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Occupational Health and Safety Risk Assessment in an Electricity Generation Company

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Abstract- Electricity generation operations involve a wide range of occupational health and safety (OHS) hazards which lead to increased fatal and non-fatal injury rates. Therefore, electricity companies apply OHS management systems to reduce these rates. Risk assessment and management is one of the key elements in such management systems. The objective of the current study is to perform risk assessment in a Saudi electricity generation company with application in the isolated power plants (IPPs). The risk assessment was conducted based on the five-star OHS management system using a combined hazard severity/ probability risk assessment matrix. The results of the OHS risk assessment in the IPPs indicate that there is a variety of hazards in this type of electricity generation plants, such as fire, electric hazards, physical and chemical hazards, and injury hazards. Most of the identified OHS hazards had high or medium risk levels, indicating the need for many action plans to control these hazards on the short or the long run. Because of the similarity of all IPPs, the results of the current study apply to all IPPs and, hence, the electricity company may use them for planning OHS management in all IPPs. The study recommends further research on hazard control measures that eliminate or reduce the risks to as low as reasonably practicable (ALARP) levels.

Keywords- *Occupational Health and Safety, Risk Assessment, Electricity Company*

I. INTRODUCTION

Previous research on occupational health and safety (OSH) performance of the Saudi electrical power industry has shown poor safety culture and relatively high accident and injury rates [1]. The published literature on OHS in the same sector reveals that the situation is almost similar in other countries [2-7]. The reason behind this is that the workers of this sector are exposed to a variety of hazards, including hazardous environmental conditions, physically and psychologically demanding tasks, using hazardous equipment, electrical current, working at heights, using flammable agents, and extensive travel and driving [2,7-9].

In response to the OHS outcomes of the hazardous working conditions, many electric power companies establish appropriate occupational health and safety management system (OHSMS). For instance, the Saudi Electricity Company has recently started an OHSMS based on the Five-star system. The objective is to minimize the currently-high injury, illness and fatality rates resulting from occupational accidents and exposures.

Similar to other OHSMSs (e.g., BS 8800, AS/NZS 4801, OHSAS 18001, ILO-OHS-2001 and ISO 45001), the Five-star system is based on the Plan-Do-Check-Act (PDCA) model of continuous quality improvement [10]. The four elements of the PDCA model involve several activities and arrangements that enable organizations to manage their occupational risks, and help managers to control health and safety challenges in the workplace [11].

Among all activities, risk assessment and management is the basis of the whole OHSMS [12]. This element consists of ongoing identification of the hazards associated with all activities within the organization; assessment of the risks in terms of the probability and severity of each of the hazards; and the implementation of necessary control measures to eliminate or reduce the risks to acceptable (tolerable) levels. The best practice is to proactively apply risk assessment and management. Previous research shows that most of the accidents could have been predicted and avoided if risk management had been properly carried out [13].

The Saudi Electricity Company is a large organization with multiple activities, e.g., electricity generation, transportation and distribution throughout the country. Therefore, implementation of a company-wide successful OHSMS is a challenge. Since the risk assessment and management is the core element of the OHSMS, the Company is in urgent need to apply effective techniques to organize the risk assessment and management activities. For instance, many power generation units or plants are identical in layout and activities. The risk assessment results in a sample of units may apply to all similar units. This approach will save the cost and effort of the time-consuming risk assessment of all the units. Example of these is the isolated power plants (IPP), which are temporary or permanent electricity generation plants serving the remote or rural areas which are difficult to be connected to the main electrical network. The majority of IPPs are similar in layout, units and activities.

The objective of the current study is to identify the OHS hazards in a sample of these IPPs and to make risk assessments of these hazards as well as proposing management strategies for eliminating or minimizing the risks. The results of the current study can be generalized to all other IPPs in Saudi Arabia.

II. METHODS

A. *Study Location*

Risk assessments were conducted in five IPPs selected randomly as a representative sample whose results can be generalized to all IPPs in the country. Each of the IPP was divided into 16 areas (or operations). The details of the locations and the average number of workers involved are shown in Table (I). The average number of workers was found to be 82 workers, depending on the number of generators in the plant.

