CHAPTER 1

INTRODUCTION

Risks from dams are low-probability and of high-consequence. Dam breaks destroy buildings, wreak economic havoc and affect the environment. The context of dam safety depends on a number of varied safety decisions and dam owners (Bowles, 2001).

A renewable energy source, hydroelectricity uses water flow in rivers from precipitation such as rain or snow, and tides driven by earth's movement. Hydroelectric power is derived from the energy of falling water, water flowing downhill, tides or water moving in other ways, to produce electricity. It involves converting mechanical energy of flowing water into electrical energy using turbine-driven generators. The power generation is often from dams or sites where water flows down a slope or coasts with a large tidal range (Hydroelectric dam- definition. http://www.wordiq.com /definition / Hydroelectric_dam, September 2011).

In particular, the Safety Management System (SMS) phase ''Identification and evaluation of major hazards'' refers to implementing systematic steps for identifying major hazards during usual and special operations and predicting their ''likelihood and severity''. The SMS involves choosing risk analysis methods and their results, in terms of frequency of occurrence and extent of consequences (Demichela et al., 2004). Over the past ten years, heightened interest in applying dam safety risk assessment has been in tandem with a search for risk criteria for use in making decisions (Bowles, 2001).

Meanwhile, it is better to deal with health and safety issues before they become a problem and major hazard in work place as well. According to the Occupational Health and Safety Department of Malaysia, an OSH policy is a document in writing expressing an organization's dedication to employee health, well being and safety. It is a basis for efforts made to ensure a proper workplace environment. This policy must encompass all the organization's activities encompassing staff, equipment and materials selection, work procedures and design as well as provision of goods and services (Department of Occupational Safety and Health Malaysia, 2011).

1.1 INTRODUCTION TO HAZARD IDENTIFICATION, RISK ASSESSMENT AND RISK CONTROL

All workplaces are subjected to hazards and risks. Safety is possible when we identify these risks and guard ourselves properly until such risks have been removed. Accidents are caused, and therefore preventable. Too often we end up regretting doing something or not doing something that could have prevented that accident to identify the causes of accidents, and prevent the accident before it happens.

Hazard: a workplace situation capable of engendering harm (i.e., able to cause personal injury, workplace related disease or death). Hazard identification is aimed at highlighting critical operations of tasks, or tasks presenting huge risks to employee health and safety besides emphasizing those hazards associated with specific, equipment due to energy sources, working conditions or activities done. Hazards fall into three major areas of health, environmental and safety hazards (Department of Occupational Safety and Health Malaysia, 2008).

For hydroelectric power generation plants, there are numbers of hazards which have been identified, the following causes should be seriously considered as some main hazard in hydroelectric power generation house. Unexpected release of hazardous energy, flammable/ explosive atmosphere, oil-filled transformers, insufficient oxygen, air contamination (toxic chemical material, toxic gas) and chemical reaction leading oxygen deficiency, electrical cables and switchgear, cooling system and large quantities of combustible hydraulic oil. Also there are so many aspects of hazard related to risky incidents such as heat injury, poor visualization, over-noise, physical barrier or movement limitations (ergonomics problem) 'as well as' other unsafe conditions like electrical hazards, spill, and mechanical equipment hazard, for instance.

Risk, which refers to the chance of a hazard actually causing injury or disease, is evaluated in terms of results and likelihood. Risk is defined in varying ways to communicate the findings of analysis and enable decision making for risk containment. For qualitative method risk analysis using likelihood and severity, a risk matrix is effective in communicating results of evaluating how risk is distributed in a plant or workplace (Department of Occupational Safety and Health Malaysia, 2008).

The following formula is used for risk calculation:

L x S = Relative Risk

L = Likelihood

S = Severity

Risk assessment is a series of processes consisting of risk analyses, assessment of magnitude of risk, judgment on whether the risk is acceptable or unacceptable, and creating and assessing risk control options, to attain this goal. That is to say, detect the hazard in the system, determine the probability of occurrence and magnitude of harm, estimate the risk, assess the results of the estimation, and then propose and assess risk control option based on assessed results. Risk assessment will play an important role when the part related to the risk within decision made by an organization is to be rationally implemented (Nippon Kaiji Kyokai, 2009). Generally the risk assessment procedure can be illustrated in the following way (Figure 1.1).

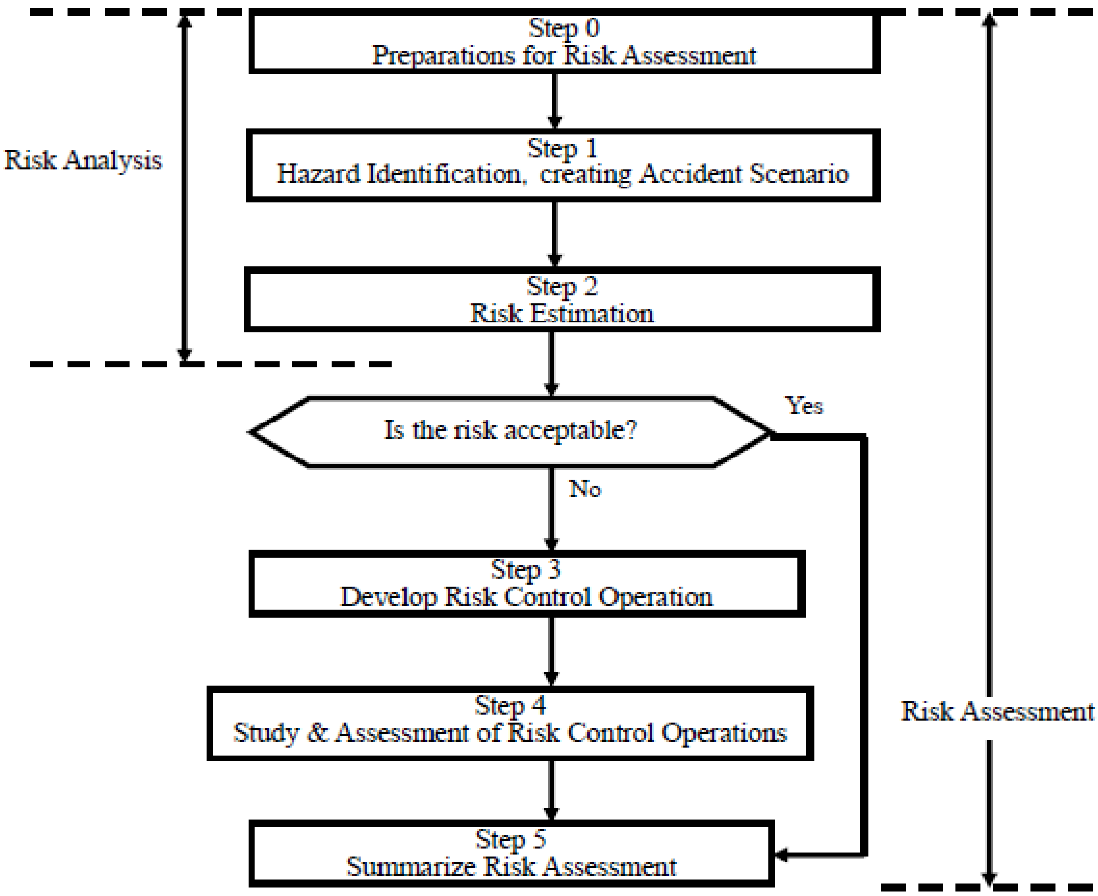


Figure 1.1: General flow of risk assessment (Nippon Kaiji Kyokai, 2009).

Control means eliminating or inactivating a hazard so that it no longer poses risk to those entering an area or working on equipment in the course of scheduled work. Hazards must be contained at source (where the problem begins). It is preferable for a control to be near the hazard source. Control of risk refers to steps taken to prevent harm occurrence (Department of Occupational Safety and Health Malaysia, 2008).

There are some common hazards such as falling objects and people, electrical, vibration, chemical hazardous substances, machinery and equipment failing, biological agents and ergonomic that can make risks in every hydro power plant.

In Peninsular Malaysia three hydroelectric schemes are operated by Tenaga Nasional Berhad with generating capacity of 1,911 megawatts (MW). They are the Sungai Perak, Terengganu and Cameron Highlands hydroelectric schemes comprising a total of 21 running dams. Table 1.1 shows the name of hydroelectric power stations with their electrical capacity in Malaysia by year 2012 (List of power stations in Malaysia. Retrieved from http://en.wikipedia.org/wiki/List_of_power_stations_in_Malaysia#cite_ note-0, January 2012).

Table 1.1: Hydroelectric power stations in Malaysia

Peninsular Malaysia	
Sungai Perak hydroelectric scheme	Total : 1249 MW
Sultan Azlan Shah Bersia Power Station	72 MW
Chenderoh Power Station	40.5 MW
Sultan Azlan Shah Kenering Power Station	120 MW
Sungai Piah Upper Power Station	14.6 MW
Sungai Piah Lower Power Station	54 MW
Temenggor Power Station	348 MW
Sultan Ismail Petra Power Station	600 MW
Terengganu hydroelectric scheme	Total: 400 MW
Sultan Mahmud Power Station	400 MW
Cameron Highlands hydroelectric scheme	Total: 262 MW
Sultan Yusof Jor Power Station	100 MW

Table 1.1,continued

Sultan idris Woh Power Station	150 MW
Odak Power Station	4.2 MW
Habu Power Station	5.5 MW
Kampong Raja Power Station	0.8 MW
Kampong Terla Power Station	0.5 MW
Robinson Falls Power Station	0.9 MW
Sabah and Sarawak	
Bakun Dam in Sarawak	2400 MW
Batang Ai Dam at Lubok Antu, Sarawak	25 MW
Murum Dam in Sarawak (proposed)	944 MW
Tenom Pangi Dam at Tenom, Sabah	66 MW

1.2 SCOPE OF THE STUDY

Generally study of safety and risk of hydroelectric dam can be done in two different sections, the dam and its associate structures and the power generation plant. The scope of study in this project focused on the development of a theoretical safety and risk evaluation model on Sultan Yusuf Power Station (JOR Hydroelectric power generation plant).

1.3 CAMERON HIGHLANDS HYDROELECTRIC POWER GENERATION PLANT

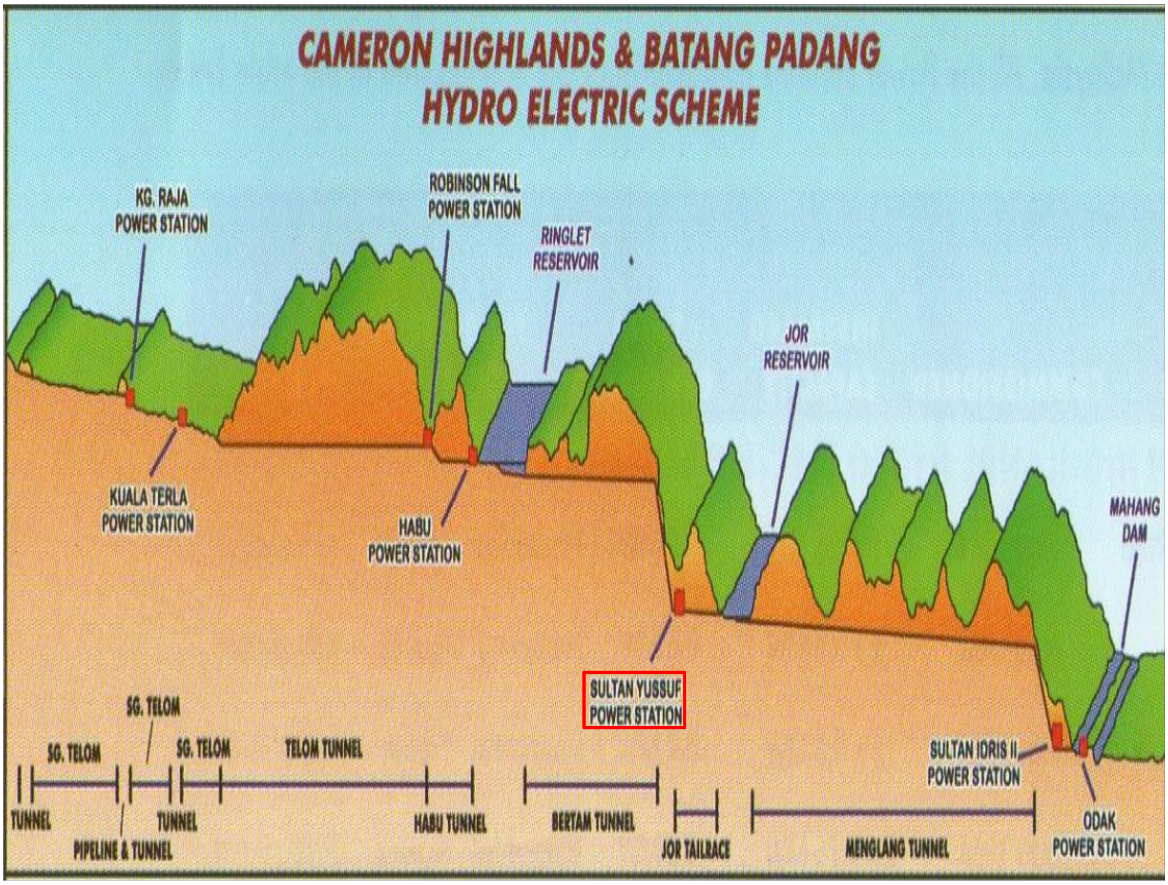
Hydroelectric Power generation plant is one of the best green plants that can produce electricity with renewable source of energy and minimum pollution. There are different types of hydroelectric power generation plant based on Installed Capacity that can be designed to produce electricity. General classification may be considered as shown in Table 1.2.

Table 1.2: Classification of hydroelectric power generation plant based on capacity

Size of hydroelectric power generation plant	Power output
Pico hydropower	< 500 W
Micro hydropower	>0.5 - 100 kW
Mini hydropower	>100 kW - 1 MW
Small hydropower	> 1-100 MW
Medium hydropower	> 100-500 MW
Large hydropower	> 500 MW

Cameron Highlands power stations consist of two hydroelectric schemes, the upper Cameron Highlands Hydroelectric scheme and the lower Batang Padang Hydroelectric schemes. These two schemes span three states (Pahang, Perak and Kelantan) in Peninsular Malaysia.

The schemes started from the Plauur diversion intake at the border of Kelantan and Pahang, across the tourist resort of Cameron Highland district in the state of Pahang and ends at the tail race of Odak power station in the state of Perak. The station operated since 1959 as a hydro electricity contributor and it is still operating until today to fulfil electricity demand in this challenging era. After operating for more than 40 years, life extension project of this station was planned and implemented to enhance station availability and efficiency. Under this project, the old systems were replaced with new technology employing best practices in power generation. Figure 1.2 shows the Cameron Highlands & Batang Padang hydro electric scheme.



Source. Sultan Yusuf Hydroelectric Power Plant Headquarters.

Figure 1.2: The Cameron Highlands & Batang Padang hydro electric scheme

According to the Sultan Yusuf Hydroelectric Power Plant (JOR Power Station) headquarters the plan is located at the 31th Km road to Tanah Rata from Tapah. It is an underground station, 287 M below the surface and uses the 597 M of net head to generate 100 MW with four horizontal shaft Pelton turbines running at 428 rpm. The alternators are each rated at 25 MW, 0.9 power factor and generate at 11 KV. The electricity is sent to the transformer and switchyard which connected to the National Grid. The voltage generated will step up to 132 KV before synchronization with the Grid System.

Water is supplied from Ringlet reservoir, which leads into Bertam Tunnel, approximately 7 km in length, to the two high- pressure penstocks of the power station. From the turbines, the water is discharged through a tailrace tunnel, 5 M and 43 cm in diameter and 2.5 Km long to JOR Reservoir at the 27^{th} km.

1.4 PROBLEM STATEMENT

The current research aimed to apply Hazard Identification, Risk Assessment, Risk Control in sultan Yusuf hydroelectric power plant (JOR Power Station) at Cameron Highlands in Pahang, Malaysia. Using hydro electric power generation plant are gradually increasing amount the nations. Hydro electric dams can help countries to reduce fossil fuel and rise using renewable energy such as water to produce green energy with less pollution. Besides the advantages of hydro electric power plant there are some important hazards which are involved with the system and if the organizations do not be aware about relevant hazards, it can be fatal problems for those who are engaged with the system such as employers, employees and etc, as well as economical crisis due to damaging the facilities and environment. Unfortunately there are so many cases have been happened owing to lake of safety in different part of the world specifically at hydro electric power generation plant that caused serious problems. For example On December 2000, at the Bieudron Hydroelectric Power Station in Switzerland, the penstock that was feeding the Pelton turbines ruptured. The failure appears to have been due to several factors including the poor strength of rock surrounding the penstock at the rupture location and low maintenance. The ensuing rapid release of a very large quantity of high pressure water destroyed approximately 100 hectares of pastures, orchards, forest, as well as washing away several chalets and barns, damage the facilities and three people were killed in the tragedy (Bieudron Hydroelectric Power Station. http://www.tutorgigpedia.com/ed/Bieudron_Hydroelectric

_Power_Station#_note-2, December 2012).

The current study concentrated on safety and risk evaluation in hydroelectric power plant. In safety management system, safety risk assessment is one of the main functions. An important element of safety risk assessment is identification of existing hazards. Hydroelectric power generation plant hazards are quite varied and have significant effects. Hence the current study tries to recommend applicable method to reduce the risks and control the residual impact to increase the safety in plant. For this study the sultan Yusuf hydroelectric power plant was selected as a case study due to geographical location, weather condition and similar process flow in system with most Malaysian existing and under construction hydroelectric power plants.

1.5 OBJECTIVES

The objectives of this project are:

1. To identify hazards in the hydroelectric power generation plant
2. To evaluate risks by applying suitable techniques in that plant.
3. To identify and mitigate wastes that can cause risks on purpose existing power generation plant.
4. To recommend control measures, by elimination or minimizing the hazards identified.

With the above objectives, designing a Hazard Identification, Risk Assessment and Risk Control (HIRARC) model for safety and health in the study hydroelectric power generation plant can help the Manager and safety officer to be aware of the particular hazards and try to reduce the risk probability.

CHAPTER 2

LITERATURE REVIEW

2.1 THE EVOLUTION OF THE OPERATIONAL SYSTEM OF A POWER GENERATION PLANT IN A HYDRO ELECTRIC DAM

Introduction

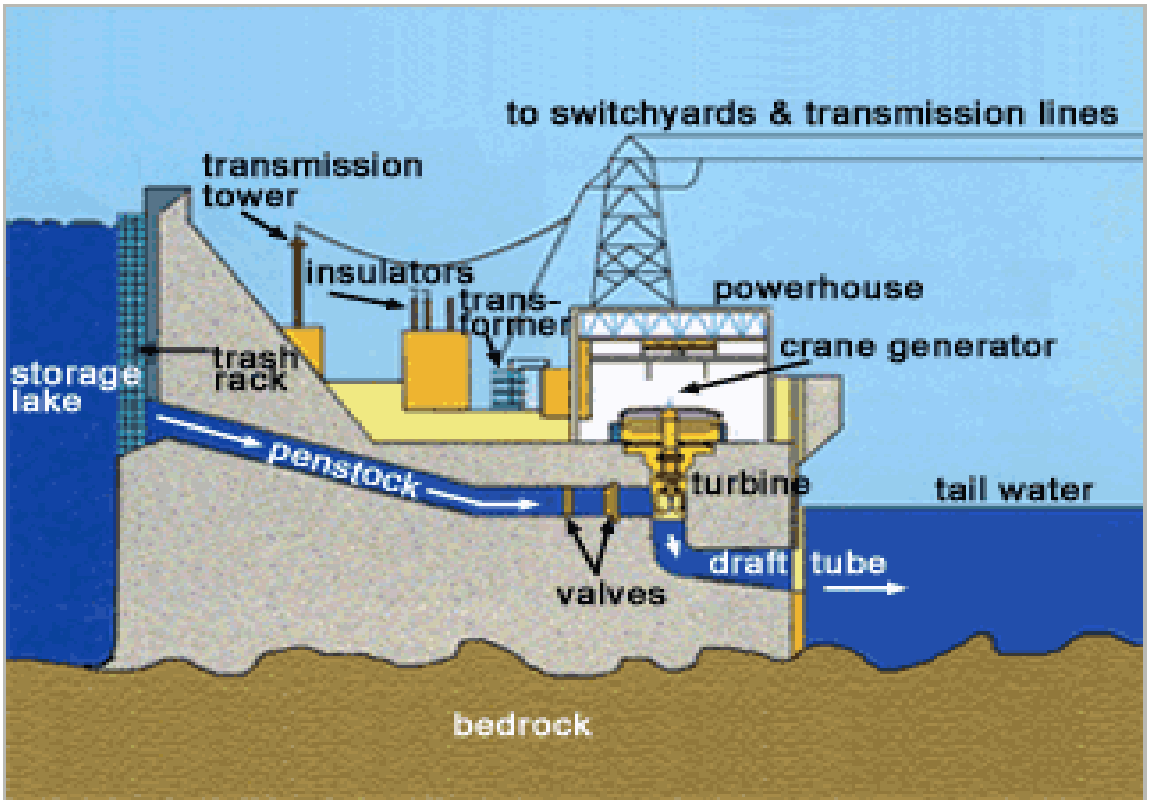
Moving water has helped man for ages. The waterwheel based on similar principle as the turbine had been used by ancient Greeks and Romans, to turn machinery. Ancient China used the waterwheel tool. Medieval Europe used waterwheels for grinding corn and wheat to make flour (Global Climate Change and Energy. Alternative Energy Sources: Hydroelectric Power. http://www.planetseed.com/node/15257, August 2011). In the mid-1770s, a French engineer Bernard Forest de Bélidor's article *Architecture Hydraulique* published in the 18th century described vertical- and horizontal-axis hydraulic machines. Electric generators were developed by the late 19th century and together with hydraulics marked an advance in energy production (Hydroelectricity.http://www.absoluteastronomy.com/topics/Hydroelectricity, September 2011). In the early nineteenth century, textile works in England and New England were powered by water mills. Steam turbine development improved the efficiency of water power. Accelerated demand for Industrial Revolution products fostered development and led to electricity and hydroelectric plants mushrooming in the late 1800s. The world's first hydroelectric power scheme at Cragside in Northumberland, England was established in 1878 by the William George Armstrong who used the energy for his workplace (Global Climate Change and Energy. Alternative Energy Sources: Hydroelectric Power.http://www.planetseed.com/node/15257, August 2011). Two years later, in Grand Rapids, Michigan a water turbine combined with a Brush dynamo, an early electric generator invented by Charles F. Brush powered lighting for buildings. Another Brush dynamo and turbine combination lighted up streets at Niagara Falls, New York in 1881 (Global Climate Change and Energy. Alternative Energy Sources: Hydroelectric Power. http://www.planetseed.com/ node/15257, August 2011).

