect of the Sun instead of manpower in solar energy plants where have very little human factors. It may be possible to prevent work accidents and occupational diseases as a result of identifying the existing hazards and risks with proactive approaches. Hazard is defined as the potential for harm of anything. This potential could be a situation or a behavior. Risk, on the other hand, refers to the probability of events such as death, injury, and loss of limb that may occur as a result of an event [4,5].

The aim of occupational health and safety services is to adopt proactive approaches against work accidents and occupational diseases by providing a healthy and safe work environment for employees. Preventing work accidents and occupational diseases is possible with regulatory preventive measures by identifying hazards and risks as a result of risk assessment in workplaces[6].

According to the Occupational Health and Safety Law No.6331, employer / employer representatives are obliged to make a risk assessment or have them done in order to ensure the health and safety of their employees and the continuity of production in the workplace. With risk assessment, it will be possible to prevent work accidents and occupational diseases, and if they cannot be prevented, to reduce their rate [5,7].

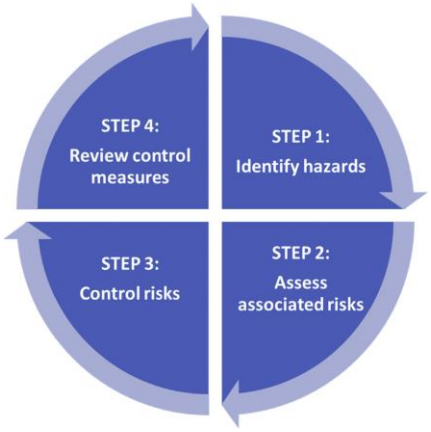

Fig. *Risk Assessment Process Stages*

During the identification of hazards and risks of a business , risk assessment is divided into two in terms of quality and quantity [8]. In the risk assessment application, a change is observed from qualitative approaches to semi-quantitative and traditional quantitative approaches [9]. According to Altenbach (1995), there are differences in the way of implementing risk assessment due to various reasons such as manpower, time, management perception, opinion of the OHS expert, applicability and understandability [10].

In the literature, risk analysis methods are divided into three groups as numerical (quantitative), verbal (qualitative) and mixed. Mathematical theorems are used when calculating the risk score with quantitative risk analysis, while performing qualitative risk analysis, the probability of occurrence of the threat and its potential effect in case of existence are calculated and the results obtained are processed with mathematical and logical methods and the risk score and degree are obtained [11]. Some of the risk analysis methods in the literature are classified as follows by dividing them into two groups as qualitatively and quantitatively[12],

Qualitative Risk Assessment Analysis;

- ✓ Preliminary Hazard Analysis – PHA ,
- ✓ Job Safety Analysis – JSA,
- ✓ What if ?
- ✓ Risk Assessment Decision Matrix
- ✓ Failure Mode and Effects Analysis - FMEA
- ✓ Hazard and Operability Studies - HAZOP
- ✓ Fault Tree Analysis - FTA
- ✓ Event Tree Analysis - ETA
- ✓ Hazard Analysis and Critical Control Points
- ✓ Preliminary Risk Analysis - PRA
- ✓ Preliminary Risk Analysis Using Checklists - PRA
- ✓ Safety Audit

Quantitative Risk Assessment Analysis;

- ✓ Monte Carlo Simulation
- ✓ Markov Analysis,
- ✓ Bayesian Networks,
- ✓ Decision Tree,

Occupational health and safety experts in our country use qualitative 5x5 Matrix and Finney-Kinney Risk analysis in identifying hazards and risks, calculating the risk score and categorizing the results, creating regulatory and preventive action plans [14].

1.1.1. Matris Risk Analysis

Although the matrix risk analysis X-Matrix is shown in 5x5 Matrix and L-Matrix shapes, it is the same in logic. It occurs only when the difference is calculated with 5x5 and the results are shown different in shape [13-14]. Matrix risk analysis is a method used to explain the relationship between two or more variables. It is an easier method in terms of being understandable and evaluating the results by the risk assessment team [15].

1.1.2. L-Type Matris Risk Analysis

It is a simple understandable method used in interpreting cause and effect relationship [16]. L matrix is implemented as 3 * 3, 4 * 4, 5 * 5. It is a method based on evaluating the data obtained as a result of multiplying probability and severity each other which are the concrete components of risk analysis, within a logical framework. In this method, probability and severity factors are taken into account while the risk score is calculated.

It is calculated as Risk Value (R) = Probability = (P) X Severity (degree of damage).

Probability, the state that a danger occurs in a timeframe; violence, on the other hand, is defined as the degree of damage to the workplace if danger occurs [15-18].