B. *Hazard Identification*

Hazard identification plays a crucial part of the risk analysis due to the fact that only the identified potential hazards can be taken into account, and if all the relevant hazards are not identified then the risk analysis will result in biased decision-making, which in general will be cost inefficient and ultimately could lead to unacceptably high risks to people and the environment [14].

The recognition and identification of the hazards was performed using walk-through survey method [15] and utilizing standard checklist designed for the IPPs based on the 73 auditing elements of the implemented Five-star OHSM system. These elements are organized under main five sections [16]. Only the first three sections were considered in the risk assessment process: (1) premises and housekeeping, (2) mechanical, electrical and personal safeguarding, and (3) fire protection and prevention. The remaining two are for auditing safety and health organization and record keeping. The elements are divided into more detailed items to guide the risk assessment process. Table (I) shows the average number of applicable elements in each of the 16 inspected locations in the IPPs.

C. *Risk Assessment*

The risk assessments of the OHS hazards were conducted using the risk assessment matrix shown in Table (II) and recommended by the OHSMS applied. The matrix is a combination of hazard severity (consequence) and probability of occurrence [17], i.e., Risk Rating = Hazard Probability × Hazard Severity. Table (II) shows the severity as impact on safety and health of people, environmental damage and business losses. In case one hazard had more than one consequence (impact), the one with the highest rating was selected. The table presents also the definition of various risk levels based on the risk rating.

TABLE I. THE SELECTED LOCATIONS (OPERATIONS) IN IPPS FOR RISK ASSESSMENT

Location number and name	Location description	Average number of workers	Number of applicable auditing elements
1. Diesel tanks	This area contains 25,000-50,000 liter-capacity tanks for storage of diesel which is used as fuel	2	8
2. Fuel station	The area for discharging diesel tankers and for testing the quality of the fuel	3	7
3. Hazardous substances storage	Open and closed areas for storage of hazardous substances, depending on the standards' requirements	2	9
4. Generators	Open area containing movable generators	40	9
5. Store room	Used for storage of spare parts on tagged shelves according to size and type	2	10
6. Control room	Prohibited area that has highly sensitive devices and panels to monitor and control the electrical system in the IPP	9	18
7. Open yard	Demarcated area that has corridors for workers, traffic and equipment, and includes the emergency assembly point	2	9
8. Engine room	Closed area for fixed power generators machines	4	16
9. Mechanical workshop	Contains wide range of machines for metal lathes, drill press, grinding, bending, cutting, power saw, heat treating, electroplating, painting, and welding	5	12
10. Electrical workshop	Contains several tools and equipment for maintenance and testing	3	12
11. Security room	Restricted room equipped with a monitoring system for all the plant facility to assess and monitor the entries of the workers, equipment, and trucks	4	5
12. Battery room	Closed area for the batteries which operate switchgear, engines, etc.	1	6
13. Water treatment room	An area in which raw water is purified, filtered and treated from salts and impurities to become usable in the bathrooms, the firefighting and other facilities	1	6
14. Office building	This includes offices, bathrooms, and kitchen	1	8
15. Oil filter wash	An area where the engine filters are cleaned by special chemical substance and the oil is separated	1	6
16. Waste storage	An area where all unused or damaged equipment and materials are stored until removed from the site	1	3