The first hydroelectric power plant in the United States, was launched in Appleton, Wisconsin in 1882. It produced only 12.5 kilowatts of electricity. By 1886 a bigger plant replaced it, which produced enough power for the town's electric streetcars. Gaining in popularity, by 1886 hydroelectricity featured 45 power generation projects in the U.S. and Canada; by 1889 there were 200 in the U.S. alone (Hydroelectricity. http://en.wikipedia.org/wiki/Hydroelectricity, September 2011).

In the 20th century many small hydro power plants were built in mountains near cities. By 1920 hydroelectricity accounted for 40% of the US energy supply; The Federal Power Act created the Federal Power Commission to oversee hydro power plants on federal property. The associated dams were also used for flood mitigation and irrigation (Hydroelectricity.http://en.wikipedia.org/wiki/Hydroelectricity, September 2011).

Hydroelectric facilities then became established worldwide; Italy built its first plant in 1885 at Tivoli near Rome. Other countries such as Canada, France, Japan, and Russia with conducive conditions for hydroelectric power soon built plants. In the first half of the 20th century hydropower use saw a rapid increase. Early hydroelectric power plants sent out electricity as Direct Current (DC) hence curtailing the transmission distance. When it was developed in the late 1880s, Alternating Current (AC) enabled long distance electric transmission which meant that remote plants could power faraway cities. After the 1940s, cheap fossil fuels began overtaking hydroelectricity in electricity generation and oil, natural gas, and coal surpassed hydropower (Global Climate Change and Energy. Alternative Energy Sources: Hydroelectric Power. http://www.planetseed.com/node/15257, August 2011).

Lamark et al., (1998) indicated that the development in hydro electric power emphasized on operating of many power stations from only one control room usually placed in one main power plant. This set-up placed extreme demands on safety monitoring equipment. A very good fire and water leakage alarm system is crucial for ensuring safety. To better understand the system, Figure 2.1 shows the general hydroelectric power generation plant process flow diagram.



Source. Http://www.usbr.gov/uc/power/hydropwr/genbasics.html.September 2011

Figure 2.1: The Hydroelectric power generation process

Advances in Hydroelectric Power Generation

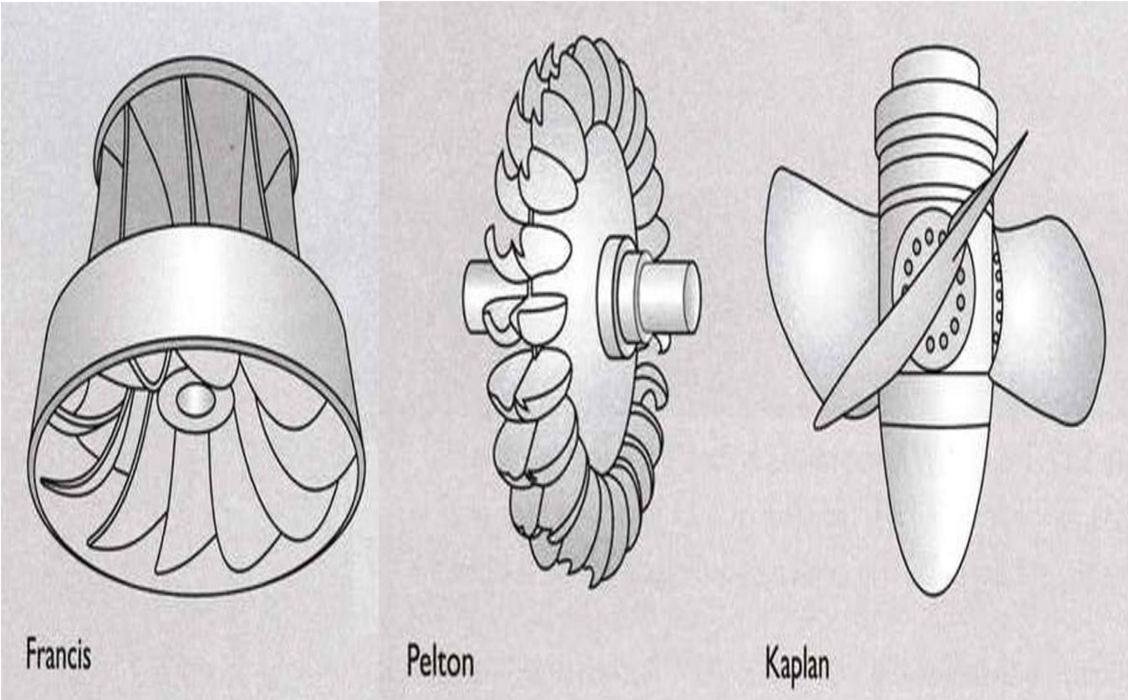
According to Zumerchik (2009), when Benoit Fourneyron won the Société d'Encouragement pour l'Industrie Nationale competition for a new water-powered design, it marked the transition from the vertical waterwheel to the much more efficient turbine design. In 1837, two Fourneyron turbines—curved blades driven by the radial outward flow design—generated 60-horsepower at the Saint Blaisien textile mill. Because Fourneyron's design only performed well under specific flow and pressure conditions, efforts were made to create more flexible designs that would evacuate the water with the lowest possible loss of potential energy. This resulted in the inward-flow turbine design patented by James B. Francis in 1849 which used spiral casings of decreasing diameter to accelerate the water onto submerged angled blades, with the evacuating water flowing through the centre outlet.

Fixed angle blades were ideal for sites with large natural storage reservoirs which had minor differences in water elevation, thus enabling a reliable year-round steady flow. For most sites without large reservoirs, the Kaplan turbine introduced in 1920 was welcomed because the blade pitch was adjustable to best match the flow and pressure conditions at any given time.

A turning point for water power occurred when turbines were coupled with electricity generators in Godalming, England in 1881, and Appleton, Wisconsin in 1882. The introduction of alternating current made it possible to decouple industry from water power, allowing industrial sites to be located far from water power resources. Switzerland built over 200 small-scale installations by the early 1890s, and on a larger scale, a 3.72-megawatt, 10-unit plant in Niagara, New York began generation in 1895. Good sites for hydroelectric power depend on pressure (high water falls), volume (high flow rate), a large storage area, and proximity to load centres. Both high head and high flow rate are ideal, yet a low head can be compensated for by a high flow and vice versa. The dam is constructed to create a reservoir that will accumulate water that can be released through pinwheels as needed to meet demand. A facility with a second reservoir at a higher elevation can store large quantities of energy. When baseline power plants produce more electricity than needed, this electricity can be used to pump water from the lower reservoir to the upper reservoir. Secondary storage serves as a valuable reserve of energy that can be released through turbines to the lower reservoir when demand rises unexpectedly or under exceptional weather conditions such as high air conditioning demand (Zumerchik, 2009).

Turbines

Turbines techniques for hydroelectric power production have changed little over the last five decades (Lamark et al., 1998). In large and medium size plants usually have 3 different types of turbines: Pelton, Francis and Kaplan (Figure 2.2). Turbines are joined to generators usually without a gearbox. The most significant change for hydro power plants is increased efficiency. Turbine lifetime can range between 15 to 40 years, depending on operating conditions. Replacement turbines could give up to 5% increased efficiency, given the more efficient blade shape.



Source. Http://www.publicresearchinstitute.org/Pages/hydroturbines/hydroturbines.htm. September 2011

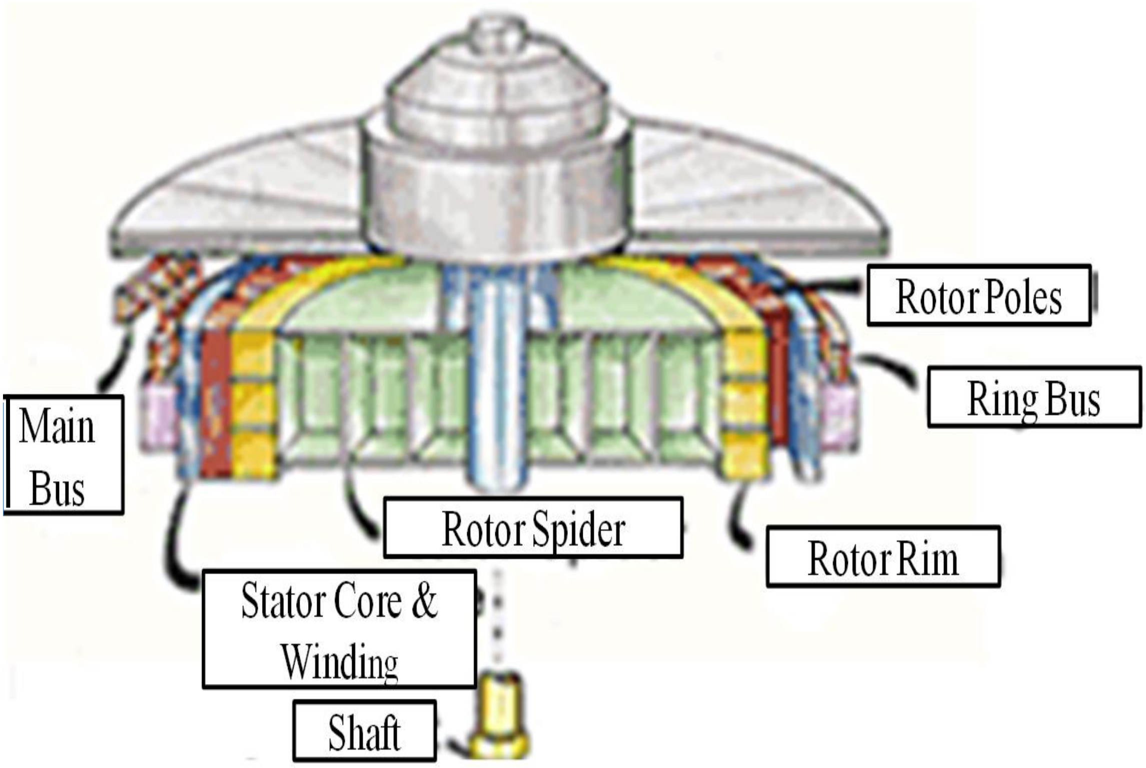
Figure 2.2: Three different types of turbines

Generators

Generator design has also remained the same over the years (Lamark et al., 1998). Generator windings older than 35 years are insulated with a viscous impregnating agent and have usually lost their original quality. New generator windings are insulated with quenching polymeric material with better aging properties.

In the late 1990s one of the main generator manufacturers revealed a new generator which could attached directly to the power grid, so step-up transformers are no longer required in large generating plants. The increased total efficiency results from elimination of energy losses in the transformer. Figure 2.3 shows a typical generator in hydroelectric dam. Hydroelectric power plants (hydropower was referred to as *white coal* for its power and abundance) continued to expand in the 20th century. In 1936, Hoover Dam's initial 1,345 MW power plant was the world's biggest hydropower plant;

it was soon surpassed by the 6809 MW Grand Coulee Dam in 1942. By 1984 the 14,000 MW Itaipu Dam in South America was the largest plant, but this was surpassed in 2008 by the Three Gorges Dam in China at 22,500 MW. Hydroelectricity would eventually be the major source of supply in some countries, such as Norway, Democratic Republic of the Congo, Paraguay and Brazil. The United States has more than 2,000 hydroelectric power plants supplying 49% of its renewable electricity (Hydroelectricity. http://en.wikipedia.org/wiki/ Hydroelectricity, September 2011).



Source. Http://www.usbr.gov/uc/power/hydropwr/genbasics.html, September 2011.

Figure 2.3: Hydroelectric dam generator

According to the U.S. Department of Energy (2006), hydroelectric power is an important component of U.S. electricity generation. Hydropower supplied from 5.8 percent to 10.2 percent of generated power between 1990 and 2003. Hydroelectric power output depends on the amount of available water, the prevailing weather and local hydrology, besides competing water use, such as flood control, water supply and recreation. Hydroelectric power is important for stabilizing the electrical transmission grid and meeting peak loads, reserve requirements and other ancillary electrical energy needs because it can react speedily to fluctuating demand.

Today hydroelectricity provides more than 50% of all global renewable energy. Hydroelectric plant design and operation is highly diverse, with projects ranging from large, multipurpose storage reservoirs to run-of-river projects that have little active water storage. Sources of water in hydroelectricity generation are given as follows:

Conventional (dams)

Hydroelectric power is produced mostly from the potential energy of dammed water driving a water turbine and generator. Water is delivered by a huge pipe or “penstock” to the turbine. The power drawn from the water is related to its volume and the “head” or height range between the water source and its outflow.

Pumped-storage

The pumped-storage method generates electricity for peak periods by moving water between reservoirs at different heights. When energy demand is low, the extra generating capacity is used to bring water up to the higher reservoir. To cope with high demand, the water is pushed through the turbine into the lower reservoir. Such storage projects currently supply the most commercially important means of large-scale grid energy storage and enhance the daily generation system capacity.

Run-of-the-river

Run-of-the-river hydroelectric stations facilities have a no reservoir or just a small one hence water from upstream sources must be used for generation at that moment, or must be made to bypass the dam.

Tide

Tidal hydro facilities are coastal set-ups that depend on daily tidal fluctuation of ocean water; they are quite predictable, and if storage is available they generate power for high demand usage. A rare type of hydro scheme uses the kinetic energy of water or undammed sources such as open water waterwheels.

Underground

Underground power stations rely on the huge difference in height between two waterways, such waterfalls or mountain lakes. Water is led by underground tunnels from the reservoir at high level to the underground generation hall to the lowest point of the water tunnel; a horizontal tailrace then removes water to the lower outlet waterway (Hydroelectric Power Plant Animation.http://technicvideo.net/hydroelectric-power-plant -animation.html, September 2011).

Size and capacity of hydroelectric facilities

Hydroelectricity forms a key energy source globally. Many Scandinavian and South American nations almost entirely depend on hydroelectricity as an energy source. Venezuela, Norway and Paraguay depend almost completely on hydro power. The Itati Dam in Paraguay exports a huge amount of energy to neighbouring states. Other nations with heavy reliance on hydro power are Brazil, Switzerland, New Zealand **(**Green

World Investor, 2011). Table 2.1 shows the capacities of hydroelectricity in selected countries by year 2011.

Table 2.1: Capacities of hydroelectricity generation in selected countries

No	Name of Country	Capacity
1	China	200 GW
2	Canada	89 GW
3	USA	80 GW
4	Brazil	70 GW
5	Russia	45 GW
6	India	33 GW
7	Norway	27 GW
8	Japan	27 GW
9	Venezuela	15 GW

Large

Currently, the largest operating hydroelectric power station in the world is The Three Gorges Dam generating 22,500 MW. Although the capacity range of large hydroelectric power stations is not officially defined, large hydroelectric facilities generally produce from over a few hundred megawatts to more than 10GW. Only three plants producing more than 10GW (10,000MW) are in operation in the world: Three Gorges Dam (22.5 GW), Itaipu Dam (14 GW), and the Guri Dam (10.2 GW) (Hydroelectricity.http://en. Wikipedia .org/wiki/ Hydroelectricity, September 2011).

Small

Small hydro refers to hydroelectric power projects in a small settelement or industrial site. The definition differs but small hydro has a maximum 10 megawatts (MW) generating capacity. This may be stretched to 25 MW and 30 MW in Canada and the United States. Small-scale hydroelectricity production grew by 28% between 2005 and 2008, raising the total world small-hydro capacity to 85 GW, with the main sources coming from China (65 GW), Japan (3.5 GW), the United States (3 GW), and India (2 GW). When joined to normal distribution grids, small hydro plants function as a low-cost renewable energy source. They are also found in remote places too costly to serve from a national network, or in places without a national power distribution network. Because they normally have small dammed areas and structures, they are regarded as more environmental friendly as opposed to large hydro.

Micro

Micro hydro projects generate power of below 100 KW. These can light up isolated towns and villages, or are at times connected to power supply networks. Such installations exist around the world, especially in developing countries where they serve as a low cost energy source without purchase of fuel. The micro hydro plants are alternatives to photovoltaic solar energy units because in many areas hydro power availability is greatest in winter when solar power is least available.

Pico

Pico hydro is defined as hydroelectric power generation of below 5 KW. Small, remote communities use pico hydro because they need very little electricity to power appliances for a few houses only. Turbines of size 200-300W may provide energy for a house in a developing country with a slope of just three feet. Usually dams are unnecessary in pico-hydro projects which use pipes for channeling water flow down a slope and to the turbine before returning it downstream (Hydroelectric Power Plant Animation. http://technicvideo.net/hydroelectric-power-plant-animation.html, September 2011).

2.1.1 Advantages and disadvantages of hydroelectricity

Advantages

Economics

Strength of hydroelectricity is fuel cost elimination. Hydroelectric plant operation costs avoid the rising costs of natural gas, oil or coal, and needs no imports. Hydroelectric plants can be in service for 50-100 years. Operating labour cost is usually low, as automated plants require few staff on site during normal operation. Where dams have multiple uses, hydroelectric plants may be built at low additional costs to provide revenue for covering dam operation costs. The sale of electricity from the Three Gorges Dam has been estimated to cover construction costs after 5 to 8 years of full generation (Hydroelectricity.http://en.wikipedia.org/wiki/Hydroelectricity, September 2011).

CO_2 Emissions

Hydroelectric dams never use fossil fuels therefore do not spew carbon dioxide directly into the atmosphere. Dam building may release carbon dioxide but this is a minor emission when compared to fossil-fuel generating plants. The Extern project by the Paul Scherrer Institut and the University of Stuttgart report states that hydroelectric plants produce the lowest level of greenhouse gases compared to all energy sources.

Other Uses of the Reservoir

Hydroelectric scheme reservoirs present opportunities for water sports, and sometimes act as tourist draws. Reservoir aquaculture is common in some countries. Multi-use dams created for irrigation encourage farming by ensuring constant water availability. Large hydro dams are also used for flood control.

Comparison with Other Power Generation Methods

Hydroelectricity does not release flue gases such as carbon monoxide and sulphur dioxide, dust, or mercury. It lacks the dangers of coal emissions, produces no nuclear waste, and unlike uranium, it is a renewable resource. Unlike wind-based sources, hydropower offers reliable supply, can generate power when needed and can be easily regulated to deal with fluctuating energy demands.

However, unlike fossil-fuelled turbines, hydroelectric plants requires a long lead-time for site studies before construction, hydrological studies, and environmental impact assessment. Up to five decades of hydrological data is needed to ascertain the most suitable spots for huge hydropower projects. Unlike conventional fuelled plants, only limited sites are feasible for hydroelectric power development; often, the most commercially viable sites have been used. New hydro sites tend to be remote, hence requiring long transmission lines. Since hydroelectric generation relies on rainfall, it may be hampered by periods of low rainfall or snowmelt. Climate change may affect long-term energy supply so utilities relying on hydroelectric power may have to spend more for extra capacity to ensure supply during droughts (Hydroelectricity. http://en.wikipedia.org/wiki/Hydroelectricity, September 2011).

Disadvantages

The disadvantages of hydroelectric plants can be categorized into those related to the power generation facilities and those related to the dams.

Hazards of Power Generation Facilities

According to McManus (2011) a hydro generating station has a dam that traps a large quantity of water, a spillway for controlled release of water surplus water and a powerhouse. The powerhouse contains channels guiding water through turbines that convert the linear water flow into a rotating flow. Since the turbine and generator are joined together, the rotating turbine will cause the generator rotor to rotate.

The electric power potential from water flow is related to water mass, the fall height and gravitational acceleration. The mass depends on the amount of water available and its rate of flow. Power station design determines the height of the water. The majority of designs take in water from the top of the dam to discharge it at the base into an existing downstream riverbed. This optimizes height while ensuring controlled water flow.