Table 1. L-Type Matrix Analysis Probability Table

Value	Categorization	Frequency
1	Very low	Once a year
2	Low	Once every three months
3	Medium	Once a months
4	High	Once a week
5	Very high	Every day

Table 2. L-Type Matrix Analysis Loss Level Table

Value	Result	Rating
1	Insignificant	No loss of working hour requiring first-aid
2	Minor	No loss of working day, requiring first-aid
3	Moderate	Mild injury requires treatment
4	Major	Death, Serious injury, occupational disease
5	Catastrophic	Multiple deaths, permanent incapacity

Tablo 3. L-Type Risk Score Rating Matrix

Result (Severity)						
Probability		**5**	**4**	**3**	**2**	**1**
		Critical	**Severe**	**Moderate**	**Minor**	**Negligible**
5	Very High	25	20	15	10	5
4	High	20	16	12	8	4
3	Medium	15	12	9	6	3
2	Low	10	8	6	4	2
1	Very Low	5	4	3	2	1

1-2 Points: Insignificant risk. Risks that do not matter much and can be accepted.
3-6 Points: Tolerable risk. It is a tolerable risk group that requires attention in the long term.
8-12Points: Moderate risk. They are significant risks that need to be taken measures in the short term.
15-16 Points: Significant risk. It is the risk group that is extremely important and should be taken measures immediately
20-25 Points: Not tolerable risk. It is the risk group that it is not accepted to start work without any measures.

The fields shown with red color in the risk matrix indicate unacceptable risks and mean that measures must be taken as soon as possible. The fields shown in yellow express risks that need to be fixed as soon as possible. The fields shown in green express nonurgent risks that need to be fixed in the long term.

1.1.3. X Type Matrix Risk Analysis

It is a risk analysis that requires a disciplined work done as a team with the establishment of a risk team. L type matrix and X type matrix risk analysis are similar.There is only a difference in shape. The most preferred in practice is 5x5 Risk Matrix Analysis. The risk score is the same in both methods, but the order and shape are different from each other.

Tablo 4. A Sample Risk Assessment Analysis

Risk no	**Sample photos**	**Activiy / Risk area/ department**	**Work done / hazard / risk**	**Impact \ Result**	**Before the measure is taken**		**Measures to be taken**		**Contact person**	**Deadline**	**Result**	**Sinature**	**After the measure is taken**		
					P	**S**	**SCORE**						**P**	**S**	**SCORE**
1		FIRE EXTINGUISHERS	Lack of fire extinguisher	Aggravation of the situation	4	5	**20**	The type and number of portable extinguishers should be determined according to the existing situation and risks.	COMPANY	IMMEDIATELY			1	5	5

1.2. Fine Kinney Risk Analysis

It is one of the risk analysis methods used in occupational health and safety. Although it is a bit more complicated than the matrix risk analysis, it is a more ordered risk analysis in terms of separating the business lines from each other by frequency factor. It was first put forward by Fine in 1971, and then, in 1976, Fine's proposal was developed by Kinney and Wiruth and became a risk analysis method [19]. It was first used to protect against explosives in the military field, and then became the most preferred risk analysis method in dangerous and very dangerous enterprises such as construction and mining when it began to be used in the OHS profession.[19-20].

Although Fine Kinney Risk Analysis is more complex than Matrix risk analysis, it has higher accuracy and frequency factor. In this analysis method, the risk score is obtained by multiplying three variables, namely probability (P), severity (S) and frequency (F).

Table 5.Risk Score Calculation Table

RISK=PXSXF	R: Size of the Risk
	P: Possibility of Hazard Occurrence
	S: Potential Violent Damage of the Hazard
	F: frequency of repetition of work

Tablo 6. Probability Value Chart

Probability Value	Definition	% Probability
10	Expected / Certain	50
6	High / Quite Possible	10
3	Possible	1
1	Rarely but Possible	10—3
0,5	Unexpected but Possible	10—4
0,2	Practically Not Possible	10—5
0,1	Only Theoretically Possible	10—6

Table 7. Severity value definition table

S Value	Severity – Scoring The Damage / Element (V) (Estimated damage to human and / or environment)	
	Definition	
	Loss of work	Material loss
100	Multiple fatal accidents environmental disaster	> 10.000.000
40	Fatal accident / Serious environmental damage	1.000.000 – 10.000.000
15	Permanent damage / injury, loss of work	100.000 – 1.000.000
7	Creating environmental barriers, significant damage / injury from the immediate environment, getting external first aid	10.000 – 100.000
3	Minor damage, injury, internal first aid, limited environmental damage on land	1.000 – 10.000
1	Escape with littlle or no harm / no environmental damage	100 – 1.000

Table 8. Frequency value definition table

Frequency Scoring (F)	
F Value	Definition
10	Almost continuously (several times in an hour)
6	Frequently (once or several times a day)
3	Occasionally (once or several times a week)
2	Not often (once or several times a month)
1	Rarely (several times a year)
0,5	Hardly ever (once a year or less)

Table 9. Risk Score Definition Table

Risk Identification			
Risk Rating	**R Value**	**Risk Class**	**What to Do**
1	R ≤ 20	Minor risk	Precaution is not a priority
2	20 < R ≤ 70	Acceptable risk	Should be applied under observation
3	70 < R ≤ 200	Moderate risk	Should be improved in the long term
4	200 < R ≤ 400	Significant risk	Should be improved in the short term (within a few months)
5	R > 400	Unacceptable risk	Necessary precautions should be taken immediately or the facility, building, production or its surroundings should be closed.