TABLE II. THE RISK ASSESSMENT MATRIX

		Severity/Consequence (Impact/Hazard Effect) (Where an event has more than one loss type , choose the consequence with the highest rating)				
Potential losses as a result of the event type		**1 Insignificant**	**2 Minor**	**3 Moderate**	**4 Major**	**5 Catastrophic**
Harm to People (Safety/ Health)		First aid case/exposure to minor health risk	Medical treatment case/ exposure to major health risk	Loss time injury/ reversible impact on health	Single fatality/ irreversible impact on health	Multiple fatalities/ impact on health ultimately fatal
Environmental Impact		Minimal environmental harm incident	Moderate environmental harm	Serious environmental harm incident	Major environmental incident	Extreme environmental harm/irreversible
Business Interruption/ Material/ Damage/ Losses		No disruption to operation SR 1.0K to 10K	Brief disruption to operation SR 10K to 100K	Partial shutdown SR 100K to 1M	Partial loss of operation SR 1.0M to 10 M	Substantial loss of operation SR ≥10 M
Likelihood	Example explanations	Risk Rating				
5 Almost Certain	Unwanted event occurred frequently; occurs in order of one or more times per year & is likely to reoccur within 1 year	**5 (L)**	**10 (M)**	**15 (H)**	**20 (Ex)**	**25 (Ex)**
4 Likely	Unwanted event occurred infrequently; occurs in order of less than once per year & is likely to reoccur within 5 year	**4 (L)**	**8 (M)**	**12 (H)**	**16 (Ex)**	**20 (Ex)**
3 Possible	Unwanted event occurred in the business at some time; or could happen within 10 years	**3 (L)**	**6 (L)**	**9 (M)**	**12 (H)**	**15 (H)**
2 Unlikely	Unwanted event occurred in the business at some time; or could happen within 20 years	**2 (L)**	**4 (L)**	**6 (L)**	**8 (M)**	**10 (M)**
1 Rare	Unwanted event has never been known to occur in the business; or it is highly unlikely that it will occur within 20 years	**1 (L)**	**2 (L)**	**3 (L)**	**4 (L)**	**5 (L)**

Risk rating scheme:

Color code	Risk rate	Risk level
(red)	16 - 25	(Ex) - Extreme
(orange)	12 – 15	(H) – High
(yellow)	8 – 10	(M) - Medium
(green)	1 - 6	(L) - Low

III. RESULTS AND DISCUSSION

A. Types of Hazards

Table (III) shows the number of hazards identified in the IPPs classified based on the type of hazard. For instance, fire and explosion hazard was identified in 15 activities or locations in every IPP. The most obvious sources of this hazard are the diesel tanks and the fuel station. Storage tanks are common sources of fire in industry [18]. Other important sources are the hazardous substance storage and the generators areas. The fire source could be electrical sparks, flames or hot surface [19].

Many activities or operations (exactly 35) involved electrical hazard, which could be a source of electrocution, burns, or even death. Most of these were found in the control room, the electrical workshop, mechanical workshop, office building and the generator area. Electrical hazard is one of the most common hazards in the Saudi electric generation and transportation industry [1].

Other injury hazards, such as contact with machinery and vehicles, trapping or crushing under or between objects, and slips, trips and falls were found common in the IPPs. These types of hazards were found in most of the locations, including engine room, mechanical workshop, generators area, store room, open yard and waste storage area. The injuries resulting from these hazards are common in electricity generation plants in other countries [2-7].

The physical hazards (noise, vibration, thermal stress and radiation) were found in 33 locations (Table III). Thermal stress is a common hazard in Saudi Arabia [20] and all the workers involved in outdoor activities are exposed to high temperature levels. Furthermore, noise and vibration were found dominant in the generator area, engine room and mechanical workshop due to the type of activities and machinery involved. Other studies found the same hazards in similar operations [21,22]. On the other hand, chemical hazards were found in the hazardous substance storage area, oil filter wash area and from the exhaust of the generators, similar to previous studies [23,24].

TABLE III. SUMMARY OF HAZARD IDENTIFICATION

Types of Hazards	Frequency
Fire & explosion	15
Electrical hazards	35
Contact with machinery & vehicles	16
Trapping/crushing under/between objects	15
Slips, trips & falls	10
Ergonomic hazards	10
Physical hazards	33
Chemical & biological hazards	11
Total	145

B. Risk Assessment

The summary of the risk assessment is presented in Table (IV). The number of hazards with extreme risk was found very low (3 hazards). Fortunately, they can be corrected within days or few weeks at most. Two of them were related to absence of hazardous machine safety guards in the generators area and the engine room and, therefore, installing the proper machine guards were recommended with temporary strict tagout system to prevent workers from using these areas until the guards be installed. The third extreme-risk was in the control room which was behavioral one, and in particular it was related to violation of personal protective equipment (PPE) use in a very hazardous operation. Although other locations involved hazards with severe consequences, such as fire, they were somehow controlled so that their likelihood was relatively reduced, resulting in risk levels lower than extreme (i.e., high, moderate and low).