Most generating stations now have vertically aligned turbo generators. These structures rise above the main floor of the power stations. The bulk of the structure – such as the generator pit, the turbine pit and intake and discharge tube- is found beneath the visible main floor. In older stations, turbo generators are horizontally aligned (McManus, 2011). The turbine shaft protrudes into the powerhouse from a wall, where it connects to the generator or huge electric motor. The rotor motion and the magnetic field present in the rotor windings induce electromagnetic field in the stator windings. The magnetic field maintained in the generator rotor windings is powered by lead-acid or nickel cadmium batteries. The electromagnetic field induced provides the electrical energy supply for the power grid. Electric voltage is the electrical pressure arising from the flowing water. The electricity flow can lead to electrical arcing in the exciter assembly of the rotor; this can produce ozone which may damage rubber in fire hoses and other sensitive materials.

Very high currents and high voltages are produced by hydroelectric power generators. Conductors from the generators join a unit transformer and subsequently connect to a power transformer for boosting the voltage and reducing the current for long distance delivery; low current minimizes heating –related energy loss during transmission. Some systems use sulphur hexafluoride gas instead of conventional oils as insulators. Breakdown products of electrical arcing can be more dangerous than sulphur hexafluoride (McManus, 2011).

Hazards Related to Dams

Ecosystem damage and loss of land

Dams associated with hydropower generation would flood large areas of land required for the reservoir. This may lead to destruction of biologically diverse and productive environments. Land loss is exacerbated by habitat fragmentation. Projects can affect surrounding aquatic ecosystems. In fact, studies have shown that dams along the Atlantic and Pacific coasts of North America have affected salmon fisheries by curtailing access to spawning grounds upstream even with fish ladders. Salmon spawn are also affected on the way downstream when they pass through turbines. The dam tail waters usually contain very little suspended sediment, which can encourage river bed and river bank erosion (Hydroelectricity .http://en.wikipedia.org/wiki/Hydroelectricity, September 2011).

Siltation

Flowing water can transport particles heavier than itself downstream. This affects the dam and subsequently their power stations, especially those on rivers or within catchment areas with high siltation. Silt may overwhelm a reservoir and hamper its flood mitigation role. Eventually, some reservoirs can become completely choked with mud which render them useless; they may over-top during heavy rain and even break (Hydroelectricity. http://en.wikipedia.org/wiki/Hydroelectricity, September 2011). Figure 2.4 shows the siltation and sedimentation of the water reservoir that can cause serious problem for hydroelectric dam and power generation plant equipments.

Source. Http://www.inforse.dk/europe/dieret/Hydro/hydro.html.September 2011.

Figure 2.4: Sedimentation in Hydroelectric dam

Huge facilities have a limited power production life, as sedimentation eventually builds up behind the dam walls, curtailing power production by clogging the turbines' entranceway (Zumerchik, 2009). Moreover, the absence of silt downstream makes downstream riverbanks more vulnerable to flooding and prevents deposition of sediments downstream, which reduces the fertility of agricultural lands and fishery production. Dams also adversely affect water quality because warm stagnant water behind the dam promotes algae growth, and raises the mineral content due to heightened evaporation. Because small hydro facilities produce fewer environmental impacts than large facilities, they are more favored in the developed world and in rural areas of developing countries where very little power is needed. (Zumerchik, 2009).

Flow shortage

River flow fluctuations correspond to the amount of power a dam can generate. Reduced river flows from natural phenomena will decrease the live storage in a reservoir hence decreasing the quantity of water for hydroelectricity generation. Decreased river flow can cause power outage in areas dependent on hydroelectric power. Climate change may increase the risk of flow shortage. Studies in the United States suggest that a 2 degree centigrade temperature rise causes a 10% fall in precipitation, and might lower river run-off by 40% (Hydroelectricity. http://en.wikipedia.org/wiki/Hydroelectricity, September 2011).

Methane emissions (from reservoirs)

Tropical regions have lower positive impacts since reservoirs in the tropics may produce large quantities of methane from anaerobic decay of plant material in flooded areas. The World Commission on Dams observed that if reservoirs are large in relation to their generating capacity and forest clearing was not done before creating the reservoir, the reservoir greenhouse gas emissions may exceed those of traditional oil-fired plants. These emissions represent already existing carbon, unlike fossil deposits sequestered from the carbon cycle; however, they give out greater amounts of methane gas from anaerobic decay, causing much more damage than would otherwise occur from natural forest decay (Hydroelectricity http://en.wikipedia.org, September 2011).

Relocation

Another drawback of hydroelectric projects is the relocation of populations from the planned reservoir sites. In February 2008 it was estimated that dam construction physically displaced 40-80 million people worldwide. In many instances, compensation cannot replace the sites of spiritual value to the displaced people. Sites of historical and cultural value can be flooded and lost, for example in the Aswan Dam in Egypt between 1960 and 1980, the Clyde Dam in New Zealand, the Three Gorges Dam in China, the Ilisu Dam in Turkey and the Bakun Dam in Malaysia (Hydroelectricity. http://en.wikipedia.org/wiki/Hydroelectricity, September 2011).

Failure hazard

Large conventional hydro power plants hold back enormous amounts of water, so a structural failure, terrorism, or other cause can devastate downriver communities and infrastructure. Some of the largest man-made disasters in history were the resulted of dam failures. Good design and construction on their own are inadequate for ensuring safety because dams make attractive targets for terrorist attack and sabotage. (Hydroelectricity. http://en.wikipedia.org/wiki/Hydroelectricity, September 2011).

Worldwide, the objective of constructing stable dams is not always achieved. between 1900–1965, about 1% of the 9000 large dams worldwide have failed, and another 2% have suffered serious accidents (de Wrachien & Mambretti, 2009). There have been around 200 notable dam and reservoir failures worldwide in the twentieth century (Lencina, 2007). These failures have caused severe devastation downstream both in terms of lives lost and widespread infrastructure and property damage. The flood wave in dam failure can lead to loss of human lives and destructive economic losses. Thus researchers have made efforts over many years to find ways to determine the extent and timing of the flood wave (de Wrachien & Mambretti, 2009).

Over recent years efforts have been made to enhance the understanding of the theoretical and practical aspects of dam failures. Since real-time field measurements are hard to do, most dam-break studies are based on laboratory data. These studies involve fixed bed cases, without considering the strong eroding capability of the transient flow. The properties of the moving fluid mixture of debris and water are very different from those of purely water floods, noted that although improved engineering knowledge and better construction quality have improved dam safety, a full non-risk guarantee is not possible and an accident can occur, triggered by natural hazards, human actions or age-related dam strength loss (de Wrachien & Mambretti, 2009).

Hazard and Risk Definition

According to The World Bank (1997), hazards are defined as sources of possible harm, whereas risk relates to frequency and severity of destruction from hazards. Risk assessment means evaluation of actual and perceived risks for decision making. Hazard refers to a property of substances, microorganisms, and others or a situation that in certain circumstances could result in harm or may lead to bad consequences. Hazard assessment implies identifying the hazards and determining their effects on potential recipients such as humans, natural resources or living things such as plants and animals, Risk on the other hand is seen as a function of the likelihood or frequency of a hazard happening and the size of its effect. Risk thus represents the probability of realizing a potential hazard. The International Hydropower Association (2006) in its Sustainability

Assessment Protocol, details five levels of risk in hydropower plants from “Almost Certain” (A) to “Rare” (E) and the consequences ranging from “Insignificant” (1) which implies very minor impact to “Catastrophic” (5) which is of national or even global significance.

Risk estimation means we identify the likelihood of injury resulting from a proposed action or unanticipated event. Risk evaluation determines the significance of estimated risks, including risk perception. Risk assessment in turn combines risk estimation and risk evaluation. The risk assessment method can calculate the relative costs and benefits of a situation or proposed development. Risks under voluntary control are seen as less potentially hazardous than those, such as seismic events, which cannot be controlled. Managing risk means enforcing decisions about risk acceptance or control often based on cost-benefit analysis. Risks may be controlled by applying technology, procedures or alternative practices. In risk management the alternative actions must also be re-evaluated for related risk (The World Bank, 1997).

Taylor and Van Marcke (2005) state that infrastructure risk management does not just rely on technical evaluation; many other assumptions, caveats and other contextual issues have to be considered. Political, social, environmental and ethical issues, among others, need to be taken into account as well.

2.2 HAZARDS IDENTIFICATION IN HYDROELECTRIC DAM, POWER GENERATION PLANT

The Federal Energy Regulatory Commission (1992) has identified public hazards at hydroelectricity generation plants. Kim Froats and Tanaka (2004) have stated that public safety in the vicinity of hydroelectric power generating stations has become a major concern among the facility managers and operators. Waterways associated with hydro power plants are often set aside for recreation; these recreational uses must be weighed against the risks and hazards of strong currents, rising water levels and rugged topography.

According to the National Safety Council (NSC), drowning is a major hazard for dam visitors involved in water-related activities. In 2001, boating accounted for 701 fatalities in the U.S.; of these, 445 fatalities were avoidable if the victims had used life jackets (NSC) (Kim Froats & Tanaka, 2004).

Although hydroelectric generating stations account for only a minority of these accidental deaths operators must ensure they handle the public safety issues. Many general risk evaluation methods are available for determining the extent of risk. Drowning is the obvious major public hazard given the amount of deep water in reservoirs. Falling presents another major hazard. A risk assessment is the initial step in devising a waterway safety management plan. Each facility can include the following structures and related hazards in the plan: 1) head pond; 2) water conveyance structure (dam structure, power intake canal, overflow spill walls, stop log sluices and sluice gates); 3) spillway; 4) powerhouse tail-race; and 5) downstream (Au Yong, 2009).

OHSAS 18001 clearly spells out requirements for effective hazard identification, risk assessment, and risk control (HIRARC) processes. The process is based on identifying the hazard, assessing the current risk level related to the particular hazard and determining if controls are enforced to bring the risk down to manageable levels.

Au Yong (2009) noted that ISO 14001 standards emphasize environmental aspect/impact studies while OHSAS 18001 emphasizes HIRARC. The standard entails systematic assessment of all aspects; even trivial ones must be taken into account. A detailed review is required of the facility and its processes to identify the significant environmental effects and liabilities. Ratings of laws, public perception, financial impact, severity and likelihood of occurrence are used to quantify the environmental aspects. The organization must come up a list of environmental aspects covering the facility, the suppliers 'as well as' the products. The OSH risk assessment should evaluate workplace and lifestyle risks, where the OSH hazards need to be quantified using risk matrices. OSH tools must also consider maintenance operations planning, workers' risks associated with non-routine operations, and management of contractors. The OSH hazards then must be curtailed by the hierarchy of hazard elimination, substitution, engineering controls (e.g. enclosure), administrative controls and personal protective equipment (PPE) (Au Yong, 2009).

For HIRARC to succeed, it needs to follow the hierarchy of controls in choice of suitable controls. The most important outcome of an incident is the enforcement of effective, high-level safety controls to avoid or greatly decrease the possibility of recurrence. McManus (2011) has noted that electrical utilities are by tradition "bottom-up" organizations; their organizational structure favoured upward mobility with workers starting with entry-level positions and ending as senior management. Very few join the utility laterally; hence supervisory and management staff usually has undergone similar working experiences as those now holding entry-level posts. Such organizational structures can affect potential exposure to hazards, particularly those having cumulative effects. In noise exposure, for example, the current management could have suffered serious hearing loss themselves when exposed to workplace noise. Their chronic hearing loss could remain undetected in audiometric testing programs, since these programs are generally for workers currently exposed to high workplace noise levels.

2.3 RISK ASSESSMENT AND CONTROL MEASUREMENT IN HYDROELECTRIC DAM, POWER GENERATION PLANT

Duarte (2004) highlighted the difficulties in fire protection encountered by Brazilian hydroelectric plants. According to Duarte (2004) power plants have been around for some time, so much safety engineering experience exists. Plant management also have an economic incentive for accident prevention. Although technology, management, and incentives exist to prevent plant and substations explosions, fires may happen on occasion, killing workers and causing large losses. Substation fires range from minor impact fires which entail no operational interruption to major catastrophes such as the 1995 major blackout in Buenos Aires (Duarte, 2004).

While engineers who designed the substation know how to recognize the fire hazard within the system and take risk reduction measures, substation operators are responsible for the daily safe operation. Thus they must be aware of the existing process hazard. Fire safety practice today is bound by traditional regulatory codes and standards based on past experience. These methods are suited to simple workplaces producing simple and unchanging products or services, but power plants and substations today are complex and thus necessitate more effective fire safety approaches (Duarte, 2004).

New ways of thinking will allow using of past data and state-of-the-art information for forecasting fire hazards. The approach to fire and explosion hinges on performance analysis involving scenario identification and consequence analysis. Hydroelectric stations share many fire hazards with fossil-fuel plants; thus they share the same policies regarding equipment and personnel. Oil-filled transformers, generators, cables and large amounts of flammable hydraulic oil are examples of the shared hazards. Usual fire hazards include hot work, smoking, general storage, and construction materials. Hydro facilities differ from thermal power stations because they are usually below ground structures without windows (Dieken, 2009). More extreme safety risks are found in hydro plants because of limited access, lack of natural lighting, and embedded structures; all these add to risk of fire at upper levels trapping workers on lower levels. Dieken (2009) noted that facility fire safety protection features usually depend on the design standards in force during original construction. Safety designs for all buildings have a common goal: evacuating the workers in a safe and orderly manner during emergencies before conditions turn dangerous.

The National Fire Protection Association (NFPA) 101 Life Safety Code (LSC) is the most all- encompassing documented fire protection standard. The LSC specifies that, for hydroelectric facilities all water-surrounded structures must have protection appropriate to the particular hazard and designed to minimize danger during fires or other emergencies.

A life safety facility evaluation is quite complex, requiring a fire protection professional having specialist expertise. Hydroelectric plant refurbishment involves several key design issues related to Exit and Maximum Distances, Escape Stairs, Fire Doors, Administrative Areas, Fire Alarms, Lighting and Water works. Pressurized penstock water can be utilized for fire control with sufficient head pressure. When the penstock is drained for maintenance, tailrace water can also be used. Medium- and high-head facility water supply are under sufficient pressure for fire protection use (Dieken, 2009).

Hazards

Hydroelectric power generation is associated with a variety of hazards. Some hazards are common to all employees while others are limited only to those working with or maintaining electrical or mechanical equipment. The main chemical and biological hazards are given in Table 2.2 which details the prevention and minimization steps for the hazards (adapted from McManus, 2011)

Table 2.2: Controlling exposures to selected chemical and biological hazards in hydroelectric power generation

Exposure	Where found	Affected workers	Control Measures
Abrasive dusts (blasting)	Dust can contain blast material and paint dust. Paint applied prior to 1971 may contain PCBs.	Mechanical maintenance workers	Dust control system Personal protective equipment Respiratory protection Personal hygiene measures Medical surveillance (depends on circumstances)
Asbestos	Asbestos may be present in generator brakes, pipe and electrical insulation, spray-on coatings, asbestos cement and other products; exposure depends on friability and proximity to source.	Electrical maintenance workers, mechanical maintenance workers	Adopt current best practices for work involving asbestos-containing products. Personal protective equipment Respiratory protection Personal hygiene measures Medical surveillance (depends on circumstances)
Battery explosion products	Short circuit across terminals in banks of batteries could cause explosion and fire and exposure to liquid and aerosols of the electrolyte.	Electrical maintenance workers	Shielding of battery terminals and noninsulated conductors, Practices and procedures to ensure safe conditions of work around this equipment

Table 2.2,continued

Coating decomposition products	Emissions can include: carbon moNO$_x$ide, inorganic pigments containing lead and other chromates and decomposition products from paint resins. PCBs may have been used as plasticizers prior to 1971. PCBs can form furans and dioxins, when heated.	Mechanical maintenance workers	Local exhaust ventilation Respiratory protection Personal hygiene measures Medical surveillance (depends on composition of the coating)
Chlorine	Chlorine exposure can occur during connection/disconnection of chlorine cylinders in water and wastewater treatment systems.	Operators	Follow chlorine industry guidelines when working with chlorine cylinders Escape respirator
Degreasing solvents	Degreasing of electrical equipment requires solvents with specific properties of inflammability, solvation and rapid evaporation without leaving a residue; solvents meeting these characteristics are volatile and can pose inhalation hazards.	Electrical maintenance workers	Local exhaust ventilation Personal protective equipment Respiratory protection
Diesel exhaust emissions	Emissions primarily include nitrogen dioxide, nitric oxide, carbon mono$_x$ide, carbon dioxide, sulphur dioxide and particulates containing polycyclic aromatic hydrocarbons (PAHs) from vehicles or engines operated in the powerhouse.	All workers	Prohibit operation of automobiles and trucks in buildings. Local exhaust system to collect exhaust at source Catalytic converters on exhaust systems
Insect remains	Some insects breed in the fast waters around the station; following mating, the adults die and the carcasses decay and dry; some individuals develop allergic respiratory sensitization to substances in the dust.	All workers	Insects that spend part of their lives in fast-running waters lose habitat as a result of construction of hydrogenating station. These organisms may use the water channels of the station as surrogate habitat. Dust from dried remains can cause allergic sensitization.

Table 2.2,continued

Insect remains	Following draining, insect larvae living in the water channels may attempt to lower their bodies into remaining water by production of thread-like ropes; some individuals may develop allergic respiratory sensitivity to dust resulting from drying out of these materials.	Maintenance workers	Control measures include: Lighting that does not attract flying insects. Screens on windows, doors and openings in the building envelope. Vacuum cleaning to remove carcasses
Oils and lubricants	Oils and hydraulic fluids coat windings of the rotor and stator; decomposition of hydrocarbons in contact with hot surfaces can produce polycyclic aromatic hydrocarbons (PAHs). Exposure can occur by inhalation and skin contact. Skin contact can cause dermatitis.	Electrical maintenance workers, mechanical maintenance workers	Personal protective equipment (depends on circumstances)
Paint fumes	Paint aerosols contain sprayed paint and diluent; solvent in droplets and vapour can form flammable mixture; resin system can include isocyanates, epoxies, amines, peroxides and other reactive intermediates. Solvent vapours can be present in paint storage and mixing areas, and paint booth; flammable mixtures can develop inside confined spaces during spraying.	Bystanders, painters	Paint spray booth Personal protective equipment Respiratory protection Personal hygiene measures Medical surveillance (depends on circumstances)
Polychlorinated biphenyls (PCBs)	PCBs were used in electrical insulating fluids until the early 1970s; original fluids or residuals may still be present in cables, capacitors, transformers or other equipment; exposure can occur by inhalation or skin contact. Fire or extreme heating during service can convert PCBs into furans and dioxins.	Electrical maintenance workers	Personal protective equipment Respiratory protection Medical surveillance (depends on circumstances)
Sulphur hexafluoride and breakdown products	Electrical arc breakdown of sulphur hexafluoride produces gaseous and solid substances of considerably greater toxicity.	Electrical maintenance workers	Local exhaust ventilation Personal protective equipment Respiratory protection

Table 2.2,continued

Sulphur hexafluoride and breakdown products	Release of large quantities of sulphur hexafluoride into subgrade spaces can create oxygen deficiency by displacing the atmosphere.	Electrical maintenance workers	Medical surveillance (depends on circumstances)
Welding and brazing fumes	Cadmium, lead, silver in solder	Electrical maintenance workers	Local exhaust ventilation, Personal protective equipment, Respiratory protection, Personal hygiene measures
Welding and brazing fumes	Work primarily involves carbon and stainless steels; aluminium welding may occur. Build-up welding is required to repair erosion due to cavitation.	Mechanical maintenance workers	Medical surveillance (depends on composition of base metal and metal in wire or rod)
Awkward working postures	Prolonged work in awkward posture can lead to musculoskeletal injury. Fall hazard exists around pits and openings in structures.	All workers	Equipment designed to reflect ergonomic principles, Training in muscle conditioning, lifting and back care, Work practices chosen to minimize occurrence of musculoskeletal injury
Confined spaces	The dam, control structures, control gates, water-conducting channels, generator and turbine machinery contain many pits, sumps, tanks and other enclosed and partially enclosed spaces that can become oxygen deficient, can confine hazardous atmospheres, or can contain other hazardous conditions.	All workers	Air testing devices Portable ventilation systems Personal protective equipment Respiratory protection
Drowning	Drowning can occur following a fall into fast-moving water in the forebay (intake zone) or tailrace (discharge zone) or other area. Extremely cold water is present in higher latitudes during spring, fall and winter months.	All workers	Personnel containment barriers Fall-arrest systems Life jackets

Table 2.2,continued

Electrocution	Areas in the station contain energized, unshielded conductors; equipment containing shielded conductors can become live following removal of the shielding. Electrocution risk results from deliberate entry into unauthorized areas or from accidental failure of protection systems.	All workers	Establish practices and procedures to ensure safe conditions of work with electrical equipment.
Electromagnetic fields (including radiofrequency)	Generating and other electrical equipment produces DC and 60 Hz (and higher) AC fields; exposure depends on proximity to source and shielding offered by structures. Magnetic fields are especially difficult to attenuate by shielding. Significance of exposure has yet to be established.Radio frequency: Effects on humans not fully established.	All workers	Hazard not established below present limits
Heat	Generators develop considerable heat; generators and heat exchangers may discharge heated air into the powerhouse; powerhouse structure can absorb and radiate solar energy into the building; heat injury can occur during warmer months, depending on climate and level of exertion.	Indoor workers	Deflecting heated air towards the roof, shielding, engineering controls,- Electrolyte replacement drinks Personal protective equipment
Noise	Steady-state noise from generators and other sources and tasks could exceed regulated limits; air blast breakers produce very high levels of impact noise; these could discharge at any time.	All workers	Apply noise control technology. Personal hearing protection

Table 2.2,continued

Shift work	Shift operations can produce physiological and psychosocial stresses; psychosocial stresses can be especially serious for the small numbers involved in small and isolated communities where these operations tend to be located.	Operators	Adopt work schedules that reflect current knowledge about circadian rhythms.
Vibration, hand-arm	Vibration produced by powered hand tools and hand-held equipment is transmitted through hand grips.	Electrical maintenance workers, mechanical maintenance workers	Utilize tools meeting current standards for hand-arm vibration. Vibration-absorbing gloves
Vibration, whole-body	Structure-borne vibration originating from the rotational motion of generators and turbulence of water flows is transmitted through floors and walls.	All workers	Monitor and service rotating equipment to minimize vibration.
Visual display units	Effective use of computerized workstations depends on application of visual and office ergonomic principles.	Office workers managemen , administrative & technical staff	Apply office ergonomic principles to selection and utilization of video displays
Weather-related problems	Ultraviolet energy can cause sunburn, skin cancer and cataracts. Cold can cause cold stress and frostbite. Heat can cause heat stress.	Outdoor workers	Work clothing that protects against cold, Work clothing that shields against solar radiation, Eye protection that provides protection against solar radiation, Sunscreens (seek medical advice for prolonged use)

Common Types of Failure in Hydroelectric Power Plants

According to Lamark et al. (1998), the following types of failure (not ranked in order) which can cause costly damage and power outages are responsible for the most frequent losses in hydroelectric power plants:

- Failure in the stator winding of the generator
- Failure in switch control room and set of electrical tracks and cable fire

- Failure in control equipment
- Disappearance of auxiliary and power supply
- Failure in transformers
- Cracks and breakage in shovels and other turbine failures
- Failure in bearings with lubrication and cooling systems
- Flooding of machine hall and other room for machinery equipment
- Fire in the machine hall or other engine rooms

Failure in the Stator Winding

Stator winding failure depends on winding design insulation type, age, rated voltage, operating conditions and maintenance history. Windings above 35 years are insulated by a viscous impregnating agent, which lose their original quality with time; in many older plants it is critical to replace them with new windings insulated with quenching polymeric material with better aging qualities. Regular control of stator windings will reduce the likelihood of severe damage (Lamark et al., 1998).