2. Materıal And Method

This study was made as a result of the field observations of OHS experts who have Class B occupational safety certificates in the profession of occupational health and safety of a power plant consisting of solar panels where manpower is not used. It is a study that consists of calculating the risk scores of the hazards and risks identified as a result of the observations using the 5x5 Matrix qualitative risk analysis method and recommending regulatory preventive actions. Calculation method for 5x5 Matrix Risk score analysis is as follows

Tablo 10. Risk Score Calculation Table

Risk Factor Calculatıon System: The one with a higher risk parameter will be taken.					
Probability (Exposure-Incident frequency)			**Severity (Possible Losses)**		
Parameter	**Probability**	**Occurrence Frequency**	**Parameter**	**Severity**	**Rating (For Human)**
1	Very low	Once a year	1	Negligible	Absent
2	Low	Once every three months	2	Minor	First-aid required
3	Medium	Once a months	3	Moderate	Loss of labour force <3 Days
4	High	Once a week	4	Severe	Death, Loss of limb
5	Very high	Every day	5	Critical	Multiple deaths

Tablo 11. Risk Score Definition Table

Risk Score	**Severity**				
Probability	**1 (Negligible)**	**2 (Minor)**	**3(Moderate)**	**4 (Severe)**	**5 (Critical)**
1(Very low)	Meaningless 1	Low 2	Low 3	Low 4	Low 5
2 (Low)	Low 2	Low 4	Low 6	Medium 8	Medium 10
3(Medium)	Low 3	Low 6	Medium 9	Medium 12	High 15
4 (High)	Low 4	Medium 8	Medium 12	High 16	Very High 20
5(Very high)	Low 5	Medium 10	High 15	Very high 20	Not tolerable 25

Table 12. Acceptability Values of Results and Order of Priority

Not tolerable Unbearable Risks (20, 25) –Priority 1	The work should not be started until identified risk is reduced to an acceptable level, and if there is an ongoing action, it should be stopped immediately. If it is not possible to reduce the risk in despite of the measures taken, the action should be prevented.
Significant Risks (15,16) - Priority 2	The work should not be started until the identified risk is reduced, if there is an ongoing action, it should be stopped immediately. If the risk is related to the continuation of the work, urgent measures should be taken and as a result of these measures, it should be decided to continue the action.
Moderate Risks (8,9,10,12) - Priority 3	Actions should be started to reduce the identified risks. Risk reduction measures can take time.
Tolerable Risks (2,3,4,5,6) – Priority 4	Additional control processes may not be needed to eliminate identified risks. However, existing controls should be continued and it should be checked that these controls are continued.
Minor Risks (1) – Priority 5	It may not be necessary to plan control processes and keep records of actions to be carried out to eliminate identified risks.

Risk Score = Probability X Severity

In the light of the above data, the hazards and risks identified in the solar power plant, the regulatory and preventive actions to be taken and the risk score that can be reduced as a result of the actions are as follows. . There are no part-time or full-time employees in this solar power plant. Only technical personnel coming from outside can enter the power plant. The system is remotely controlled.

Table 13.Acceptability Values of Results Matrix risk analysis data applied to the solar power plant