Table (IV) shows that the number of hazards with high risk level was 42 (29.0% of the identified hazards). The highest numbers of high risks were found in the engine room, control room, fuel station and generator area, having nearly half of them. Most of the hazards with high risk levels were fire and electrical hazards, and some of them were related to physical exposures and injury hazards. The projected consequences of these types of hazards were in agreement with what was previously observed in the injury statistics of the same company [1] and other electricity companies worldwide [5,25-27].

The high number of hazards with high risk levels is an indicator of poor safety conditions since the high level of risk means high probability of accident occurrence and/or severe consequences. It is also a measure of the amount of corrective/proactive actions needed on the short run. In most of the risk assessment models, such as BS [28], a high (or equivalent) risk level requires proactive planning and implementing specific control or action plans to eliminate or minimize the risk within few days, weeks or months, depending on the specific hazard or the type of control. Furthermore, the hazard should be continuously monitored until the control is implemented.

Out of the uncovered hazards in the IPP, about 34.5% had medium risk levels that necessitated monitoring to prevent them from developing to have higher risk levels. Almost all types of hazards were in this level. It should be noticed that the control of most of these hazards was found easy and inexpensive. For instance, using PPE, proper procedures and organizational solutions are examples of these.

Finally, the remaining 34.5% of hazards had low risk levels. In this case, no action was required and the risk was acceptable for all of them.

TABLE IV. SUMMARY OF RISK ASSESSMENT IN IPP LOCATIONS WITH RESPECT TO NUMBERS OF HAZARDS AND LEVELS OF RISKS

Location	Numbers of hazards according to risk level				
	Low	*Medium*	*High*	*Extreme*	*Total*
1. Diesel tanks	1	1	3	0	5
2. Fuel station	0	3	4	0	7
3. Hazardous substances storage	3	2	2	0	7
4. Generators	0	3	4	1	8
5. Store room	4	4	1	0	9
6. Control room	4	5	6	1	16
7. Open yard	2	3	1	0	6
8. Engine room	3	5	6	1	15
9. Mechanical workshop	5	6	2	0	13
10. Electrical workshop	5	6	2	0	13
11. Security room	4	3	2	0	9
12. Battery room	0	2	3	0	5
13. Water treatment room	2	1	2	0	5
14. Office building	10	3	1	0	14
15. Oil filter wash	3	2	1	0	6
16. Waste storage	4	1	2	0	7
Totals	50	50	42	3	145

IV. CONCLUSION

The results of the OHS risk assessment in the IPPs indicate that there is a variety of hazards in this type of electricity generation plants. The presence of flammable materials, e.g., generators' fuel, could be a source of fire or explosion. Similar to many other electricity generation companies, electrical hazard is a dominant one in IPPs. As a result of the operation of generators, physical hazards (such as noise) and chemical hazards (such as exhaust gases) affect most of the workers. Furthermore, thermal stress exists due to hot weather in Saudi Arabia. Few hazards had extreme risk level. On the other hand, most of the identified OHS hazards had high or medium risk levels, indicating the need for many action plans to control these hazards on the short or the long run. Nevertheless, many of these risks can be reduced or eliminated by applying simple and inexpensive solutions within few days or weeks. Since the layout and operations design are similar in all IPPs in the Saudi Electricity Company, the risk assessment results of the sampled IPPs in this study can be generalized to all IPPs, and the company may build on it for planning the resources needed for OHS management in the IPPs throughout the country. However, slight variation from one IPP to another is probable and, therefore, attention should be given when deciding the risk level of the same hazard in different IPPs. For instance slight increase of the likelihood could raise the risk to a higher level. The study recommends conducting further research on the best hazard control methods that eliminate or reduce the risks to acceptable levels using the as-low-as-reasonably-practicable (ALARP) approach to make a balance between the consequence of the hazards and the cost of control.

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