Failure in Switch Control Room

In larger plants, dangers occur from short circuits in the electrical primary system from the generator to the transformer and grid outside. A short circuit with electrical arcing will lead to substantial damage. Systems with connected equipment must be designed to ensure an acceptable possibility of failure and reasonable care for personal safety. While old plants are often deficient in safety features, modern plants have enhanced safety by making standard phase enclosed electrical tracks and primary apparatus. Auxiliary power cables are often laid in areas with limited access in case of fire. In older plants fire detection systems are poor or negligible. Results of a cable fire may vary, but it can be devastating for the plant, especially because of chloride in the fire smoke from burning of PVC- insulated cables (Lamark et al., 1998).

Failure in Control Equipment

The plant may be damaged by failure in control- and automatic equipment or in supervision equipment. The following are some examples: Faults in the generator's automatic synchronizer may cause huge currents in the generator windings in failures of phasing the unit to the grid. Overheating may happen should failure to cut off the generator breaker causes the generator's asynchronous operation. Damage can be reduced by regular control and maintenance of control equipment (Lamark et al., 1998).

Loss of Auxiliary Power Supply

Severe damage to hydropower plant equipment have happened following loss of maneuver voltage and consequent outage of control systems. Highly reliable supply of maneuvering voltage, with redundant or back-up systems is crucial for increased safety. Many hydropower plants now have spare diesel driven generators, enabling them to start during grid power outages. A secure power supply for dam gate openings is also important in emergencies (Lamark et al., 1998).

Transformer Failure

Faults rarely occur in transformers. The main transformer is the most critical. Damage could result in a very lengthy breakdown if an alternative transformer is unavailable. Most big plants have a transformer for each phase and spare transformers are usually available (Lamark et al., 1998).

Cracks and Breakage in Shovels and other Turbine Failures

Francis and Kaplan turbines are robust. Damage due to cavitation on shovels is highly likely. Cavitation reduces efficiency and it is normally redressed prior to turbine damage. Water ways such as head race- and draft tube need to be emptied during turbine inspection and this is done every few years, or more frequently in special cases (Lamark et al., 1998).

Failure in Bearings with Lubrication and Cooling Systems

In power units with vertical shafts the water pressure on the turbine wheel could be considerable at a plant with high vertical drop. Lubrication and oil supply inconsistencies may rapidly induce bearing damage due to the huge pressure on the bearing. Such disturbances can result from a sudden leakage in the oil system. Even cooling system disruption can cause damage, but the temperature rise is usually so low that the machine can be stopped before damage occurs. Temperature measurement of the oil and the metal of the bearing should be done periodically (Lamark et al., 1998).

Flooding of Machine Hall and other Room for Machinery Equipment

Flooding of the machine hall may cause severe destruction. The cause of flooding varies, ranging from natural catastrophes to dam breaks. Water damage safety measures need to be taken in to account separately for each plant, and prevention steps need to be instituted (Lamark et al., 1998).

Fire in the Machine Hall or other Engine Rooms

Plants vary in their fire safety protection measures. Newer plants generally have a high standard of fire protection, while in older plants fire protection has often been enhanced slowly with fire alarm installation, given that many plants now are unmanned. Fires are usually related to handling of flammable liquids or hot works (Lamark et al., 1998).

Plant Safety

To ensure safe hydro electric power plant operation, maintenance and supervision programs are essential. These should have a schedule for essential upgrading as well as renewal of plant equipment. This is critical for cost efficiency, safety and to avoid material damage and breakdown. In unmanned stations common today, evaluations are carried out according to schedule, hence placing higher demand on the reliability of control and safety measures. Early automatic detection of some incidents such as flooding is very hard in unmanned facilities. Table 2.3 illustrates the risk exposures for a hydroelectric power plant (Lamark et al., 1998). As stated by Smith (2000), ongoing hazard monitoring and effective control measures are essential for ensuring continuous improvement process in occupational health and safety.

Table 2.3: The risk exposures for a hydroelectric power plant

Item /Peril	Fire	Frequency, Machinery, Breakdown	Natural Perils	Consequence
Dams	---	low	low	large
Water ways	---	low, low, medium	low	medium
Valves	---	low, low, medium	low	medium
Turbine	low	medium,	low	large
Generator	low	high	low	large
Transformer	low	high	low	medium
Switchgear	low	medium	low	Small
Lines	low	medium	low	medium

Source. Lamark et al. (1998)

2.4 HISTORY OF TESTING (HIRARC) MODEL FOR SAFETY AND HEALTH IN HYDROELECTRIC DAM, POWER GENERATION PLANT

The literature focusing on HIRARC in hydroelectric power facilities is lacking. Most studies take a macro view of such projects. Nordgård et al., (2005) for example examine the risk analyses in multi criteria decision making for hydroelectric projects. ASCE Hydropower Task Committee (2007) explored flood proofing, oil containment, systems critical for emergency operations, electrical power backup, communications and emergency access. Brauner (1995) has written on plant safety using integrated control systems, while Pejovic et al., (2007) discussed the risks of smaller hydroelectric power generation projects.

To achieve OSH objectives we need to look into HIRARC which forms the foundation of occupational safety and health. HIRARC is a combination of three consecutive activities: Hazard Identification, Risk Assessment and Risk Control. Hazard identification is the recognition of what may cause injury or harm. Risk assessment refers to examining the likelihood of harm happening to an individual if subjected to a hazard. Risk control is the introduction of measures which will eliminate or reduce the risk of a person being exposed to a hazard.

For Malaysia, the Department of Occupational Safety and Health (2008) has published guidelines on HIRARC. The guidelines suggest a systematic approach to assessing hazards and their related risks to provide objective measures of recognized hazards as well as a way to contain the risk. It represents one of the duties falling under the Occupational Safety and Health Act 1994 (Act 514) where employers need to provide a safe workplaces for employees.

According to the guidelines, HIRARC is aimed at:-

a. identifying all the factors that may harm workers and others (the hazards);

b. considering the chances of that harm actually affecting anyone in a certain case and the possible severity that could come from it (the risks); and

c. enabling employers to plan, introduce and monitor preventive measures to ensure adequate control of risks at all times.

HIRARC activities shall be planned and carried out:

a. in cases where hazards pose significant threat; where one is uncertain about the adequacy of existing controls; or/and before instituting corrective or preventive measures.

b. by an organization intending to continuously enhance its OSH Management System.

Employers have the duty of assigning trained personnel to lead a team associated with one particular process or activity to conduct HIRARC.

Process of HIRARC

The HIRARC process involves 4 simple steps: (a) categorize work activities; (b) identify hazard; (c) carry out risk assessment (estimate the risk from each hazard), by calculating or estimating hazard likelihood of occurrence, and severity; and (d) decide if risk can be tolerated and enact control measures if required.

Employers must institute a hazard identification and assessment methodology taking into account the following documents/data:

i. any hazardous occurrence investigation reports;

ii. first aid records and minor injury records;

iii. workplace health protection programs;

iv. results of workplace inspections;

v. any employee complaints and comments;

vi. any government or employer reports, studies and tests concerning employee health and safety;

vii. any reports made under the Occupational Safety and Health Act, 1994 regulations

viii. the record of hazardous substances; and

ix. any other pertinent information.

According to the Ministry of Health Malaysia, before beginning to identify any hazards, knowledge of categorization and definition of hazard, risk and danger is necessary (Ministry of Health Malaysia. http://ppg.moh.gov.my/thewe/?_page=2, August 2011).

- Hazard – whatever may result in harm.
- Risk – the likelihood of harm occurring.
- Danger – relative exposure to a hazard.

Hazards comprise health or safety hazards.

Health hazards include: Physical hazards (such as noise, heat, radiation, vibration, pressure, machinery, electricity); Chemical (gases, vapours, acids, alkali, poisons, aerosols, irritants); Biological (such as pathogens, fungi, other micro organisms); Psychosocial (such as stress, social problems, accidents, fear of failure, retrenchment); Ergonomic (such as workplace design, layout of workstation, excessive manual handling, and design of tools).

Examples of Safety hazards are Mechanical (cuts, entanglement ... etc); Heights (falling objects ... etc); Electrical (shock, burns ... etc); Fire/Explosion (burns, injury, death ... etc); Confined space (poisoning ... etc)

Hazards can be identified by:

1. Risk analysis
2. Workplace inspection
3. Safety audits
4. Job safety analysis
5. Feedback from workers
6. Observations
7. Advice from specialists
8. Accident records
9. MSDS/CSDS ... etc.

Risk assessment is achieved by (a) Collecting data about each identified hazard; (b) Using the data to assess the likelihood and result of each hazard and (c) Creating a qualitative or quantitative risk table.

Hierarchy of risk control:

1. Elimination
2. Substitution
3. Isolation
4. Engineering control
5. Administrative control
6. Personal protective equipment

Under Malaysia's Occupational Safety and Health Act (1994) the employer's duty is to:

a) Ensure workplace safety, health and welfare by providing and maintaining safe plant and systems of work; ensuring safety and absence of risks to health in connection with the use or operation, handling, storage and transport of materials; provide instruction, training and supervision necessary to ensure workplace safety and health; maintain the workplace in a safe condition without risks to health, provide and maintain means of access to and exit from it.

b) Formulate safety and health policy: as often as may be appropriate revise a written statement of his general policy with respect to the safety and health at work; arrangements for the time being in force for carrying out the policy; to inform all employees of the statement and any revision of it.

c) Employ a competent person Safety and Health Officer at the workplace exclusively for ensuring due observance of the OSHA and its regulations and promote safe conduct of work at the workplace.

d) Establish a workplace Safety and Health Committee if there are 40 or more persons employed there.

e) Consult the Safety and Health Committee in maintaining arrangements which will enable employees to co-operate effectively in promoting workplace safety and health and in checking effectiveness of such measures.

f) Notify the nearest Occupational Safety and Health Office of any accident, dangerous occurrence, occupational poisoning or occupational disease which has happened or is likely to happen at the workplace.

Employees in turn have a duty to take reasonable care for their own safety and health, co-operate with employers in carrying out duties or requirement imposed on their employer by OSHA, use any protective equipment or clothing provided by employers at all times for preventing safety and health risks; and abide by any safety and health instruction mandated by their employer under the OSHA (Laws of Malaysia, Act 514, 2006).

How to create a safe workplace

1. Predict the hazard
2. Identify the hazard
3. Evaluate the risk
4. Carry out control measures
5. Review the control measures.
6. Carry out Job Hazard Analysis

The Department of Occupational Safety Malaysia (2008) recommends that Job Hazard Analysis (JHA) be done to identify the hazards under HIRARC.

Job Hazard Analysis (JHA) requires breaking down jobs or tasks into specific steps, analyzing each step for specific hazards, developing safe work procedures for eliminating or decreasing the hazards, and integrating safe work procedures into safety and health programs. JHAs must be done for each task and supervisors must collaborate with workers to complete the JHA together.

2.5 EVALUATE RISKS CAUSED BY WASTES AT POWER GENERATION PLANT IN HYDROELECTRIC DAM

According to the National Energy Education Development Project, even though they burn no fuel, hydropower facilities can raise many environmental issues. Dams could permanently impact wildlife habitats; fish may be restricted from swimming upstream. Plant operations may also release dissolved metals deposited by factories in the past, may encourage silting, affect water temperatures, and reduce dissolved oxygen levels. Some problems can be managed by building fish ladders, dredging the silt, and monitoring plant operations. Hydropower is advantageous because flowing water is clean and renewed annually by precipitation. Hydro plants do not emit pollutants into the air because they burn no fuel, and they offer several other benefits such as flood control, water supply regulation and recreational or tourism activities. In contrast to wind and solar power hydropower is a very controversial (National Energy Education Hydropower has some indirect health effects.

The following observations can be made:

- Dam construction leads to reduced flow and stagnation of water and this can affect the prevalence of disease vector populations. In tropical countries dams could lead to increase in population of malaria vectors. However, other dangerous organisms may lose their breeding grounds, since fluctuating water levels may hinder breeding in the reservoir area.
- Groundwater may be affected by hydropower operations, which in turn may affect well water quality.
- The reduced water flow can also hinder dilution of river pollutants arising from other industrial activities.

However, few studies exist on the evaluation of health risks following habitat alteration, or societal impact resulting from hydropower development (National Energy Education Development Project. http://www.need.org/needpdf/ Infobook _activities/ SecInfo/HydroS.pdf, August 2011).

Updated information regarding the social and socio-economic impact is given in a World Commission on Dams report (2000). The report states that while multi-purpose projects often benefit local society, hydroelectric development benefits for communities under environmental strain are often in question. The effect on other land use from river damming is often readily seen, while the economic gain is not (World Commission on Dams, 2000).

That environmental effects of hydroelectric plants are apparent to biologists but not to the average citizens. Companies usually emphasize their “clean” electricity production but keep silent about long-term environmental hazards. Dams retain mud and debris; the silt deposited in the reservoir concentrates pollutants such as heavy metals. Finally the dam becomes inoperable; future generations must remove the debris or live with a possibly dangerous mudflow that could devastate downstream areas.

Hydropower may be more environment-friendly than fossil-fuel sources, but its future is uncertain and other alternatives may be needed. The National Hydropower Association noted that hydropower projects usually take 8 to 10 years to be licensed. In contrast, natural gas fired plants can be licensed in under two years. Hence few investors are willing to risk funds on new hydro projects. Some consider abandoning projects as opposed to relicensing because relicensing is complicated, involving dam re-evaluation every three to five decades. Some favor dam decommissioning for restoring rivers, but American Rivers noted that this is unlikely in the majority of bigger dams. Savings in carbon emissions from hydropower as opposed to fossil fuel plants pale when compared to the cost of removing silt and other material if the river is to be restored. Future generations must choose whether to retain mud-filled dams or decommission them. Leaving loose sediment in dams would be potentially hazardous, but removal charges are uneconomic compared to the lifetime value of power generated by the dam

(Alternative Energy. http://www.altenergy.org/renewables/hydroelectric.html,August 2011).

The International Hydropower Association has published a sustainability protocol for hydroelectric power sources (International Hydropower Association, 2006). These aspects of sustainability have been chosen to give adequate consideration to relevant economic, social, and environmental issues. Assessment is scored from 5 through to zero, and considers both process and performance against each aspect. The assessment process relies on a systematic approach to managing issues related to economic, social and environmental aspects.

The European Small Hydropower Association (2006) has also written on the control of waste from hydropower plants. According to the Association, nearly every modern hydropower plant has a trash rack cleaning machine for removing rubbish to prevent it from damaging plant equipment. Tons of material (largely plastic bags, cans, bottles, as well organic material and all kinds of material thrown into the water by man and nature) are removed annually, from rivers. Many countries mandate that when something is removed from the water, it automatically becomes waste that must be removed at extremely great disposal costs. SHP operators are doing a public service by removing anthropogenic waste from the water.

The Environmental Mitigation Technology for Hydropower (2010) report details the environmental impact resulting from hydropower plant operations. According to the report the main quality issues related to hydroelectric power plants are temperature and dissolved oxygen changes in the tail waters. In temperate areas, deep reservoirs may become thermally stratified. Turbine intakes draw water from the depths of the reservoir; hence summer water temperatures in the discharged water are generally lower than in free-flowing rivers. In winter the reverse could happen when warmer tail waters may affect aquatic life. This cold water discharged in summer can slow fauna growth rates and reduce fishery productivity, but could also enable coldwater fishery in previously unfeasible areas. On the other hand, water temperature changes in winter can hasten the metabolic rate of fauna so that premature emergence occurs. Aquatic life require sufficient dissolved oxygen (at least 5 mg/L in most waters), but thermal stratification can reduce dissolved oxygen concentration in the reservoir discharge. Stagnant bottom waters never undergo replenishment of dissolved air unlike surface waters subjected to wind mixing. Dissolved oxygen can be removed from bottom waters by bacterial breakdown of organic matter and chemical oxidation, or by intake of oxygen-consuming organic materials from upstream.

Lastly, the International Energy Agency, in its document comparing hydroelectric power generation with other types of power generation, concluded that although hydropower is considered to a renewable energy source, some greenhouse gas emissions normally occur, at least during construction. Emissions are very low for run-of-river facilities, while opinions differ regarding emissions from reservoir facilities. Various studies have suggested different emission rates; recent reports put emissions at between 4 and 410 g CO_2 per kWh. Following measurements of dissolved carbon dioxide and organic carbon transport in the Nile before and after impoundment it was suggested that a net sequestration of carbon of at least 1 g per kWh accompanied the anticipated electricity production over 100 years. Low temperature also enhances dissolved oxygen and decreases the rate of methane release. Actual eutrophication potentials relate to whether eco-systems are Phosphorus-limited or Nitrogen-limited. As for ecotoxic impact, the highest quantities of ecotoxic potent elements and compounds released during the hydropower lifecycle are cadmium, mercury, nickel and lead for water and zinc and aromatic hydrocarbons for soil (The International Energy Agency, 2002). Large dams may induce seismic activity. Such effects are unpredictable but damage can be prevented by proper design and selection of building materials. The probability of inducing changes in the bedrock by large reservoirs is negligible in areas of low tectonic activity. Whether reservoirs can influence earthquake timing and magnitude is still debatable. The most memorable disaster blamed on a reservoir happened in 1967 at India's Koyna dam when a Richter Scale 6.3 magnitude earthquake destroyed a whole village, killing 180 people (The International Energy Agency, 2002).

This literature review has described the development of hydroelectric power, the changes in power generation processes over the years, hazards in hydroelectricity generation (dam hazards, as well as, plant hazards) and also the HIRARC guidelines for Malaysia. It can be concluded that the literature on HIRARC specific to hydroelectric power generation is lacking, so the present study will add to the existing literature on this topic.

CHAPTER 3

METHODOLOGY

This chapter describes the methodology that was used to identify risk factors to improve safety at Sultan Yusuf Hydroelectric Power plant (JOR Power Station). The methodology is divided into three sections: inspection hazard identification, risk assessment and risk control method. In general there is a common HIRARC form (Appendix A) that helps to identify, collect and analyze all the above parameters. The research is included primary and secondary data collection, primary data collection which was applied by questionnaires and archived documents used to collect secondary data to identify hazards, risk matrix ranking applied to evaluate and assess risks along with control recommendations. Some steps are designed according to above sections in order to carry out the research. Several site visits were implemented to achieve data collection.

The application of safety has direct relation to the rate of hazards generated at plant. It depends on different factors such as types and severity of work, number of accidents, education level of employers and employees, monitoring by relevant authorities, cost, and etc. Therefore the aim of HIRARC is to find out every parameter that can consider as a risk to reduce accident and increase safety. The framework of process was provided in Figure 3.1.