No	Department	Action	Hazard	Risk	Who may be affected by the rısk	Risk value: Probability	Risk value: Severity	Risk value: Rısk score	Risk value: Rısk defınıtıon	Measures to be taken	Contact person	Deadlıne	Explanatıon / sıtuatıon	Rısk assessment after measures: Probability	Rısk assessment after measures: Severity	Rısk assessment after measures: Rısk score	Rısk assessment after measures: Rısk defınıtıonı
1	WORKING AREA (GENERAL)	Emergencies	Fire extinguishers are not in suitable places, have obstacles in front of them, fire xtinguishers are not indicated with signs, expiration dates of fire extinguishers loss of functionality	. In case of emergencies, as a result of delay fire fighting injury, death, damage to machinery-equipment-materials	ALL EMPLOYEES, MATERIAL LOSSES IN THE BUSINESS	3	5	15	HIGH-LEVEL RISK	Fire extinguishers will be placed in visible and accessible places in the workplace and there will be no obstacles in front of them. It is required to have a suitable type of 6 kg fire extinguisher by adding one in number for each independent section and one ın number for 200 m2 floor space. The locations where the fire extinguishers are located will be marked in accordance with the Safety and Health Signs Regulations. (It should be ensured that fire-fighting signs are rectangular or square; white pictogram-red parts on red background cover at least 50% of the area of the sign. The functionality and expiration dates of fire fighting equipment should be constantly checked. Periodic control and maintenance of fire extinguishers should be continuously implemented.	EMPLOYER / REPRESENTATIVE OF THE EMPLOYER	In a month at the latest	 In the facility, there are a total of 15 pieces DCP fire extinguishers of 6 kg which include 12 pieces next to inverters and 3 pieces in the transformer buildings. Controls and maintenance of tubes should be done at regular intervals. Besides, FE with Carbon Dioxide, which is a more effective fire extinguisher in electrical fires, is recommended for the facility. In addition, it is recommended to use automatic fire extinguishing systems that can extinguish the fire in the case of fire in transformers.	3	4	12	MEDIUM- LEVEL RISK
2	WORKING AREA (GENERAL)	Maintenance- Repair	Maintenance and repair done by unauthorized and uninformed persons	Electric shock, fire, injury, death	ALL EMPLOYEES	4	5	20	HIGH-LEVEL RİSK	After the necessary measures are taken in the section where maintenance-repair will be made, attention should be increased with warning signs and unautorised persons should be prevented from entering the maintenance section. Panels and transformers should be kept locked and surrounded to prevent unauthorized people from approaching.	EMPLOYER / REPRESENTATİVE OF THE EMPLOYER	in a month at the latest	 A warning sign is posted in the maintenance section. Panel and transformers are kept locked. There are attention-enhancing signs stating that unauthorized persons should not interfere. It is recommended to surround the panels and transformers in a way that prevents approaching.	2	5	10	MEDIUM LEVEL RİSK

4	3	No
WORKING AREA (GENERAL)	WORKING AREA (GENERAL)	Department
Entering the facility	**Underground Cables**	Action
Entry of third parties to the field	The route of underground cables inside the facility is unknown	Hazard
Lack of personal protectors	Injury, loss of limb, death	Risk
ALL EMPLOYEES	ALL EMPLOYEES, MATERIAL LOSSES IN THE BUSINESS	Who may be affected by the risk
3	2	Probability / Risk value
3	5	Severity / Risk value
9	10	Risk score / Risk value
MEDIUM-LEVEL RISK	**MEDIUM-LEVEL RISK**	Risk definition / Risk value
In order to ensure the safety of visitors during the visit of the work environments, visitors should be given personal protective equipment and these protectors should not be removed during the visit. People who have not taken security measures by the security unit should be warned and taken out. Visitors should be ensured to reach the interview area safely within the framework of precautions.	The locations of the AC cables going underground should be located and prevented harm in uncontrolled excavations.	Measures to be taken
EMPLOYER / REPRESENTATİVE OF THE EMPLOYER	EMPLOYER / REPRESENTATİVE OF THE EMPLOYER	Contact person
In a month at the latest	In a month at the latest	Deadline
Visitors are not given personal protective equipment. Visitors should be given the necessary personal protective equipment to be used during the field visit.	 The AC cables from the inverters to the transformer center go under the in-house vehicle road. However, the place where the line crosses is not marked. In addition, it is recommended to use remarkable materials such as sand around the cables.	Explanation / situation
3	2	Probability / Risk assessment after measures
3	5	Severity / Risk assessment after measures
9	10	Risk score / Risk assessment after measures
MEDIUM-LEVEL RISK	**MEDIUM-LEVEL RISK**	Risk definition / Risk assessment after measures

5	No
WORKING AREA (GENERAL)	Department
Electric transmission cables and connection points	Action
Wearing off cables and loosening of their connections	Hazard
Electric shock, fire	
ALL EMPLOYEES, MATERIAL LOSSES IN THE BUSINESS	Who may be affected by the risk
2	Probability / Risk value
5	Severity / Risk value
10	Risk score / Risk value
MEDIUM-LEVEL RISK	Risk definition / Risk value
The strength of the connection points of the electrical cables should be checked continuously. Deformed cables and fasteners should never be used and should be replaced as soon as possible. Electrical installation checks should be carried out periodically.	Measures to be taken
EMPLOYER / REPRESENTATIVE OF THE EMPLOYER	Contact person
In a month at the latest	Deadline
 Cable and cable fasteners in the enterprise should be checked continuously. It is recommended that the protective faces of the cables are laid in a sun-proof manner in order not to be damaged by the sun.	Explanation / situation
2	Probability / Risk assessment after measures
5	Severity / Risk assessment after measures
10	Risk score / Risk assessment after measures
MEDIUM-LEVEL RISK	Risk definition / Risk assessment after measures