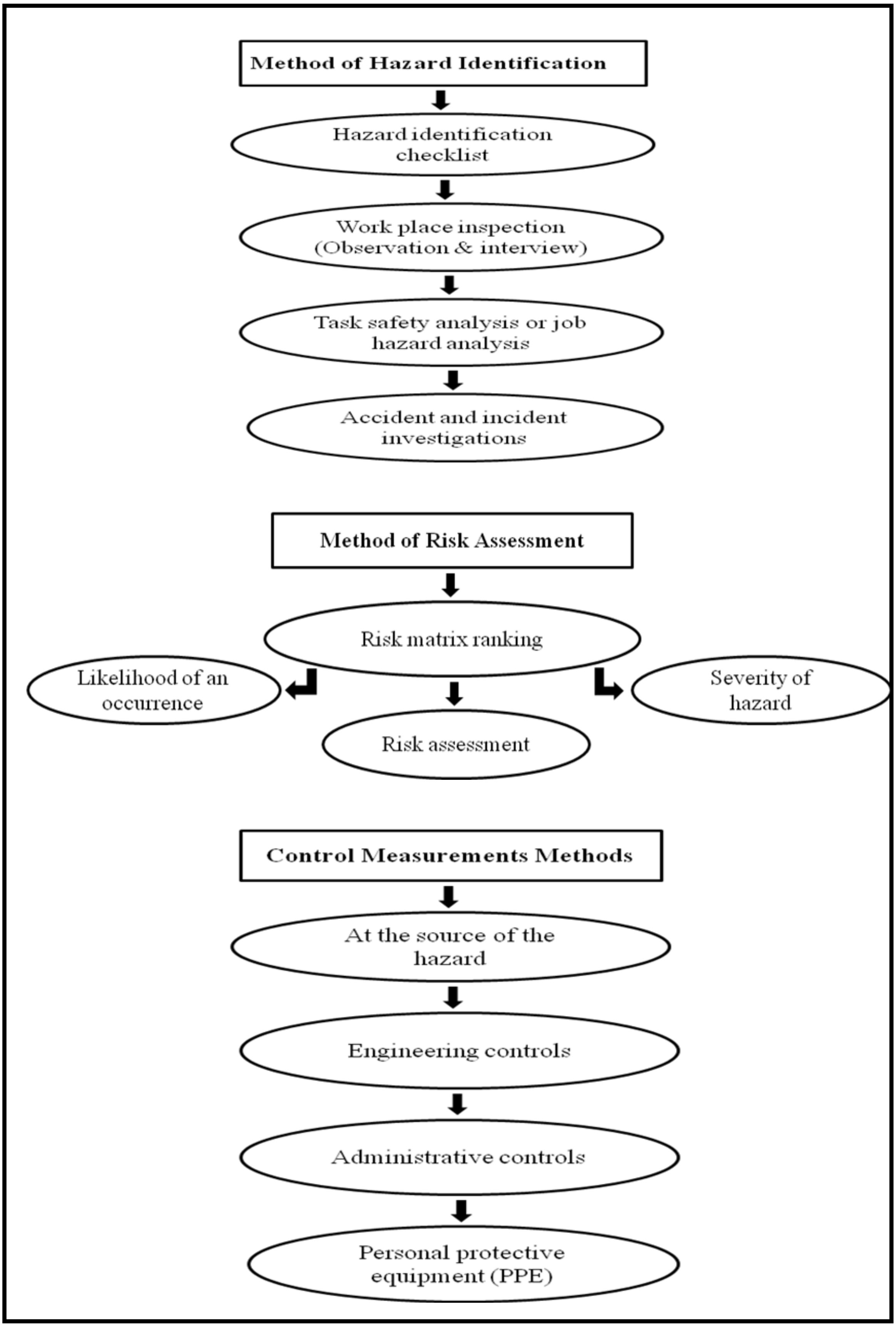


Figure 3.1: Framework of the methodology

3.1 METHODS OF HAZARD IDENTIFICATION

In this study hazard identification was referred to the identifiying of undesired events leading to hazard materialization and the mechanism of their occurrence. To complete hazard identification in the study area several techniques to identify hazards were used. In fact, the identification methods were dependent on the size of the power plant. To examine the hazard identification in the hydro electric power generation plant in this study, the following methods were used to ascertain the hazard aspects at that particular area:

3.1.1 Hazard identification checklist

In purpose plant hazard identification checklists will list known hazards or causes of hazards drawn from past experience which may be in the form of previous risk assessments of similar systems or operations, or actual incidents that have happened.
This technique involved the systematic use of an appropriate checklist and considering whether each item on the checklist could possibly apply to a particular system. Checklists should always be validated for applicability before use (Safety Management System and Safety Culture Working Group, 2009).

In this study the hazard identification checklist (Appendix B) comprises seven sections that include: general Chemical, Electrical, Mechanical, Ergonomic, Biological, first-aid, fire-fighting equipment and methods of control. The checklists were distributed among the white and blue –collar workers during and after working hours respectively.

3.1.2 Workplace inspection (observation and interview)

Visits were conducted to the JOR hydroelectric power generation plant and Inspections were used as tools for assessing workplace hazard. Direct observation was essential during the survey. Photographs from the study area and relevant places were taken to have visual observations of the sites and activities. Many inspection checklists are found in various OR-OSHA publications. In this study "inspection" was a general walk-around inspection of the worksite follow the process flow of the plant to identify conditions of non-compliance to safety standards. This encompassed routine industrial hygiene monitoring and sampling. At times the term "audit" is preferred to "inspection." Audits usually involve locating ineffective or missing safety programs. Audits are similar to evaluation tools because they involve assigning numerical ratings to items audited. Inspections, on the other hand, involving locating hazardous conditions.

In this study area observation was crucial because it is a tool for effective identification of behaviors that account for most workplace injuries. It takes into account how these behaviors interact with the hazardous environment. Furthermore an interview was applied as a one-on-one verbal exchange conducted in private with the relevant authority in the Sultan Yusuf Hydroelectric Power Plant (JOR power station) which has had the potential to collect more information from the plant in different dimension (Identifying and Controlling Hazards. http://www.orosha.org/educate/training/pages/104xm3.html, September 2011). Appendix C & D shows the workplace inspection checklist and interview questionnaire to inspect and better understand work place hazard.

3.1.3 Task safety analysis or job hazard analysis

A job hazard analysis or JHA is a technique focusing on job tasks to identify hazards before their occurrence. In this study JHA is a multi-step procedure designed to analyze a job by investigating its several steps, hence providing a way to identify and then eliminate or control related hazards. The JHA results in detailed directions for finishing a certain job safely. It will help avoid injuries to employees (NPS Risk Management Division, 2005). A job hazard analysis form (Appendix E) is used in this study for examining the health and safety aspect of the process in the hydro power generation plant.

3.1.4 Accident and incident investigations

Accidents happen when hazards are undetected during job or process safety analysis, or when hazards are not obvious, or are the result of combination of unforeseen factors. In the purpose study area a thorough accident investigation identified formerly overlooked physical, environmental, or process hazards, unsafe work practices and the need for more extensive safety training. The main point of investigating accidents is to determine the facts surrounding them and the lessons to be learned to prevent future similar occurrences. Investigation should never be focused on placing blame; instead, it must be seen as a chance for enhancing safety.

In general, investigation was carried out for:

a. All injuries (even the very minor ones)

b. All accidents with potential for injury

c. Property and/or product damage situations

d. All “Near Misses” where there was potential for serious injury

Incident reporting and investigation enable hazard identification and control before hazards lead to even worse incidents. Accident investigations enable detecting hazards missed earlier or hazards involving failed controls. Investigation is only useful when aimed at identifying root causes. All incident contributing factors should be exposed and suggestions given to avoid recurrence (Colorado State University Occupational

Health and Safety Section, 2001). Appendix F shows an example of an accident investigation form.

The methodology for hazard identification and assessment shall include:

a. Steps and time frame for identifying and assessing the hazards.

Steps must be defined for identifying hazards and a time frame given for their identification. Information documented should include:

i. Who will be held responsible identification, whether it should be the workplace health and safety committee, or an individual/individuals appointed by the committee;

ii. How the identification reports are processed: for example, compiled and processed by the committee, or by individuals appointed by the committee;

iii. The identification time frame.

b. The keeping of a record of the hazards.

After identifying the hazards, an identification record must be established and maintained in print or electronic form.

c. A time frame for reviewing and revising the methodology.

The date for identification reviewing: for example, identification method review will be carried out every three years (Department of Occupational Safety and Health Malaysia, 2008).

3.2 METHODS OF RISK ASSESSMENT

Risk assessment means determining the likelihood and severity of the accident/event sequences in order to gauge magnitude and to prioritize identified hazards. Risk assessment can be done by quantitative, qualitative, or semi quantitative approaches. This study mixed all above methods for risk assessment for better results.

Qualitative analysis uses words to describe the extent of potential severity and the possibility that severity will occur. These scales can be adapted to the circumstances and varied descriptions may be used for different risks. This technique relies on expertise and experience to gauge the likelihood and severity category.

Quantitative analysis describes risk in numerical terms and not the descriptive scales used in qualitative and semi-quantitative analysis. Both severity and likelihood are given values, using data from sources such as previous accidents occurring and results of scientific studies.

Semi-quantitative analysis assigns values to qualitative scales such as those described above. This is aimed at producing a more expanded ranking scale than conventionally found in qualitative analysis, not to suggest realistic values for risk as in quantitative analysis.

We can determine severity by modelling outcomes of events or sets of events, or by extrapolating from experimental research or previous data. Severity may be denoted by monetary, technical or human impact terms, or some other criteria. Expression of severity and likelihood and their combination to express risk level depends on the type of risk and how the risk assessment output will be used.

3.2.1 Risk matrix ranking

3.2.1.1 Likelihood of an occurrence

In this study area the value depended on the likelihood of an event happening. One question is “How many times has this event happened in the past?” Assessing likelihood in the plant was based on worker experience, analysis or measurement. Likelihood levels ranged from "most likely" to "inconceivable". Table 3.1 elaborates different ranges of likelihood with their rating.

Table 3.1: Likelihood values

LIKELIHOOD (L)	EXAMPLE	RATING
Most likely	The most likely result of the hazard / event being realized	5
Possible	Has a good chance of occurring and is not unusual	4
Conceivable	Might be occur at sometime in future	3
Remote	Has not been known to occur after many years	2
Inconceivable	Is practically impossible and has never occurred	1

Source. Department of Occupational Safety and Health Malaysia, 2008.

3.2.1.2 Severity of hazard

Severity could be divided into five categories. Severity was based upon an increasing level of severity to an individual's health, the environment, or to property. Table 3.2 shows the rating of severities by giving an example.

Table 3.2: Indications of severity

SEVERITY (S)	EXAMPLE	RATING
Catastrophic	Numerous fatalities, irrecoverable property damage and productivity	5
Fatal	Approximately one single fatality major property damage if hazard is realized	4
Serious	Non-fatal injury, permanent disability	3
Minor	Disabling but not permanent injury	2
Negligible	Minor abrasions, bruises, cuts, first aid type injury	1

Source. Department of Occupational Safety and Health Malaysia, 2008.

3.2.1.3 Risk assessment

Risk could be presented in different ways to communicate the results of analysis and facilitate decision-making for risk control. For risk analysis that used likelihood and severity in the qualitative method, presenting results in a risk matrix is an effective way of communicating the risk distribution in a plant or workplace. Table 3.3 shows an example of risk matrix to identify the risk value.

Risk can be calculated using the following formula:

L x S = Relative Risk

L = Likelihood

S = Severity

Table 3.3: Risk matrix values

	Severity (S)				
Likelihood (L)	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

High (red) Medium (yellow) Low (green)

Source. Department of Occupational Safety and Health Malaysia, 2008.

To use this matrix, we first find the severity column that best describes the outcome of risk. Then we follow the likelihood row to find the description that best suits the likelihood that the severity occurred. The risk level is where the row and column intersect.

The relative risk value can be used as a guide for prioritizing needed actions in effective management of workplace hazards. Table 3.4 express the level of the risk in particular values.

Table 3.4: Risk descriptions

RISK	DESCRIPTION	ACTION
15-25	High	A HIGH risk requires immediate action to control the hazard as detailed in the hierarchy of control. Actions taken must be documented on the risk assessment form including date for completion.
5-12	Medium	A MEDIUM risk requires a planned approach to controlling the hazard and applies temporary measure if required. Actions taken must be documented on the risk assessment form including date for completion.
1-4	Low	A risk identified as LOW may be considered as acceptable and further reduction may not be necessary. However, if the risk can be resolved quickly and efficiently, control measures should be implemented and recorded.

Source. Department of Occupational Safety and Health Malaysia, 2008.

Hazards evaluated as “High Risk” require immediate actions, to resolve risk to life safety and/or the environment. Personnel responsible for taking required action, including follow up must be clearly identified.

Analysis of data for HIRARC, graphs and statistical representations were based on Microsoft Excel.

3.3 CONTROL MEASUREMENT METHODS

In this study control measure methods applied with four major categories, namely the source of the hazard, engineering control, administrative control, and personal protective equipment control to verify or regulate hazards by conducting a parallel experiment or by comparing with standard to reduce or prevent the hazards. The details of control measurement methods are as bellow:

3.3.1 At the source of the hazard

At the source of the hazard is one of the control methods to control hazards by implementing Elimination and Substitution parameters in the plant.

a. **Elimination** - Getting rid of a hazardous job, tool, process, machine or substance is perhaps the best way of worker protection.

b. **Substitution** -Controls must protect workers from repetitive and any newly created hazard.

3.3.2 Engineering controls

Engineering controls is the mechanical modification of machinery or processes to prevent and reduce the discharge of hazards into the working atmosphere. Depends on the type of hazards different factors of engineering control can apply in the plant. Table 3.5 shows some different types of engineering controls.

Table 3.5: Engineering control parameters

Parameters	Remark
Redesign	Jobs and processes can be reworked for better safety. For example, containers can be made easier to hold and lift.
Isolation	If elimination or replacement is impossible, the hazard can sometimes be isolated, contained or otherwise kept away from workers.
Automation	Dangerous processes can be automated or mechanized.
Barriers	A hazard can be blocked before it reaches workers.
Absorption	Baffles can block or absorb noise. Lockout systems can isolate energy sources during repair and maintenance. Usually, the further a control keeps a hazard away from workers, the more effective it is.
Dilution	Some hazards can be diluted or dissipated.

3.3.3 Administrative controls

Administrative controls comprise a variety of policies and requirements that are recognized at an administrative level. Administrative controls implement by the plant authority (Management, Safety department, safety committee or safety officer). Following parameters can implement as an administrative control to minimise and control risks in working area (Table 3.6).

Table 3.6: Administrative controls parameters

Parameters	Remark
Safe work procedures	Workers can be required to use standardized safety practices. The employer is expected to ensure that workers follow these practices. Work procedures must be periodically reviewed with workers and updated.
Supervision and training	Initial training on safe work procedures and refresher training should be offered. Appropriate supervision will assist workers in identifying possible hazards and evaluating work procedures.
Job rotations	Can reduce worker exposure to a hazard. For example, workers can be rotated through jobs requiring repetitive tendon and muscle movements to prevent cumulative trauma injuries. Noisy processes can be scheduled when no one is in the workplace.
Housekeeping, repair and maintenance programs	Housekeeping includes cleaning, waste disposal and spill cleanup. Well maintained tools, equipment and machinery are less likely to cause injury.
Hygiene	Hygiene practices can reduce the risk of toxic materials absorption by workers or risk of carrying toxins home. Street clothing should be kept in separate lockers to avoid contamination by work clothing. Eating areas must be isolated from toxic hazards. Eating should be banned in toxic work areas. Where applicable, workers should be required to shower and change clothes at the end of the shift.

3.3.4 Personal protective equipment

Personal protective equipment (PPE) use is determined by hazards identified in hazard analysis. PPE should only be used as the last resort, after exhausting all other controls or when more significant hazard controls are not feasible. In this study personal protective equipment control focus on the workers safety by preparing all protection equipment such as Eye and Face, Head, Foot and Leg, Hand and Arm, Hearing and Body Protection (Department of Occupational Safety and Health Malaysia, 2008).

CHAPTER 4

RESULT AND DISCUSSION

The HIRARC studies in the Sultan Yusuf Hydroelectric power plant (JOR power station) were conducted to determine the hazards, as well as, appraisal risks to improve safety. The results focused on:

4.1 HAZARDS IDENTIFICATION AT SULTAN YUSUF HYDROELECTRIC POWER GENERATION PLANT (JOR POWER STATION)

Hazard identification in the study area was done using a hazard identification checklist, workplace inspection checklist (observation and interview), job hazard analysis and accident investigation checklist. Hazard can happen for various reasons everywhere in the plant. The main aim was to select the best and effective method for identifying hazards related to environment, facilities and workers. The first step conducted to develop hazard identification was looking for the process flow diagram and familiarizing with the system, collecting some basic information before applying different methods to identify hazards; it helps to select the best method for the study area. Finally as a result, hazards were classified into five different main types such as chemical, biological, physical, ergonomic, and electrical follow by level of risks which was categorized as high, medium and low risks.

In general, hazard identification in the study plant had two possible purposes:

To do a “failure case selection” or obtain a list of hazards for subsequent evaluation using other risk assessment techniques.

To perform a “hazard assessment” or qualitative evaluation of the significance of the hazards and the measures for reducing their risks.

Based on selected methods a survey was conducted to identify hazards in JOR hydroelectric power generation plant and the detail results of the analysis are as below.

4.1.1 Hazard identification checklist

The aim of using hazard identification checklist in this study was to list all expected and unexpected hazards to navigate and better understand the hazard. The hazard identification checklist was mainly aimed at assessing every parameter involved in the hazard identification process in the systematic identification of hazards, to review the effectiveness of safety measures selected and, where required, to implement the safety measures to achieve a tolerable residual risk.

In this study hazard identification checklist (Appendix B), was a prepared and checked with expert and was conducted in Sultan Yusuf hydroelectric Power generation Plant (JOR Power Station). Based on this checklist the power station is following OSH regulations under the Occupational Safety and Health Act 1994 (Act 514) and internal TNB safety program. The checklist comprised some main aspects as follows:
In this study chemical hazard and exposure to chemical component was generally under control, all employees were aware of the potential hazards involving chemical hazards, and employees were required to use personal protective equipment when in contact with chemicals, Personal Protective Equipments (PPE) were available and the checklist for PPE needs to be filled up by the Department of Safety every month.

While, all parameters of safety are in order, sometimes some items were unintentionally missed in the system. For example lack of respirators, less employees were given instruction in the right usage and limitations of respirators also no operating procedures for the choice and use of respirators where needed, cause hazardous exposure to chemical components and emergency cases. System had suitable ventilation equipment for removing contaminates from the air and it is operating satisfactorily with inspection mandated every three months.

In this study there were no major complaints from workers regarding health problems such as headaches, dizziness, irritation, nausea or other types of discomfort when they were in contact or working with chemicals.

According to McManus (2011), in many cases polycyclic aromatic hydrocarbons (PAHs) are produced by decomposition of hydrocarbons in contact with hot surfaces of the rotor insulation. Exposure to PAHs can occur by inhalation and skin contact hence causing dermatitis.

Leaking and mixing of the chemical component on the floor, soil and water, in cooling system, transformer and transporter are the main problems that can cause chemical hazard for the system, workers and environment in the JOR hydroelectric power station plant. Therefore the safety officer and supervisor should enhance monitoring by checking the system and strictly enforce current regulations to reduce the specific hazard. Table 4.1 shows the checklist of hazardous chemical exposures in the JOR hydroelectric power station.

Table 4.1: Results of hazardous chemical exposures checklist

HAZARDOUS CHEMICAL EXPOSURES	Y	N	Comment
1. Are employees aware of the potential hazards involving various chemicals component?	✓		
2. Is employee exposure to chemicals kept within acceptable levels?	✓		The employees are under chemical control program and industrial hygiene.
3. Are all employees required to use personal protective clothing and equipment when contact chemicals (i.e. gloves)?	✓		
4. Where needed for emergency use, are respirators stored in a convenient, clean and sanitary location?	✓		
5. Are respirators intended for emergency use adequate for the various uses for which they may be needed?		✓	
6. Are employees prohibited from eating in areas where hazardous chemicals are present?	✓		
7. Is personal protective equipment provided, used and maintained whenever necessary?	✓		The checklist for PPE should be filled up every month.
8. Are there written standard operating procedures for the selection and use of respirators where needed?		✓	
9. If you have a respirator protection program, are your employees instructed on the correct usage and limitations of the respirators?		✓	
10. Are the respirators NIOSH approved for this particular application?	✓		
11. Are they regularly inspected and cleaned sanitized and maintained?	✓		
12. If hazardous substances are used in your processes, do you have a medical or biological monitoring system in operation?	✓		Training and applying chemical handling procedure for all employees

Table 4.1, continued

13. Are you familiar with the Threshold Limit Values or Permissible Exposure Limits of airborne contaminants and physical agents used in your workplace?	✓		
14. Have control procedures been instituted for hazardous materials, where appropriate, such as respirators, ventilation systems, handling practices, and the like?	✓		All control measure for hazardous material are including in the working instruction program.
15. Do you use general dilution or local exhaust ventilation systems to control dusts, vapours, gases, fumes, smoke, solvents or mists which may be generated in your workplace?	✓		
16. Is ventilation equipment provided for removal of contaminants from such operations, and is it operating properly?	✓		System inspected every three month
17. Do employees complain about dizziness, headaches, nausea, irritation, or other factors of discomfort when they contact and working with chemical component?		✓	
18. Is there a dermatitis problem--do employees complain about skin dryness, irritation, or sensitization?		✓	
19. Have you considered the use of an industrial hygienist or environmental health specialist to evaluate your operation?	✓		Chemical hazard risk assessment has been conducted
20. If internal combustion engines are used, is carbon monoxide kept within acceptable levels?	✓		
21. Is vacuuming used, rather than blowing or sweeping dusts whenever possible for clean up?	✓		
22. Is Asbestos a hazard in powerhouse area?		✓	
23. Have you faced with any Battery Explosion products during the process?		✓	

Table 4.1, continued

24. Does Coating Decomposition products make hazard (e.g., copper, lead)?		✓	
25. Is there any gas emission by arcing in the rotor and other electrical equipment (e.g., ozone)?		✓	
26. Do disturbances of lubrication and oil supply in turbine can rapidly lead to water and cause hazard?	✓		Probably in cooling system and transformer

Electrical hazard in hydroelectric power generation plant is another important factor. The Sultan Yusuf hydroelectric power generation plant (JOR Power Station) is contracted with OSHA for doing the safety program in electrical part but Headquarter of safety in TNB manage electrical safety training for employees and all people engaged with process; furthermore JOR hydroelectric power station specifies compliance with TNB as a requirement for all contracted electrical work. Under the TNB safety program all employees are required to carry out preliminary inspections and tests to ascertain the conditions existing before beginning work on electrical equipment and the equipment have to be serviced and maintained, and measures taken to ensure necessary switches are operational.

Electrocution is one of the main hazards in hydro electric power stations. Some areas in the stations contain energized, unshielded conductors; equipment with shielded conductors can become live with removal of shielding. Electrocution risk may arise from purposeful entry into restricted areas or following unintentional protection system failure. Meanwhile radiofrequency in electromagnetic fields is the other important electrical hazard which is difficult to attenuate by shielding (McManus, 2011).

Regarding the hazard identification checklist conducted survey in Sultan Yusuf hydroelectric Power generation Plant, high voltage electricity and it radiation in switchyard area has negative impact on environment and employees working in the vicinity of the area but the manager and safety department are knowledgeable on that and try to control the system with suitable training for workers, put medical check-up frequently and install warning sign. Meanwhile the following can create electrical hazard for the station: failure of bushing device during operation due to partial discharge or localized dielectric breakdown of a small portion of a solid or fluid electrical insulation system under high voltage stress which fails to bridge the space between two conductors; and failure of circuit breaker to cut off the power supply in the event of overloading (Table 4.2).

The electricity supply and installation practice in the Sultan Yusuf hydroelectric Power generation Plant (JOR power station) are following TNB HQ recommendations, being governed by the:

1. Electricity Supply Act 1990 - Act 447
2. Licensee Supply Regulations 1990
3. Electricity Regulations, 1994
4. Occupational, Safety & Health Act 1994
5. Malaysian Standard MS IEC 60364 Electrical Installation of Buildings

Table 4.2: Results of electrical hazard checklist

ELECTRICAL	Y	N	Comment
1. Do you specify compliance with OSHA as a requirement for all contract electrical work?		✓	There is other safety program under TNB as well
2. Is there any simple access to high voltage switchyards or control areas?		✓	
3. Are all electrical power tools, leads and portable electrical equipment tagged and inspected follow the Hydro Equipment Safety regulations?	✓		
4. Do the employees have knowledge of the electrical device and their function?	✓		
5. Is there a hazard due to direct contact of persons with live parts?		✓	
6. Is there a hazard due to contact of persons with parts which have become live under faulty conditions (indirect contact)?	✓		Hazard is in place but employees are aware about it
7. Is there a hazard due to proximity to live parts under high voltage?	✓		Switchyard area
8. Is there a hazard posed by electrostatic charges?		✓	
9. Is there a hazard due to thermal radiation (heat) or the projection of molten particles from short circuits, overloads etc.?	✓		No case has happend
10. Is there any Electrical Safety Training for employee and all people who engaged with process?	✓		Under TNB HQ
11. Are electrical enclosures such as switches, receptacles, junction boxes, etc., provided with tight-fitting covers or plates?	✓		

Table 4.2, continued

12. Are all flexible cords and cables free of splices and taps?		✓	
13. Are employees instructed to make preliminary inspections and/or appropriate tests to determine what conditions exist before starting work on electrical equipment or lines?	✓		
14. When electrical equipment or lines are to be serviced, maintained, or adjusted, are necessary switches open, locked-out and tagged whenever possible?	✓		Loading out the particular part from the system and work on it
15. Are portable electrical tools and equipment grounded or have double insulation?	✓		
16. Is sufficient access and working space provided and maintained around all electrical equipment to permit safe operations and maintenance?	✓		
17. In wet or damp locations, are electrical tools and equipment appropriate for the use or location or otherwise protected?	✓		In dangers case all equipment are in off condition (not live) or protected
18. Are metal measuring tapes, ropes, handlines or similar devices with metallic thread woven into the fabric prohibited where they could come in contact with energized parts of equipment or circuit conductors?	✓		
19. Are there any potential electrical hazards for machine hall?	✓		Mostly in generator parts with short circuit hazard
20. Is there any failing of bushing device during the operation?	✓		Due to partial discharge which is localized break down under high voltage stress
21. Is there any hazard due to circuit breaker not cutting off the power supply in the event of overload?	✓		

Table 4.2, continued

22. Is there any firing hazard cause by over using of generator copper coil during the operation?		✓	
23. Are there accident caused by arc temperature, or arc brightness and hit by the lid during its removal in transformer?		✓	
24. Is there any explosion and mechanical hazard due to high voltage and low maintenance in transformer?	✓		If it happen cause by low maintenance of oil storage
25. Is there any Failure in the stator winding of the generator cause by deterioration mechanism?		✓	
26. Do the cables and their auxiliary power system face with cutting or firing hazard due to low maintenance and overloading of the cables?		✓	
27. Is there any heating losses hazard (Dissipation factor) on the environment and the workers cause by ageing or low maintenance of insulation system in switchyard?		✓	
28. Does high voltage electricity and it radiation in switchyard area have negative impact on the environment and employees?	✓		Mostly when the workers are exposing
29. Are mechanical and corrosion failures cause hazard in relays and contactors?		✓	

A comprehensive survey for Mechanical Hazard in this study area shows that generally equipment and machinery are securely in place and anchored in the station. Regarding the yearly DOSH inspection, all machinery are certified as having been subject to required testing and examinations; also the crane and overhead electric holistic are under DOSH. PMA, control and workers are familiar with the mechanical device and their function (Table 4.3).

While the systems are under control some mechanical hazards were observed in the station. These included hazard for employees doing maintenance for mechanical components such as fixing of draft tube, turbine or transformer; also hazard for cooling system caused by disturbance of oil and sediment, and hazard in turbine shaft due to cavitation on shovels. According to Lamark et al (1998), the frequency of damage to turbine of Francis and Kaplan is very low due to cavitation on shovels. Cavitation reduces efficiency and damage is usually repaired well before occurrence of turbine damage risk. Turbine inspection and control means the waterways such as head race- and draft tube need to be emptied and this is done every few years. The interveal between inspection could be closer in special circumstances. The plant safety officer believed that they cannot avoid those hazards but by applying good safety plan, suitable training and education they are able to reduce the hazards in the system.

Table 4.3: Results of mechanical hazard checklist

Mechanical	Y	N	Comment
1. Is there a training program to instruct employees on safe methods of machine operation?	✓		Safety awareness for every employee especially new employees
2. Is equipment and machinery securely placed and anchored, when necessary to prevent tipping or other movement that could result in personal injury?	✓		
3. Is a crane preventive maintenance program established?	✓		
4. Is the load chart clearly visible to the operator?	✓		
5. Is an audible warning device mounted on each crane?	✓		
6. Is sufficient illumination provided for the operator to perform the work safely?	✓		
7. Are cranes of such design, that the boom could fall over backward, equipped with boom stops?	✓		
8. Does each crane have a certificate indicating that required testing and examinations have been performed?	✓		DOSH inspection every year
9. Is each overhead electric hoist equipped with a limit device to stop the hook travel at its highest and lowest point of safe travel?	✓		It has PMA, DOSH certificate
10. Are close-fitting guards or other suitable devices installed on hoists to assure hoist ropes will be maintained in the sheave grooves?	✓		
11. Is it prohibited to use chains or rope slings that are kinked or twisted?	✓		
12. Are operators instructed to avoid carrying loads over people?	✓		But sometimes human error cause hazard and workers should wear safety hat

Table 4.3, continued

13. Are all hooks equipped with spring-loaded safety clips to prevent accidental load release?	✓		
14. Are only employees who have been trained in the proper use of hoists allowed to use them?	✓		The crane driver need to have certification from NIOSH
15. Is there any hazard for employee due to fixing or maintenance of draft tube (e.g., drowning)?	✓		The area of fixing and slope can make hazard
16. Is there any Flooding hazard for Machine Hall and other Room for Machinery Equipment caused by natural catastrophes, dam breaks or overflow?	✓		
17. Is turbine scroll case checked frequently to prevent probably leaking from the seam, lap joint or welded part cause by high pressure of water?	✓		
18. Can leakage and disturbances in oil and lubrication system cause hazard in cooling system?	✓		
19. Is there any collapse hazard in power house access gallery cause by landslides, sinkholes, and ground settlement?	✓		
20. Can electric power to each machine be locked-out for maintenance, repair, or security?	✓		
21. Are rotating or moving parts of equipment properly guarded to prevent physical contact (e.g., generators, turbines, moving chains and gears)?	✓		
22. Are machinery guards secure and arranged so they do not offer a hazard when in use?	✓		
23. Is there suitable ventilation system to gather the dusts, vapors, or gases in machine hall or access gallery to be controlled, and convey them to a suitable point of disposal?	✓		
24. Is there any hazard in turbine shaft due to cavitation on shovels or moving fast (e.g., breaking or firing)?	✓		

Table 4.3, continued

25. Do Disturbances of lubrication, oil supply and water pressure can rapidly lead to damage of the turbine bearing due to the huge pressure on the bearing?	✓		
26. Is there any mechanical failure for generator due to low maintenance and overloading?	✓		
27. Is there any collapsing hazard in all power generation house tunnels area cause by swelling clay, ageing or water pressure?	✓		
28. Do damaging and fails to run in ducts and fans in ventilation system can cause hazard in confine space?	✓		Increasing the temperature and dust
29. Is high sedimentation cause hazard for cooling system and turbine bearing?	✓		

Another two important items in the study plant were ergonomic and biological hazards. In the selected power station, ergonomic and biological parameters were considered for all employees via the safety committee and observation by safety officer according to the Occupational Safety And Health Act 1994 (Act 514).

Based on checklist and observation, workers are trained and prohibited from lifting heavy parameters (heavy pipes, transformers, lubrication tanks, used bulk, etc) and do not stoop their neck, shoulder or kneel to do work or view the task for a long time; also all seating places are adjusted, positioned, and arranged to minimized strain on all parts of the body. But using the hand tools or handling parts or objects and extra force with hands by workers, exposure to vibration caused by powered hand tools and rotational motion of generators and turbulence of water flows is transmitted by facilities or floor, musculoskeletal injury from prolonged work in awkward posture, oxygen deficiency which is a serious problem for workers in confined spaces. According to McManus (2011), hydro power generation structures may contain many tanks and other enclosed and partly enclosed areas that can become oxygen deficient, can contain hazardous air present other dangerous conditions that can create ergonomic and biological hazards for employees. Some physiological and psychosocial stresses on employees due to their working position or working schedule are ergonomic and biological hazards identified in the selected study area. To solve these problems the management and safety officer agreed to implement the latest regulations, get ready more PPE for workers, use high level engineering control and set appropriate work schedules to decrease workers' stress levels. Table 4.4 and Table 4.5 show the checklist of ergonomic and biological hazards in the JOR hydroelectric power station.

Table 4.4: Results of ergonomic hazard checklist

Ergonomic	Y	N	Comment
1. Do workers perform tasks that are externally paced?		✓	
2. Are workers required to exert force with their hands (e.g., gripping, pulling, pinching)?	✓		
3. Do workers use hand tools or handle parts or objects?	✓		
4. Do workers stand continuously for periods of time?	✓		
5. Do workers sit for a long time without the opportunity to stand or move around freely?		✓	
6. Do workers use electronic input devices (e.g., keyboards, mice, joysticks, track balls) for continuous periods of time?	✓		
7. Do workers kneel (one or both knees)?	✓		

Table 4.4, continued

8. Do workers perform activities with hands raised above shoulder height?		✓	Sometimes can happen in store
9. Do workers perform activities while bending or twisting at the waist?		✓	
10. Are workers exposed to vibration?	✓		The frequency is low
11. Do workers lift or lower objects between floor and waist height or above shoulder height?	✓		
12. Do workers lift, lower, or carry large objects or objects that cannot be held close to the body?		✓	Trolley and forklift provided
13. Do the neck and shoulders have to be stooped to view the task?		✓	
14. Are there sufficient rest breaks, in addition to the regular rest breaks, to relieve stress from repetitive-motion tasks?	✓		
15. Are all seating place adjusted, positioned and arranged to minimize strain on all parts of the body?	✓		

Table 4.5: Results of biological hazard checklist

Biological	Y	N	Comment
1. Is there any musculoskeletal injury due to prolonged work in awkward posture?	✓		One case happened when the worker pick up the heavy weight
2. Is oxygen deficient a serious problem for employees that are working in confined space (e.g., water-conducting channels, generator and turbine machinery contain many pits)?	✓		But follow to OSHA there is a procedure for confined space to reduce major problem
3. Are there any falling and drowning hazards into fast-moving water in power house area?		✓	
4. Is there electrocution hazard due to fixing and maintenance of electrical device for workers?	✓		
5. Do Generating, transformer and other electrical equipment have Electromagnetic fields (including radiofrequency) on employee?		✓	
6. Do generators and heat exchangers may discharge heated air into the powerhouse and make heat hazard for workers?	✓		There are cooling and ventilation system to reduce this hazard
7. Is noise level over the standard of the indoor air quality in powerhouse area (85db)?		✓	
8. Are there any physiological and psychosocial stresses on workers due to their working position or working schedule?	✓		
9. Is there any hazard vibration cause by powered hand tools and rotational motion of generators and turbulence of water flows transmitted through floors and walls?	✓		But not in high frequency
10. Are there frequently indoor air quality and industrial hygiene to check and control the air quality and worker health in power generation house?	✓		Yearly monitoring

Following the OSHA and industrial hygiene regulation, JOR hydroelectric power station had adequate first aid equipment and all first-aid supplies replenished as they are used in powerhouse each three month which can be used in emergency cases and according to safety officer report follow to the plant safety program workers have annual training to know how to use first-aid equipment in emergency cases; meanwhile there is a clinic for all employees and their families to cover their clinical problem and monitor workers health.

Fire hazard is another important hazard that management of JOR power station have to consider. According to Dieken (2009), hydroelectric stations share many of the same fire hazards as fossil-fueled plants and, thus, share similar equipment and personnel policies. Shared hazards include oil-filled transformers, electrical cables and switchgear, air-cooled generators, and large quantities of combustible hydraulic oil. Common fire hazards include hot work, smoking, general storage, and temporary construction/overhaul materials.

However hydro facilities, unlike thermal power plants, usually have an underground windowless structure. Hydro plants present more extreme safety issues because of limited building access, lack of natural lighting, and embedded structures hence increasing the potential of trapping workers on a lower level by a fire on a higher level. The number and type of life safety fire protection features at a facility vary widely and normally depend on who designed the plant years ago and the design standards during original construction. Life safety design requirements for all structures share the same goal: Getting the workers out of the structure in a safe and orderly manner during emergencies.

According to the survey, the study plant fire prevention plans describe the type of fire protection equipment and/or systems. A local fire department in JOR hydroelectric power station is familiar with all facilities, location, and specific fire hazards in the plant. The plant has a fire alarm system, interior standpipes, valves and fire extinguishers certified as required by OSHA. The safety department and safety committee has enforced practices and procedures to control potential fire hazards and ignition sources as detailed in Table 4.6.

Table 4.6: Results of first-aid and fire-fighting equipment checklist

First-aid and fire-fighting equipment	Y	N	Comment
1. Do you have adequate first aid in powerhouse which can be used in emergency cases?	✓		
2. Are first aid kits easy to access for every one?	✓		
3. Do workers have training to know that how they use it in emergency cases?	✓		Yearly training for correct using of first aid for all workers
4. Are first-aid supplies replenished as they are used?	✓		Checked every 3 month and it has maintenance checklist
5. Is the local fire department acquainted with the facility and its specific hazards?	✓		
6. Are portable fire extinguishers provided in adequate number and type?	✓		
7. Do you have a fire prevention plan?	✓		Yearly ERP manual and drill
8. Does your plan describe the type of fire protection equipment and/or systems?	✓		
9. Have you established practices and procedures to control potential fire hazards and ignition sources?	✓		
10. Is your local fire department well acquainted with your facilities, location, and specific hazards?	✓		
11. If you have a fire alarm system, is it tested at least annually?	✓		Inspection every three months

Table 4.6, continued

12. If you have a fire alarm system, is it certified as required?	✓		
13. If you have interior standpipes and valves, are they inspected regularly?	✓		
14. Is maintenance of automatic sprinkler system assigned to responsible persons or to a sprinkler contractor?	✓		
15. Are fire extinguishers mounted in readily accessible locations?	✓		
16. Are fire extinguishers recharged regularly and noted on the inspection tag?	✓		Yearly check
17. Are employees periodically instructed in the use of extinguishers and fire protection procedures?	✓		

In this study the system has enough control of those hazards that probably have happened in the plant, so the controls can solve the problems; hence new hazards are appropriately controlled.

In many cases a combination of controls are needed to bring down risk to the required level (Smith, 2000). Risk management involves the process of preventing the risk from turning into an incident or trying to control the risk. In JOR hydroelectric power station as Table 4.7 shows, workers have been sufficiently informed about the hazards; orientation and training programs have been adapted to handle new situations and the JOR controlling methods result in workers working in a good condition without creating new hazard and reducing most of the hazards from the work environment.

Table 4.7: Method of control checklist

Methods of control	Y	N	Comment
1. Do you have an adequate control of those hazards that probably have happened?	✓		Enterprise resource planning
2. Have the controls solved the problem?	✓		
3. Is the risk posed by the original hazard contained?		✓	
4. Have any new hazards been created?		✓	
5. Are new hazards appropriately controlled?	✓		
6. Are monitoring processes adequate?	✓		
7. Have workers been adequately informed about the situation?	✓		
8. Have orientation and training programs been modified to deal with the new situation?	✓		
9. Do your controlling methods lead to workers doing their work in a good condition without creating new hazard?	✓		
10. Are workers under protection with the proper controlling method when they are exposing to hazard?	✓		
11. Do the control methods reduce or omit the hazard from the work environment?	✓		But not cover all hazard
12. Is there a proper procedure for storage and disposal of hazardous waste?	✓		Waste management procedure

4.1.2 Workplace inspection (observation and interview)

Periodic workplace inspections are important in the overall occupational health and safety program. An inspection checklist is an aid for making clear inspection responsibilities; it controls inspection activities and provides a report on these activities. Workplace inspections can aid in preventing injuries and illnesses. They enable identification and recording of hazards for subsequent correction. Planning, conducting, reporting and monitoring of inspections can be done by joint occupational health and safety committees.

In this study general observation has been conducted by applying Workplace inspection checklist (Appendix C), to help collect actual data and independent information with walking around and inspection followed OSH regulations from the Sultan Yusuf hydroelectric Power generation Plant (JOR Power Station) via direct observation, interview with the person in charge and workers, understanding of jobs and tasks, determining underlying cause of hazard to better assess and control the hazard and give the effective recommendation. Generally in this study, the Inspection checklist covers those workplace hazards missed by the hazard identification checklist in plant.

The checklist involved fourteen parameters and the result of the inspection carried out in the Sultan Yusuf hydroelectric Power generation Plant (JOR Power Station) is given as follows:

In this checklist, the worksite generally complied with Occupational safety and health administration (OSHA) that state required posters be displayed in prominent locations and safety signs/ warnings, summary of occupational illnesses and emergency telephone numbers are posted where appropriate; meanwhile combustible scrap, debris, and waste were stored safely and removed from work areas promptly (Table 4.8).

According to the Occupational Safety and Health Act 1994 part IV general duties of employers section fifteen subsection one mentioned that it is the duty of every employer to ensure the safety, health and welfare at work of all his employees; subsection two said without prejudice to the generality of subsection one the matter includes: providing and maintaining of the plant and keeping systems safe without risk to health, and making arrangements for ensuring safety (Laws of Malaysia, act 514, 2006).

Section sixteen of Act 1994 mentions that it shall be the duty of every employer and self employed person to prepare a written statement of his general policy. Regarding the observation conducted in the study area the manager and safety department agreed to all above statements and they had plans to keep their site under the standard requirement. But in fact there were some weak points in different parts of the underground power generation hall. For example, the underground power generation hall had only a main access tunnel and it poses danger for emergency cases, because if for any reason the access road is damaged no emergency exit is available for employee rescue; another problem observed was no prevention for metallic or conductive dust from entering or accumulation on the underground power generation hall or around electrical enclosures and equipment. Fortunately the management and safety officer were familiar with those problems and have plans to solve them in the near future (Laws of Malaysia, Act 514, 2006).