No		9	8	7
Department		WORKING AREA (GENERAL)	WORKING AREA	WORK AREA (GENERAL)
Action		Electricity	Emergencies	Electricity
Hazard		Non-control of grounding	Lack of fire detection and	No insulating mat in front of the panels, not immobilized to the floor
		Electric shock, fire, injury, death	Being late in the intervention	Electric shock, fire, injury, death
Who may be affected by the risk		ALL EMPLOYEES	ALL EMPLOYEES, MATERIAL LOSSES IN THE BUSINESS	ALL EMPLOYEES
Risk value	Probability	3	3	2
	Severity	5	5	5
	Risk score	15	10	10
	Risk definition	HİGH LEVEL RISK	MEDIUM-LEVEL RISK	MEDIUM-LEVEL RISK
Measures to be taken		All grounding installations (including static electricity grounding) should be checked by authorized technical personnel every year, and a report should be prepared by specifying the control values.	Fire sensing detectors (heat and smoke sensitive detectors) and the siren system must be placed in the entire work area at certain intervals.	There should be an insulating mat in front of the panels and transformers.
Contact person		EMPLOYER / REPRESENTATIVE	EMPLOYER /	EMPLOYER / REPRESENTATIVE OF THE EMPLOYER
Deadline		It must be kept under control continuously.	In a month at the latest	In a month at latest
Explanation / situation		There are groundings in panel, transformers and lightning rods throughout the enterprise. Conformity checks are done with annual periods.	It is thought that it would be beneficial to establish a system that sends a warning to the fire sensing detector and remote control system in order to notice and interfere in the fire early.	 There is no insulating mat in front of the business panels. By providing mats with suitable properties, panels and transformers should be accessed by
Risk assessment after measures	Probability	1	2	2
	Severity	5	5	5
	Risk score	5	10	10
	Risk definition	LOW RİSK	MEDIUM-LEVEL RISK	MEDIUM-LEVEL RISK

No		6
Department		WORKING AREA (GENERAL)
Action		Transformer Section
Hazard		Transformers' cabins are not clean
		Electric shock, fire
Who may be affected by the risk		ALL EMPLOYEES, MATERİAL LOSSES IN THE BUSINESS
Risk value	Probability	3
	Severity	4
	Risk score	12
	Risk definition	MEDIUM-LEVEL RISK
Measures to be taken		Foreign materials should not be put in the panel cabinets and pollutions such as spider web should be cleaned.
Contact person		EMPLOYER / REPRESENTATIVE OF THE
Deadline		In a month at the latest
Explanation/ situation		 Foreign materials were seen in some of the panel cabinets in the enterprise. In addition, some panel cabinets have spider webs. These areas should be kept clean and empty against any fire risk.
Risk assessment after measures	Probability	3
	Severity	4
	Risk score	12
	Risk definition	MEDIUM-LEVEL RISK

No		13	12	11	10
Department		WORKING AREA (GENERAL)	WORKING AREA (GENERAL)	TRANSFORMER SECTION	TRANSFORMER SECTION
Action		Panel Cleaning	**Entering the facility**	**Battery Room**	**Transformer section**
Hazard		Not using pure water	Not determining the operating area,Intrusion of third parties into the field	Fire, explosion, deflagration	Unauthorized persons entering and leaving the transformer station
Risk		Electric shock, fire	Exposure to accidents of third parties and employees, theft, financial damage to the business	Injury, loss of limb, death	Injury, loss of limb, death
Who may be affected by the risk		ALL EMPLOYEES, MATERIAL LOSSES IN THE BUSINESS	ALL EMPLOYEES	ALL EMPLOYEES, MATERIAL LOSSES IN THE BUSINESS	ALL EMPLOYEES, THIRD PARTIES, CONTRACTOR COMPANIES
Probability	Risk value	2	2	3	3
		4	4	5	5
Severity		8	8	15	15
Risk score		**MEDIUM-LEVEL RISK**	**MEDIUM-LEVEL RISK**	**HIGH-LEVEL RISK**	**HIGH-LEVEL RISK**
Risk defination					
	Measures to be taken	It is recommended to use pure water for cleaning the panels.	The Visitor Security instruction must be applied. The purpose of this instruction should be to determine the Occupational Health and Safety issues to be applied in the parts where dangerous works are performed in the workplace and to ensure that the works are done according to these provisions. In order to prevent intrusions into the business, the business is surrounded by a wire fence and its door is kept locked. It is also monitored by business security cameras.	Use of ex-proof (flame-proof) installation material Having outward-opening doors and windows, Switches, sockets and fuses are outside,Providing suitable ventilation, Not using a discharge panel in the battery room, Fixing the battery groups against earthquakes and shakes , Ensuring the use of appropriate PPE	People who do not have the qualifications specified in Article 60 of the EKAT Regulation will not be allowed into the transformer section. Visitors can enter after getting permission from the authorities and signing the relevant forms and in accordance with the regulations.
Contact person		EMPLOYER / REPRESENTATIVE OF THE EMPLOYER	EMPLOYER / REPRESENTATIVE OF THE EMPLOYER	EMPLOYER / REPRESENTATIVE OF THE EMPLOYER	EMPLOYER / REPRESENTATIVE OF THE EMPLOYER
Deadline		It must be kept under control continuously.	It must be kept under control continuously.	It must be kept under control continuously.	It must be kept under control continuously.
Explanation / situation		 Panels get dirty over time and their efficiency decreases. Therefore, they must be cleaned at regular intervals. In the case of using conductive mains water during cleaning, being cracks in the panels or cables, a chassis may cause fire and / or electric shock. It is recommended to use insulating pure water during cleaning.	 At the entrance of the business, there is a sign that "no one can enter but the authority". The business is surrounded by a wire fence. It is monitored by security camera. Safety instructions should be created for visitors.	 It is made in accordance with the standards. Doors open to outside. There is a ventilation. There is also a ventilation fan that works when the temperature rises above 23 degrees.	The transformer section is kept closed and access of unauthorized persons is prevented.
Probability	Risk assessment after measures	1	1	1	1
Severity		3	3	5	5
Risk score		3	3	5	5
Risk definitionm		**LOW RISK**	**LOW RISK**	**LOW RISK**	**LOW RISK**