Table 4.8: Result of worksite general inspection checklist

WORKSITE GENERAL	(X) Requires Action			(O)Satisfactory
	Y	N	Condition	Comments
1. Are Occupational Safety and Health Administration (OSHA) and state required posters displayed in a prominent location?	✓		O	
2. Are safety signs/warnings posted where appropriate?	✓		O	
3. Are emergency telephone numbers posted where they can be found readily?	✓		O	
4. Is a first aid kit available and adequately stocked?	✓		O	
5. Is a substance abuse policy in place	✓		O	
6. Is the Summary of Occupational Illnesses posted?	✓		O	
7. Are emergency evacuation traffic routes identified?		✓	X	
8. Are all work areas clean and orderly?	✓		O	
9. Are combustible scrap, debris, and waste stored safely and removed from work areas promptly?	✓		O	There are separate stores for different waste material
10. Are adequate toilets and washing facilities provided?	✓		O	
11. Are toilets and wash areas clean and sanitary?	✓		O	
12. Are work areas adequately illuminated?	✓		O	
13. Are resources available to deal with very hot or very cold conditions (drinking water, lined gloves, insulated boots)?	✓		O	
14. Are work surfaces kept dry or appropriate means taken to assure the surfaces are slip-resistant?	✓		O	

Table 4.8, continued

15. Is metallic or conductive dust prevented from entering or accumulation on or around electrical enclosures or equipment?		✓	X	Need to install protection cover
16. Are work surfaces and grip surfaces safe when wet?	✓		O	
17. Do workers know the symptoms of heat cramps, heatstroke?		✓	X	

Training is one of the main programs for JOR hydroelectric power station management and safety department; according to Table 4.9 training is given to each newly assigned person to the job and initial training involves a comprehensive review of process, hazards and accidents associated with the task and instruction in the use of PPE and emergency equipment. All these parameters follow the OSHA regulation and TNB specific training plan. General observation has shown that training in the study area is at an acceptable level and employees are familiar with their duty in the system and this is a good point for the safety department has less accident record by workers mistake.

Table 4.9: Result of training inspection checklist

TRAINING	**(X) Requires Action**			**(O)Satisfactory**
	Y	**N**	**Condition**	**Comments**
1. Is training provided for each person newly assigned to a job?	✓		O	
2. Does initial training include a thorough review of hazards and accidents associated with the job?	✓		O	
3. Is adequate instruction in the use of personal protective equipment provided?	✓		O	
4. Is training for the use of emergency equipment provided?	✓		O	
5. Are workers knowledgeable in the "Right to Refuse" procedures?	✓		O	

Training is held regularly and staff should be updated with the latest program which safety department committee adjusts in case workers are knowledgeable in the "Right to Refuse" procedures.

Work process is a main parameter to help the investigator identify relevant hazard that may happen in the system. According to the occupational safety and health administration the process and Flow charts diagram illustrate how elements and processes interrelate in the system.

Based on study in JOR hydroelectric power station the work process is divided into the main categories of mechanical, electrical and administration; each part of the process has specific elements, therefore the safety committee has to be familiar with the process to select the best hazard identification method and identify all aspects and impacts of the work process (Table 4.10).

Table 4.10: Result of work processes checklist

WORK PROCESSES	**(X) Requires Action**			**(O)Satisfactory**
	Y	**N**	**Condition**	**Comments**
1. Are repetitive motion tasks properly paced and kept to a minimum?	✓		O	
2. Do joint committee members have access to material safety data sheets?	✓		O	
3. Are workers informed (by hazard signs and tags)?	✓		O	
4. Have all trucks, forklifts and other equipment been inspected and maintained?	✓		O	
5. Are lockout procedures followed?	✓		O	
6. Is ventilation equipment working effectively?	✓		O	
7. Is fume and dust collection hood properly adjusted?	✓		O	

Generally JOR hydroelectric safety department was knowledgeable about the process and their safety program tried to keep to a minimum and properly paced for repetitive motion tasks, check the process equipment frequently and keep all machinery and auxiliary in a good condition.

Record keeping in JOR hydro electric power station is in accordance with OSHA requirements, and safety department has a responsibility to keep all important documents, as well as, keeping employee, training, medical, accident records for the required moment. Table 4.11 shows some of the main record keeping items that are important in the study plant.

Table 4.11: Result of record keeping checklist

RECORD KEEPING	**(X) Requires Action**			**(O)Satisfactory**
	Y	**N**	**Condition**	**Comments**
1. Are medical records and exposure records maintained as required?	✓		O	
2. Are training records maintained in accordance with OSHA requirements?	✓		O	Some training has done under TNB safety department
3. Are employee records being maintained for the required time frames?	✓		O	
4. Are operating permits and records up-to-date?	✓		O	
5. Are procedures in place to maintain records and logs? a. Safety inspections b. Safety meeting minutes c. Accident investigations d. Emergency response drills	✓		O	All documents keep in safety section department

According to Duarte (2004), power plants and substations have been around for years and plant management have financial reasons to prevent accidents. Despite incentives to keep such plants safe, fires do occur within them, causing fatalities and huge losses.

In JOR hydroelectric power station management and safety department were aware from this type of hazards, therefore Fire emergency procedures followed the OSHA standard with fire response plan posted for each area and workers being familiar with the plan through drills held regularly. Fire extinguishers chosen for the type of fire most likely in that area and the management dedicated enough extinguishers to do the job with the location conspicuously marked; also all extinguishers are properly mounted and are easily accessible (Table 4.12).

Table 4.12: Result of fire emergency procedures checklist

FIRE EMERGENCY PROCEDURES	**(X) Requires Action**			**(O)Satisfactory**
	Y	**N**	**Condition**	**Comments**
1. Is there a clear fire response plan posted for each work area?	✓		O	
2. Do all workers know the plan?	✓		O	
3. Are drills held regularly?	✓		O	Yearly
4. Are fire extinguishers chosen for the type of fire most likely in that area?	✓		O	
5. Are there enough extinguishers present to do the job?	✓		O	
6. Are extinguisher locations conspicuously marked?	✓		O	
7. Are extinguishers properly mounted and easily accessible?	✓		O	
8. Are all extinguishers fully charged and operable?	✓		O	
9. Are special purpose extinguishers clearly marked?	✓		O	

Means of exit is important for JOR power station manager and safety officer, therefore the station on ground buildings and installations are equipped with enough exits to allow prompt escape in emergency case and all exits and exit routes are equipped with signs and emergency light. Following OSHA regulations, all exits need to be clearly designated; exit access should be such that they can be easily seen in case of emergencies; the signs must have no decorations, nor blocked by equipment which may impair visibility. Where exits are not immediately visible access must be marked by visible signs. Any passageway which may be mistaken for an exit, shall be identified by a sign "Not an Exit" or similar designation. An Exit sign with an arrow indicating the directions shall be placed in locations where the direction of travel to reach the nearest exit is not immediately apparent. As Table 4.13 shows all above statements applied in the study area and plant is following the regulation, but unfortunately after comprehensive observation, the underground power generation hall in JOR hydroelectric power station does not have any emergency exit route which creates hazard in a critical or emergency case; therefore the safety department should convince TNB headquarters about this serious parameter to solve the problem promptly before any loss.

Table 4.13: Result of means of exit checklist

MEANS OF EXIT	(X) Requires Action			(O)Satisfactory
	Y	N	Condition	Comments
1. Are there enough exits to allow prompt escape?	✓		X	Not for tunnel & underground area
2. Do employees have easy access to exits?	✓		O	In office building and control room
3. Are exits unlocked to allow egress?	✓		O	
4. Are exits clearly marked?	✓		O	
5. Are exits and exit routes equipped with emergency lighting?	✓		O	
6. Are doors that are required to serve as exits designed and constructed so that the way of exit travel is obvious and direct?	✓		O	
7. Are exit doors openable from the direction of exit travel without the use of a key or any special knowledge or effort, when the building is occupied?	✓		O	

According to OSHA Standards for Workplace Lighting, injuries resulting from poor workplace lighting happen often in various workplace conditions. Poor or wrong lighting may cause eye strain and severe headaches. The Federal Occupational Safety and Health Administration (OSHA) has devised lighting safety standards. Management or employers must consider many factors including the scope of work, the environment, day and night lighting requirements, glare or reflections from other light sources or external light. The workplace is evaluated for hazardous situations and risks to identify where extra lighting may prevent accidents (Table 4.14).

Table 4.14: Result of lighting checklist

LIGHTING	(X) Requires Action			(O)Satisfactory
	Y	N	Condition	Comments
1. Does lighting produce glare on work surfaces?	✓		O	
2. Is the level of light adequate for safe and comfortable performance of work?	✓		O	
3. Is emergency lighting adequate and regularly tested?	✓		O	Electrical maintenance provided
4. Is emergency lighting provided, with an independent power source which activates automatically when normal lighting fails?	✓		O	

General lighting will depend on the building or work space; in many cases ceiling lighting might suffice. General workplace lighting also includes access lighting in stairways and hallways. General lighting should provide the needed light for safe movement around the whole workplace. Some areas require more lighting than others if they are windowless or lack external light sources. Task lighting is a more focused light to aid workers in carrying out their jobs safely and avoid eye strain or glare; it may be needed for those sitting at desks, working at a machine or working in rooms without natural light sources.

The OSHA Standards make Emergency lighting mandatory, and such lighting will also be inspected regularly by a fire marshal. Emergency lights facilitate exit from the workplace in an emergency and are mandatory in work areas, halls and stairwells. These lights are turned on during a power outage and also when the fire alarm activates. Exits must have lighted exit signs and emergency lighting to provide safe exit from the workplace during emergencies.

With regard to the above requirements, lighting was found to be sufficient in JOR power station; the lighting level is satisfactory for safe and comfortable work performance, emergency lights adequate and regularly tested and an independent power source is available which kicks in automatically upon loss of normal lighting.

As Table 4.15 shows machine guards in the study area were in good condition and all dangerous machine parts were adequately guarded. According to OSHA standard, machine guarding shall be used for protecting the machine operator and other workers from operational hazards. Barrier guards, two-hand tripping devices, as well as electronic safety devices are some examples of guarding methods.

Table 4.15: Result of machine guards checklist

MACHINE GUARDS	**(X) Requires Action**			**(O)Satisfactory**
	Y	**N**	**Condition**	**Comments**
1. Are all dangerous machine parts adequately guarded?	✓		O	
2. Do machine guards meet standards?	✓		O	OSHA standard
3. Are lockout procedures followed when performing maintenance with guards removed?	✓		O	Maintenance do after they get permit to work

At JOR power plant, tools and machinery are well designed and kept in high maintenance; defective tools were tagged and removed from service as part of a regular maintenance program and employees are familiar with the tools and machinery in their working area. Management and safety department were satisfied with the guarding, tools and machinery according to their documents and reports which showed less injury from these sources (Table 4.16).

Table 4.16: Result of tools and machinery checklist

TOOLS AND MACHINERY	(X) Requires Action			(O)Satisfactory
	Y	N	Condition	Comments
1. Are manufacturers' manuals kept for all tools and machinery?	✓		O	
2. Do power tools conform to standards?	✓		O	They have standard license
3. Are tools properly designed for use by employees?	✓		O	
4. Are defective tools tagged and removed from service as part of a regular maintenance program?	✓		O	
5. Are tools and machinery used so as to avoid electrical hazards?	✓		O	
6. Is proper training given in the safe use of tools and machinery?	✓		X	Not for all machinery & tools

In this study, confined space in JOR underground hydroelectric power station included the power station hall, transformers, and ventilation rooms, as well as, tail race tunnel. According to Table 4.17 adequate ventilation was available in the confined space, and the air inside it was tested or repeatedly monitored during the work process; this illustrated that the confined space ventilation followed OSHA indoor air quality standard, and it had adequate illumination for confined space. Besides that, an assigned safety employee was posted outside the confined space, responsible for monitoring the work in progress and sounding the alarm in emergencies or rendering help when needed. Regarding the safety officer reports, the important activity in confined space is checked for possible toxic industrial waste.

Table 4.17: Result of confine spaces checklist

CONFINED SPACES		(X) Requires Action			(O)Satisfactory
		Y	N	Condition	Comments
1.	Are entry and exit procedures available and adequate?	✓		X	
2.	Are emergency and rescue procedures in place (e.g. trained safety watchers)?	✓		O	
3.	Is adequate ventilation provided prior to and during confined space entry?	✓		O	
4.	Is the atmosphere inside the confined space frequently tested or continuously monitored during work?	✓		O	
5.	Is adequate illumination provided in confined spaces?	✓		O	
6.	Is approved respiratory equipment required if the atmosphere inside the confined space cannot be made acceptable?	✓		X	There is, but not enough in place
7.	Is there an assigned safety standby employee outside of the confined space, whose sole responsibility is to watch the work in progress, sound an alarm if necessary, and render assistance?	✓		O	
8.	Is each confined space checked for decaying vegetation or animal matter, which may produce methane?	✓		O	
9.	Is the confined space checked for possible industrial waste, which could contain toxic properties?	✓		O	Control by waste management program

Housekeeping in JOR hydroelectric station is considered to be at an acceptable level; as Table 4.18 shows the work area was clean and aisles and passageways kept clear of obstructions, appropriate and convenience storage racks were provided for tools, raw materials, parts and wastes, but sometimes oil spills and other slips, trips and falls hazards created problems for housekeeping and they do not promptly clean up or remove them, which wastes time and money. To solve or prevent problems the supervisor should make his observation and not allow grease and dirt to build up in the system, check the labelling of all materials and containers, report deficiencies in the work area to the safety department; and try to fix them before any injury happens besides ensuring wastes are thrown away immediately and properly.

Table 4.18: Result of housekeeping checklist

HOUSEKEEPING	**(X) Requires Action**			**(O)Satisfactory**
	Y	**N**	**Condition**	**Comments**
1. Is the work area clean and orderly?	✓		O	
2. Are floors free from protruding nails, splinters, holes and loose boards?	✓		O	
3. Are aisles and passageways kept clear of obstructions?	✓		O	
4. Are permanent aisles and passageways clearly marked?	✓		O	
5. Are covers or guardrails in place around open pits, tanks and ditches?	✓		O	
6. Are appropriate and convenient storage racks provided for tools, raw materials, parts and products?	✓		O	
7. Are oil spills and other 'slips, trips and falls' hazards promptly cleaned up or removed?		✓	X	
8. Are there enough waste receptacles or containers of adequate size?	✓		O	
9. Is there provision for proper drainage of waste water or other liquids?	✓		O	

Sound level/noise in underground is an important parameter in JOR power station and employees are exposed to noise below 85dBA, in compliance with OSHA noise standard. McManus (2011) said steady-state noise from generators and other sources could exceed mandated limits. According to the OSHA noise exposure standard average noise levels of 85 dB or greater during an 8 hour workday are hazardous for workers. Determination of exposure means monitoring of workplace actual noise levels to estimate the noise exposure to employees during the workday. If significant adaptations in equipment or processes that may increase noise levels occur, remonitoring must be done to ascertain whether more employees need to undergo hearing conservation programs. Generally it is adequate to remonitor every year or every two years to ensure that all exposed employees are included in their hearing conservation programs (Table 4.19).

Table 4.19: Result of sound level/noise checklist

SOUND LEVEL/NOISE	(X) Requires Action			(O)Satisfactory
	Y	N	Condition	Comments
1. Are noise levels being measured using a sound level meter or an octave band analyzer and records being kept?	✓		O	It is under OSHA
2. Have you tried isolating noisy machinery from the rest of your operation?		✓	X	Can't do it, but prepare PPE for workers
3. Have engineering controls been used to reduce excessive noise levels?	✓		O	Checking the machinery frequently
4. Where engineering controls are determined not feasible, are administrative controls (i.e., worker rotation) being used to minimize individual employee exposure to noise?	✓		O	

Table 4.19, continued

5. Is there an ongoing preventive health program to educate employees in safe levels of noise and exposure, effects of noise on their health, and use of personal protection?		✓	X	
6. Is the training repeated annually for employees exposed to continuous noise above 85 dBA?	✓		O	
7. Have work areas where noise levels make voice communication between employees difficult been identified and posted?		✓	X	
8. Is approved hearing protective equipment (noise attenuating devices) available to every employee working in areas where continuous noise levels exceed 85 dBA?	✓		O	
9. If you use ear protectors, are employees properly fitted and instructed in their use and care?	✓		O	
10. Are employees exposed to continuous noise above 85 dBA given periodic audiometric testing to ensure that you have an effective hearing protection system?	✓		O	
11. Is protection against the effects of occupational noise exposure provided when sound levels exceed those of the Cal/OSHA noise standard?	✓		O	System is under OSHA observation

In JOR power station, engineering control has been used to reduce excessive noise levels and if it determined not feasible administrative control been used, with individual employee exposure to the noise also approved hearing protective equipment (noise attenuating devices) available to every employee and there is a periodic audiometric testing to ensure effective hearing protection therefore the working atmosphere is under safety department control and noise level is under standard level.

In this study, employees' facilities are kept clean and sanitary and in good condition; their resting area is isolated from the chemical component, switchyard and power house area. According to Au Yong (2009), OSH hazards are controlled a hierarchy; first by eliminating the hazard, followed by substitution, engineering controls, administrative controls and personal protective equipment (PPE)(Table 4.20).

Table 4.20: Result of employee facilities checklist

EMPLOYEE FACILITIES	(X) Requires Action			(O)Satisfactory
	Y	N	Condition	Comments
1. Are facilities kept clean and sanitary?	✓		O	Its under industrial hygiene control
2. Are facilities in good repair?	✓		O	
3. Are cafeteria facilities provided away from toxic chemicals?	✓		O	

In JOR hydroelectric power station, personal protective equipment is reliable and meets requirements. All PPE are under the DOSH control and warning signs of PPE are clearly displayed in all hazard areas. While every PPE are provided, observation in the underground station showed that there were inadequate respirators for emergency cases and this must be resolved to reduce harm to employees' health. Both employer and worker must be aware that PPE has its limitations. While employers are expected to require workers to use the equipment when required, they must ensure the PPE is working properly. Otherwise, PPE may give workers a false sense of protection Table 4.21 shows some of the important parameters which need to apply for PPE in the plant.

Table 4.21: Result of (PPE) checklist

PERSONAL PROTECTIVE EQUIPMENT	(X) Requires Action			(O)Satisfactory
	Y	**N**	**Condition**	**Comments**
1. Is required equipment provided, maintained and used?	✓		O	
2. Does equipment meet requirements and is it reliable?	✓		O	All PPE equipment follow DOSH specification
3. Are protective gloves, aprons, shields, or other means provided?	✓		O	
4. Are hard hats provided and worn where danger of falling objects exists?	✓		O	
5. Is appropriate foot protection required where there is the risk of foot injuries from hot, corrosive, poisonous substances, falling objects, crushing or penetrating actions?	✓		O	
6. Are approved respirators provided for regular or emergency use where needed?	✓		X	It is not adequate on power generation hall
7. Is all protective equipment maintained in a sanitary condition and ready for use?	✓		O	
8. Where special equipment is needed for electrical workers, is it available?	✓		O	
9. When lunches are eaten on the premises, are they eaten in areas where there is no exposure to toxic materials or other health hazards?	✓		O	The place is outside of station area
10. Is personal protection utilized only when it is not reasonably practicable to eliminate or control the hazardous substance or process?	✓		O	
11. Are warning signs prominently displayed in all hazard areas?	✓		O	

4.1.3 Job hazard analysis and Accident investigations

The main purpose of JHA is to focus on job tasks, break a job task into separate steps, evaluate the hazards related with each step and finally determine the appropriate controls. Regarding OSHA Job Hazard Analysis, JHA focuses on the relationship between the worker, the task, the tools, and the work environment. For this study JHA conducted to the following types of jobs in JOR hydro electric Power Station plant: Jobs with the highest injury or illness rates; Jobs with potential to result in severe or disabling injuries or illness, even without history of previous accidents; Jobs where a simple human error could generate severe accident or injury; Jobs that are new to the operation or have undergone changes in processes and procedures; and complex jobs requiring written instructions.

According to JHA checklist (Appendix E), Table 4.22 shows the result of Job Hazard Analysis in the JOR hydroelectric power station plant.

Table 4.22: Result of Job Hazard Analysis checklist

Job Task	Hazard	Consequences
Greasing over crane	Slippery & fall from the height place	Head, leg and hand injury
Lifting the stack	Heavy component weight	Backache, wrist and ankle twisting
Mixing and shifting chemical component	Chemical exposure	Eyes and skin irritation, inhalation problem
Miscommunication between the operator in control room and the maintenance part in site during the maintenance	Splashing and spilling water and oil, contact online life	Body injury, damaging the machinery
Loading heavy component with crane	Falling over workers or facilities	Body injury and damage the system

Accident investigation was the last parameter selected to identify hazards before assessing the risks in the study area. By OSH definition, “accident” is an unanticipated event that prevents completion of an activity, and that may (or may not) involve property damage or injury. Regarding conducted survey in Sultan Yusuf hydroelectric Power generation Plant (JOR Power Station) causes to examine a workplace accident consist of different parameters. The most important is to identify the cause of accident and to prevent similar accidents in future via accomplishing any legal requirements and safety training; the cost of an accident is another parameter that encourage manager to find the root cause of accident to reduce the cost and the last one was workers life as well as workers' compensation claims (Appendix F).

Generally looking at JOR power station accident investigation documents shows this station has not had many accident cases during the past years and this can be attributed to the company safety department proper planning and performance.

Table 4.23, shows the result of Accident investigation survey from the beginning of operation phase in the Sultan Yusuf hydroelectric Power generation plant. .