17	16	No		15	14
WORKING AREA (GENERAL)	WORKING AREA (GENERAL)	Department		WORKING AREA (GENERAL)	WORKING AREA (GENERAL)
Electric transmission cables and connection points	Panel and Transformers	Action		**Routine Work**	Panel and Transformers
Connections and sockets are loose	Absence of emergency stop button	Hazard		Personnel getting higher in the work area	Intra-business divisions are not specified, and no authorization is given for entrances to departments
Electric shock, fire	Work accident-wrong action late intervention	Risk		Falling, injury	work accident
ALL EMPLOYEES, MATERIAL LOSSES IN THE BUSINESS	ALL EMPLOYEES, MATERIAL LOSSES IN THE BUSINESS	Who may be affected by the risk		ALL EMPLOYEES	ALL EMPLOYEES
2	2	Probability	Risk value	2	2
5	5	Şiddet		4	4
10	10	Risk score		8	8
MEDIUM-LEVEL RISK	**MEDIUM-LEVEL RISK**	Risk definition		**MEDIUM-LEVEL RISK**	**MEDIUM-LEVEL RISK**
Inverter AC cable connections and panel transition sockets should not be loose. While laying the cables, taking into account the weather conditions, it should be ensured that the cables are neither too loose nor too tight.	The panels and transformers must have an emergency stop button. In addition, there should be breakers at the points where the energy is given to the power line and connected to the main line.		Measures to be taken	While maintaining, repairing and cleaning of solar panels, it should be avoided to get as high as possible. KKD is used for working at heights and ladders in accordance with the standards should be used for jobs that require climbing.	Working zones within the business should be determined and authorization should be made for department transitions. Access to the work areas should be controlled, except for the authorised persons.
MPLOYER / REPRESENTATIVE OF THE EMPLOYER	MPLOYER / REPRESENTATIVE OF THE	Contact person		EMPLOYER / REPRESENTATIVE OF THE EMPLOYER	EMPLOYER / REPRESENTATIVE OF THE EMPLOYER
It must be kept under control continuously.	It must be kept under control continuously.	Deadline		It must be kept under control continuously.	It must be kept under control continuously.
 Due to there is a risk of fire as a result of the inverter AC cable connections and panel transition sockets being loose, these points should be kept under constant control. In addition, it is recommended to clean the inverter fans at certain intervals.	The panels and transformers in the enterprise have emergency stop buttons. In addition, a control system is used so that it can stop and start the remote system. In addition, there is a separator at the point where the energy is connected to the main line.	Explanation / situation		 It is stated that the cleaning of the panels is done from the ground. In cases where panels and platforms need to be climbed, appropriate ladders and KKD should be used for people who climb high.	 Warning signs "no one can enter but the authority " are hung on the panels and transformers in the business .
1	1	Probability	Risk assessment after measures	1	1
5	5	Severity		4	4
5	5	Risk score		4	4
LOW RISK	**LOW RISK**	Risk definition		**LOW RISK**	**LOW RISK**

21	20	19	No	
ELECTRİCAL PANEL	WORKING AREA (GENERAL)	ELECTRIC PANELS	Department	
routine work	Transformer-Panel Section	Electrical panels / Fuse boxes	Action	
Waste collection	Not supply and not being in use of occupational safety materials and hazard warning signs	Electricity	Hazard	
Biological-chemical risk, work accident	Injury, loss of limb, death	Electric shock, work accident, injury	Risk	
ALL EMPLOYEES	ALL EMPLOYEES	ALL EMPLOYEES, MATERIAL LOSSES IN THE BUSINESS	Who may be affected by the risk	
3	2	2	Probability	Risk value
2	5	5	Severity	
6	10	10	Risk score	
LOW RISK	MEDIUM-LEVEL RISK	MEDIUM-LEVEL RISK	Risk definition	
The waste parts and scrap materials generated during and after production must be stored separately in appropriate waste collection depots.	Preparing the suitable safety material specification, Choosing the suitable safety material for the job, Applying the habit of using occupational safety material with adequate field inspections, Hanging the necessary danger and warning signs in the transformer center, wire fences, panel area and all necessary places in accordance with the regulations.	Electrical Safety Instructions need to be implemented. Electric fuses must be thermal-magnetic (automatic). Precautions should be taken for materials such as switch that is at risk of burning.	Measures to be taken	
EMPLOYER / REPRESENTATIVE OF THE EMPLOYER	EMPLOYER / REPRESENTATIVE OF THE EMPLOYER	EMPLOYER / REPRESENTATIVE OF THE EMPLOYER	Contact person	
in 2 Months at the Latest	It must be kept under control continuously.	It must be kept under control continuously.	Deadline	
 At some points in the business, random material stocks were made. These materials should be stored properly so that they do not cause accidents.	 The suitable warning signs are posted in the necessary places in the business. People who do not have the necessary personal protective equipment are prevented from interfering with the electricity generation equipment of the enterprise.	In order to prevent fires that may be caused by switch burns that frequently occur in the facility, studies have been started to monitor the system with a thermal camera.	Explanation/ situation	
3	1	1	Probability	Risk asessment after measures
2	5	5	Severity	
6	5	5	Risk score	
LOW RISK	LOW RISK	LOW RISK	Risk definition	

18	
WORKING AREA (GENERAL)	
Lightning rod	
Stroke of lightning	
Injury, work accident, fire	
ALL EMPLOYEES, MATERIAL LOSSES IN THE BUSINESS	
2	Risk value
5	
10	
MEDIUM-LEVEL RISK	
It should be ensured that it is the lightning rod positioned in the most suitable place in the business. It should be ensured that lightning rods (active system) are placed in a suitable place by the authorized units. It should be ensured that the conductivity tests of the lightning rod are done	Measures to be taken
MPLOYER /	Contact person
It must be kept under control continuously.	Deadline
There are two lightning rods in the business.	Explanation/ situation
1	Risk asessment after measures
5	
5	
LOW RISK	

No	22	23	24
Department	WORKING AREA (GENERAL)	WORKIN AREA (GENERAL)	WORKIN AREA (GENERAL)
Action	**Pest Control**	**General Work**	**Weather conditions**
Hazard	Pest, insect, gnawing animals, tick	Lack of road allocated for safe walking in	Climatic and weather conditions
Risk	Contagious disease, biological risk, damage by gnawing on electrical cables due to lack of hygiene	Work accident, fall	Diseases that may require outpatient treatment
Who may be affected by	ALL EMPLOYEES	ALL EMPLOYEES	ALL EMPLOYEES, MATERIAL
Risk value – Probability	2	2	2
Risk value – Severity	3	3	3
Risk value – Risk score	6	6	6
Risk value – Risk definition	LOW RISK	LOW RISK	LOW RISK
Measures to be taken	All kinds of measures will be taken to prevent pests, insects and gnawing animals in the workplace, All kinds of measures will be taken to destroy, insecticides and rodenticides required for their destruction will be used, the conditions that facilitate reproduction will be destroyed. Since it is in the business area, it should be also disinfected against the Crimean Congo hemorrhagic fever disease caused by ticks. Rodents should be prevented from gnawing on the cables.	A road should be allocated for safe walking in the work area.	The place where the business is established should be evaluated in terms of the frequency of weather conditions such as storm, snow and hail. The use of broken panels should be prevented in order to prevent the panels from breaking due to hail and causing fire.
Contact person		EMPLOYER / REPRESENTATIVE OF EMPLOYER	EMPLOYER / REPRESENTATIVE OF EMPLOYER
Deadline	in 2 Months at the Latest	In 2 months at the latest	It must be kept under control
Explanation/ situation	 No precaution has been taken for ticks and rodents in the business. Nests of rodents were seen in the business. It is recommended to struggle with rodents against the risk of these rodents entering transformers, panels and cutting cables. It is recommended to pass the cables through the laryngeal tube.	 The roads used to access the boards and panels within the enterprise are covered with soil and grass. Suitable walking paths are recommended for access to these points.	The area where the business is established has been evaluated and selected in terms of exposure to the storm. In addition, the fixings made throughout the enterprise should be constantly checked to prevent damage in case of a storm. In case of hail in the area where the business is located, the panels should be checked and they should be replaced in case of damaged.
Risk assessment after measures – Probability	2	2	1
Risk assessment after measures – Severity	3	3	3
Risk assessment after measures – Risk score	6	6	3
Risk assessment after measures – Risk definition	LOW RISK	LOW RISK	LOW RISK

No	Department	Action	Hazard	Risk	Who may be affected by the risk	Risk value				Measures to be taken	Contact person	Deadline	Explanation / situation	Risk assesment after measures			
						Probability	Severity	Risk score	Risk definition					Probability	Severity	Risk score	Risk definition

25	WORKING AREA (GENERAL)	Panel and Panel Platforms	Metal Burrs	Injury	ALL EMPLOYEES, VISITORS	3	2	6	LOW RISK	Cleaning to prevent damage caused by metal burrs	EMPLOYER / REPRESENTATIVE OF THE EMPLOYER	In 2 months at the latest	 There are metal burrs on some panels and platform parts in the enterprise. These burrs should be cleaned and their damages such as pricking and cutting should be prevented. In addition, unnecessary metal parts must be cut.	3	2	6	LOW RISK

3. Results And Discussion

Due to its location, Turkey has high potential in terms of solar energy. Our country has an average of 7.5 hours of sunshine per day [21]. In the works done during the conversion of solar energy into electrical energy through energy panels, fixed electrical circuits and panels are used rather than manpower. There are no insured and full time employees. However, during the control of the system, the occupational safety of the technical staff who come to the power plant during outsourcing should be ensured in order to install new technological circuits and solve various problems caused by the environment.

Various hazards and risks are at stake during the installation of panels based on energy generation in the solar power plant, doing periodic controls and the installation of new panels by technical staff. These hazards and risks can be evaluated with a 5x5 L type Matrix risk analysis and work accidents and occupational diseases can be prevented by taking the necessary measures. The aim of occupational health and safety practices is to provide employees with a healthy and safe working environment by showing the necessary proactive approaches to work accidents and occupational diseases.

As a result of the 5x5 L type Matrix risk analysis, high-level risks were shown as four and red, medium-level risks as fifteen and yellow, low-level risks as five and green. The probability score was calculated for the identified risks and the regulatory and preventive action was specified. Hazards such as the lack of location, number and control of fire tubes, unauthorized and uninformed persons coming to the power plant for technical support, not taking measures against the possibility of fire and explosion in the battery room, and lack of grounding installation that should be done once a year at the latest or not being checked constitute high -level risks. Regulatory measures should be taken in a short time.

Risks arising from dangerous movements and situations such as not showing the passage route of the cables in the ground inside the facility,the entrance of people from outside the power plant to the power plant,loosening, abrasion and breakage of the electrical transmission cables and connections,the transformer cabinets are not in compliance with hygiene rules, the lack of insulating mats in front of the panels, the lack of fire detection and siren system in emergency situations or not working, not using pure water during cleaning of solar panels, not taking the necessary measures when working at height in the power plant, the lack of emergency stop buttons and lightning rod are included in the medium-level risk group. Regulatory and preventive actions should be taken in the medium term to control these risks and prevent their harm.

Failure to store waste in the work area, to pest control and spraying, lack of a suitable walking corridor for employees and visitors in the work area, sunstroke in summer due to weather conditions, and lack of suitable place in case of cold and freezing in winter, damage caused by metal burrs in and around panel poles are defined as a low- level risk. Necessary measures should be taken in the long term.

Although the degree of risks identified may vary according to the prediction and interpretation of the observing occupational health and safety expert, the risk level remains the same. The necessary measures should be taken for identified risks and should be followed regularly. The risks identified in solar power plants are also close to each other in other solar and wind power plants. They are plants with low human factors. The risk analysis performed is a qualitative risk analysis. The response of the data obtained is expressed verbally as low, medium and high levels. In our country, occupational health and safety experts working actively in the field have difficulties in applying and interpreting Fine Kinney, which is not a quantitative analysis but a qualitative analysis. Therefore, 5x5 Matrix risk analysis is used to identify hazards and risks in the profession of occupational health and safety.

A study was done by Dündar and Ethem (2016) on the issues related to the measures to be taken in terms of occupational health and safety during the installation and field phase of solar power plants [22,24]. Çelik and Utku (2013) contributed to the literature on OHS in energy studies by working on the examination of possible situations to be experienced during the installation phase of the wind power plant in terms of occupational health and safety [23].

4. Acknowledge

I would like to thank Ahmet AKTAŞ, the owner of the solar power plant, and Asist.Prof.Dr. Berna GÜR and lecturer Ahmet Doğan ÇAKIR, who supported the preparation of the article.

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