Table 4.23: Result of Accident Investigation Checklist

Accident	Consequences
Slip on the floor during housekeeping at the turbine basement	Foot injury, Ankle twist and sprain
Hand injury during the overhauling and maintenance of turbine and draft tube	Fingers bruising and nail injury
Death of a contractor worker during the developing of switchyard area due to land slide of small hill and carelessness of bulldozer driver	Death

4.2 RISK ASSESSMENT AT SULTAN YUSUF HYDROELECTRIC POWER GENERATION PLANT (JOR POWER STATION)

General duty of department of safety in Sultan Yusuf hydroelectric Power generation Plant (JOR Power Station) is to ensure the safety and health of employees as well as safety of process and equipment in every aspect related to the work environment. Therefore risk assessment is a main parameter to evaluate the risks by prioritizing action for better control and mitigation of hazards, furthermore preventive action is considered to be effective and implemented following a risk assessment, providing improvement in the level of equipment and employee protection.

4.2.1 Risk matrix ranking

One of the most common risk assessment tools to evaluate risk is risk matrix ranking which includes consequence, likelihood and severity axis, so the combination of these parameters give us an estimate of risk or a risk ranking. According to the study, to evaluate the risk matrix we need basic information of hazards and its consequences, therefore based on comprehensive observation and data collection of Sultan Yusuf hydroelectric Power generation Plant (JOR Power Station) the following data were analyzed under Hazard Identification, Risk Assessment and Risk Control (HIRARC) framework to evaluate risks and mitigate hazard. Table 4.24 shows the result of (HIRARC) in the JOR hydroelectric Power Station plant.

Table 4.24: Result of applied (HIRARC) in JOR hydroelectric power station

Activities	Hazard Identification			Risk Assessment		
	Hazard	Consequences	Risk Control	L	S	R
Measuring and changing chemical component in transformer and cooling system	Chemical oil exposure	Inhalation and skin irritation	PPE with providing respiratory system, clothes and gloves	2	3	6(M)
Running the ventilation system in process	Failing of the ventilation system / chemical exposure	Breathing problems, eye irritation	PPE with providing respiratory equipment. Administrative control with proper investigation	1	4	4(L)
Lack of written standard operation procedures for the selection and use of respirators	Using the auxiliary equipment in a wrong way by employee	Health hazard and body injury	AD control with installing proper written standard operation and enough training	2	1	2(L)
L = Likelihood	S = Severity	R = Risk				

Table 4.24,continued

Lack of written standard operation procedures for the selection and use of respirators	Using the auxiliary equipment in a wrong way by employee	Health hazard and body injury	AD control with installing proper written standard operation and enough training	2	1	2(L)
Maintenance of generator brakes, pipe and electrical insulation	Exposure to Asbestos and chemical component	Inhalation and skin irritation	PPE by providing respiratory protection and medical surveillance	2	2	4(L)
Running of cooling system and oil supply tank	Leaking of lubrication and oil supply in cooling system	Environmental pollution,water contamination	Engineering control with high maintenance	4	4	16(H)
Fixing or checking of transformer, switchyard auxiliary and also switchyard activity	Contact direct or indirect of person with parts which have become live under faulty condition	Nerve system problem, electric shock, blood cancer or death	PPE control by providing safety boots, clothes and gloves, AD control with putting awareness labeling	2	5	10(M)

Table 4.24,continued

Overloading or short circuits in running generator and it auxiliary	Thermal radiation (heat) or the projection of molten particles	Damaging the system and equipment, body injury such as skin and eye problems	AD control regularly observation and high maintenance, PPE with providing safety clothes and glasses	2	2	4(L)
Operating of bushing device in switchyard	Failing of bushing due to partial discharge degradation in insulation under high voltage stress	Damaging the transformer and other switchyard equipment. A costly extended outage is the result, health hazard	AD control by examining the bushings frequently and giving enough information to the workers	2	3	6(M)
Operating of circuit breaker in switchyard	Create hazard due to not cutting off the power supply in the event of overloading and short circuit	Damaging the transformer, bushing, wires and make cost, also electrical shock hazard for workers	Engineering control with providing high maintenance, AD control with checking the system and give aware and enough information to employee	2	3	6(M)

Table 4.24, continued

Running of the whole switchyard system and it auxiliary	High voltage electricity and it radiation	Leukemia, brain cancer, dizziness and negative environmental impact	Engineering control with designing and installing a suitable radiation barrier, PPE with safety clothes, cloves, AD control with installing announcement	1	4	4(L)
Crane operating with carrying loads over employees and system	Failing the heavy items	Body injury and damaging the equipment	PPE with wearing the safety boots and hat, AD control with giving the proper instruction to crane operator and workers, and checking the crane frequently. Engineering control with designing safety guard for equipment	1	4	4(L)
Fixing and maintenance of draft tube	Drowning, falling and no enough space for fixing	Hand and leg injury	PPE with wearing the safety boots, gloves and life vest, Engineering control by designing the safety guard and creating enough space for fixing	2	2	4(L)

Table 4.24,continued

Fixing and maintenance of draft tube	Drowning, falling and no enough space for fixing	Hand and leg injury	PPE with wearing the safety boots, gloves and life vest, Engineering control by designing the safety guard and creating enough space for fixing	2	2	4(L)
Using of power generation house access gallery and tunnels (inlet, tailrace...)	Collapsing and blocking cause by swelling clay, ageing, land slide or water pressure	Workers imprisonment, health hazard, system and equipment are in sinking danger, electrical sparking, explosion	Engineering control with designing emergency exit tunnel for workers and water AD control by checking the tunnels frequently and keep it in high maintenance, providing emergency mobile oxygen cylinder for workers	1	5	5(M)
Running the turbine shaft	Breaking or cavitation on shovels	Damage the system and incur cost	Engineering control with keeping in high quality maintenance	1	2	2(L)

Table 4.24,continued

Operating the generator	Failing of rotor caused by short circuit, increasing the temperature by failing of cooling system and overloading	Burning of copper coil, catching fire, and make cost	Engineering control by checking the system in a good condition	2	3	6(M)
Using hand tools or hand parts or objects with employees, (gripping, pulling…)	Ergonomic hazard by extra forces with their hand and body	Hand sprained and body cramp, hand injury and twisting	AD control with giving announcement to workers and applying machine to settle work, PPE with offering gloves	3	3	9(M)
Lifting and carrying of semi or heavy items	Goods weight and Ergonomic hazard by musculoskeletal	Waist pain, shoulder, knee pain and leg injury	Engineering control with using forklift mechanical machine, AD control with giving hygiene information to workers and do medical surveillance	4	3	12(M)

Table 4.24,continued

Working of employees in confined space	Biological hazard with oxygen deficiency	Inhalation problem, increase the blood pressure, dizziness and fainting	PPE with applying moiling oxygen cylinder, respiratory equipment, AD control with medical checkup, and give useful information, Engineering control with designing suitable ventilation system	2	2	4(L)
Running the generator, transformer, heat exchangers	Discharging heat air in to the power house and make biological heat hazard	Heat stress, heat cramps, skin rashes	engineering control with controlling the cooling and ventilation system, AD control with doing indoor air quality frequently, medical surveillance	1	2	2(L)
Running the whole system	Biological hazard with noise pollution and vibration	Hearing loss, cardiovascular effect and nerve problem	PPE with using ear block, AD control with checking noise level of workplace, Engineering control with fixing some parameters and equipment to reducing vibration	1	2	2(L)

Table 4.24,continued

Employee activities such as working position and working schedule	Physiological and psychological stresses	Muscle ache, shortness of breath, headaches, high blood pressure, depression, defensiveness and poor job performance	AD control with applying different program to release job stress, medical checkup frequently and set the suitable shift schedule	2	3	6(M)
No covering the underground entrance access tunnel and all exit way	Biological and mechanical hazard by entering birds and animals, also accumulation of conductive dust & sand	Inhalation problem, increasing CO and methane, damaging the transformer and generator rotor	AD control with give proper announcement to workers and medical surveillance, Engineering control with installing suitable gate or fence	4	2	8(M)
Influence of sediment in operating system specially cooling system and turbine	Blocking and damaging the cooling system and its filter, damage turbine propeller, stuck sediment in pipe and draft tube	Increasing maintenance cost, flashback of water and sinking the equipment	Administrative control by controlling the amount of sediment, Engineering control with keeping the system in high maintenance	3	3	6(M)

Table 4.24,continued

Climb up from crane stair	Falling down	Body injury	Engineering control with designing monkey cage, AD control with toolbox talk	2	3	6(M)
Greasing over crane	Slippery and fall down	Body injury	Engineering control with fixing barrier and AD control, toolbox talk	2	3	6(M)
Greasing over crane	Fall in grease tank	Head injury	PPE control with offering toe board, safety helmet, AD control via toolbox talk	1	3	3(L)
Greasing the crane sling wire	Slippery and fall down	Body injury	AD control toolbox talk	2	1	2(L)
Greasing the crane sling wire	Grease splashing	Effect on body and skin	PPE with wearing safety clothes, gloves, helmet and AD control with toolbox talk	2	1	2(L)
Greasing the crane sling wire	Trapped during the drum rotating	Body injury	AD control via toolbox talk	1	3	3(L)
Installing, cleaning and opening air hose (JOR turbine)	Ergonomic hazard with get involved wind hose	Body injury, hand, shoulder and leg injury	PPE control with applying cotton glove and safety boots	2	2	4(L)

Table 4.24,continued

Flushing cooler system (Jor turbine)	Mixing the sludge, water with chemical component	Skin irritation	PPE control by using rubber gloves and safety boots	2	2	4(L)
Flushing cooler system (Jor turbine)	Physical hazard with liberated water compressed	Splash on body	PPE with wearing safety boots	2	2	4(L)
Open and close valve (JOR turbine)	Physical hazard by using ladder and falling	Body injury	PPE control with wearing cotton gloves and safety boots	2	2	4(L)
Open and close valve (JOR turbine)	Ergonomic hazard with working in high place without good condition and fall	Hand and leg injury, Backache, mussel stretching , neck ache	AD control by toolbox talk, PPE with wearing cotton gloves and safety boots	2	2	4(L)
Mopping the floor	Using chemical cleaner	Skin irritation and inhalation problem	PPE control with using rubber gloves, safety boots and mask	2	2	4(L)
Measuring chemical material	spilling chemical material and inhalation chemical fumes	Breathing channel and hand irritation	PPE with using sheath latex hand, providing respirator and chamber fumes	2	1	2(L)

Table 4.24, continued

Measuring and mixing chemical material	Ergonomic hazard associated with standing in the work area for a long time	Leg pain	AD control with preventing from working and standing for a long time	2	1	2(L)
Mixing chemical material	Physical hazard with mixture splashing and spilling and cause slippery floor	Body and eye irritation, falling down and leg, hand sprain	AD control with providing electrical mixture tool, PPE with using safety glasses and latex boots	2	1	2(L)
Shifting chemical material into the injection container	Mixture spilling and contact online life	Body injury and electric shock	AD control with providing suction tool and monthly inspection	2	1	2(L)
Downloading and lifting the stack	Ergonomic hazard, Goods weight	Hand injury, stack and twisting	Engineering control by using truck / forklift, PPE control by providing hand sheath	1	4	4(L)
Downloading and lifting the stack	Physical hazard by falling goods	Leg and hand injury	PPE with using safety boots, gloves and helmet	1	3	3(L)

Based on the results of HIRARC in the Sultan Yusuf Hydroelectric Power generation Plant (JOR Power Station), risk assessment and risk control were then ranked according to priority. The following list is some of the main ranking from the highest risk ranking to lowest risk ranking.

1. Chemical hazard by leaking of lubrication and oil supply in cooling system and transformer
2. Ergonomic hazard, goods weight, downloading and lifting the stack
3. Electrical hazard contact direct or indirect of employees with parts have become live under faulty condition during fixing or checking of transformer and switchyard auxiliary
4. Ergonomic hazard with using hand tools or hand parts or objective and extra forces by hand and body
5. Biological hazard by entering birds and animals, accumulation of conductive dust in power house access tunnel and power house hall
6. Chemical hazard via oil exposure during measuring and changing chemical
7. Physical hazard by slippery and falling down caused by climb up from crane stair and greasing over crane
8. Electrical hazard with failing of bushing device in switchyard due to partial discharge degradation under high voltage stress
9. Electrical hazard by failing circuit breaker due to not cutting off the power supply in the event of overloading and short circuit
10. Physical hazard with blocking and damaging the cooling system filter, turbine propeller, draft tube and pipes by high amount of sediment
11. Ergonomic hazard by physiological and psychosocial stresses relevant to employee activity
12. Electrical hazard by failing rotor in generator caused by short circuit

13. Physical hazard by falling to open and close valves in turbine with using ladder
14. Physical hazard with liberated water compressed due to flushing cooler system cause body injury
15. Biological hazard of oxygen deficiency cause by working in confined space

Data collection from Sultan Yusuf Hydroelectric Power Generation Plant (JOR Power Station) was included; data were obtained by walking survey, interviewing, hazard checklist, accident and Job hazard analysis checklist to identify hazards. According to table 4.24 with consideration of hazard items (low risk 27, medium risk 13, high risk 1) Identifying hazard indicates that, total 41 important hazard items identified in system and assessed by Checklist Analysis Technique. The result is classified in 3 levels with 3 degrees of hazard follow the methodology of risk assessment. The result of risk assessment is presented in percentage of number of items as shown in Figure 4.1.

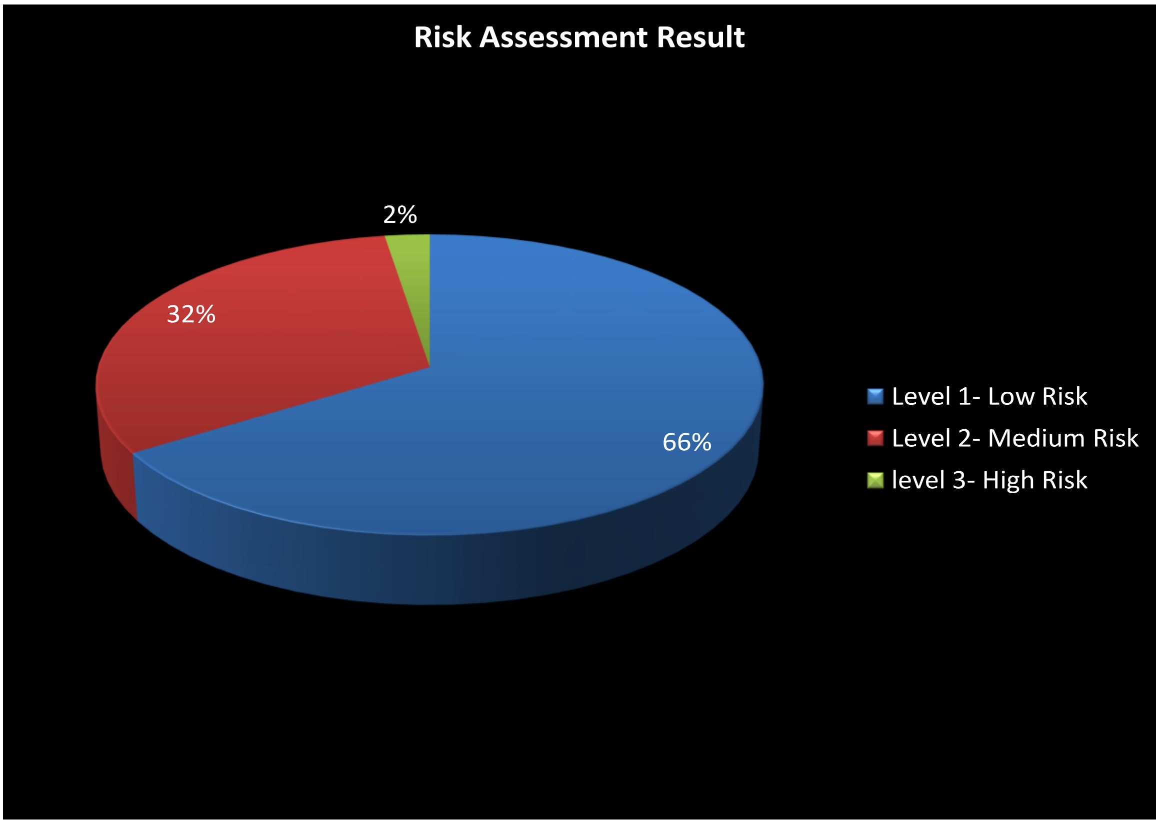


Figure 4.1: Percentage of three risk levels in the JOR power generation plant

Generally safety is important for JOR hydroelectric power station management and safety department, so there is an acceptable safety policy to implement safety and health program in Sultan Yusuf Hydroelectric Power Generation Plant. Staying safe at work means understanding hazards; some hazards form part of the job, like some mechanical equipment, extreme noise, or hazardous chemicals. Others may be due to human error, structural failures, equipment or machinery failure or misuse, power system failure or chemical spills.

Therefore to better understand and prevent the hazard in the workplace, the manager or safety officer should have suitable information about the priority of main hazard in the system. Based on HIRARC study Table 4.24 and data collection from JOR hydroelectric power station, out of the total 41 important hazards the main hazards were identified as physical, chemical, electrical, biological and ergonomic by 15, 7, 4, 9 and 6 categories respectively. The result is classified based in five items to identify the priority of hazard to implement prevention and control. The result of hazard classification is present in percentage of number of items as shown in Figure 4.2.

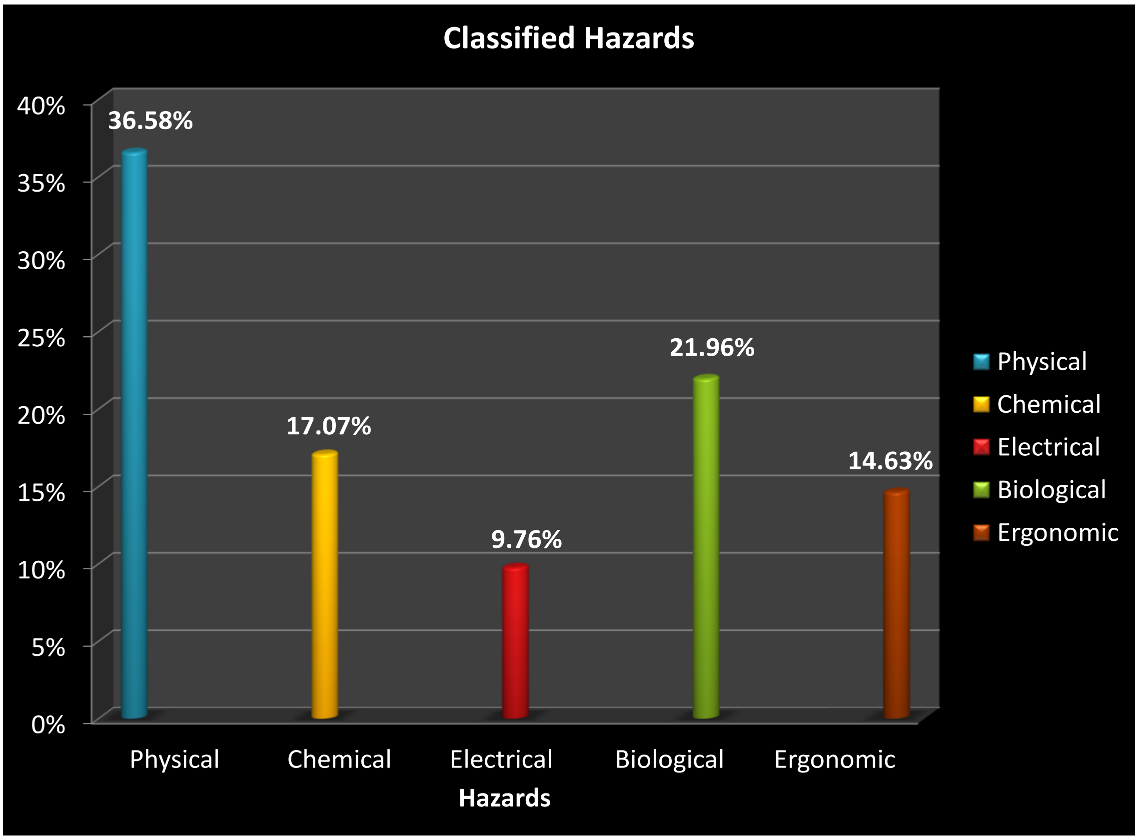


Figure 4.2: Percentage of five main classified hazards, result in JOR power plant

The result of bar chart based on the findings shows that physical hazard at 36.58% is the main hazard which safety department and safety manager should consider and find the best way to identify root cause, prevent and control method; following that is biological hazard that form 21.96% of hazard in the power station studied. Chemical and ergonomic hazard are the other main hazards in JOR hydroelectric power station with 17.07% and 14.63% respectively for each hazard of total percentage; and only 9.76% electrical hazard in JOR power station shows that electrical hazard is the minimum hazard in the study area.

There is a question for this section regarding the risk matrix analysis; what are the percentages of risk levels for each specific hazard in the system?

As Figure 4.1 shows 66% of total risk relevant to low level of risk in addition 32% of that total risk is considered as medium risk as well as 2% of high level of risk which is a minimum percentage of total risk in the study area.

Regarding to the data that has been collected from JOR hydroelectric power station Table 4.24 and risk matrix ranking Table 3.3, Figure 4.3, illustrates the result of classified risk levels for each specific hazard of risk assessment based on details in (Appendix G).

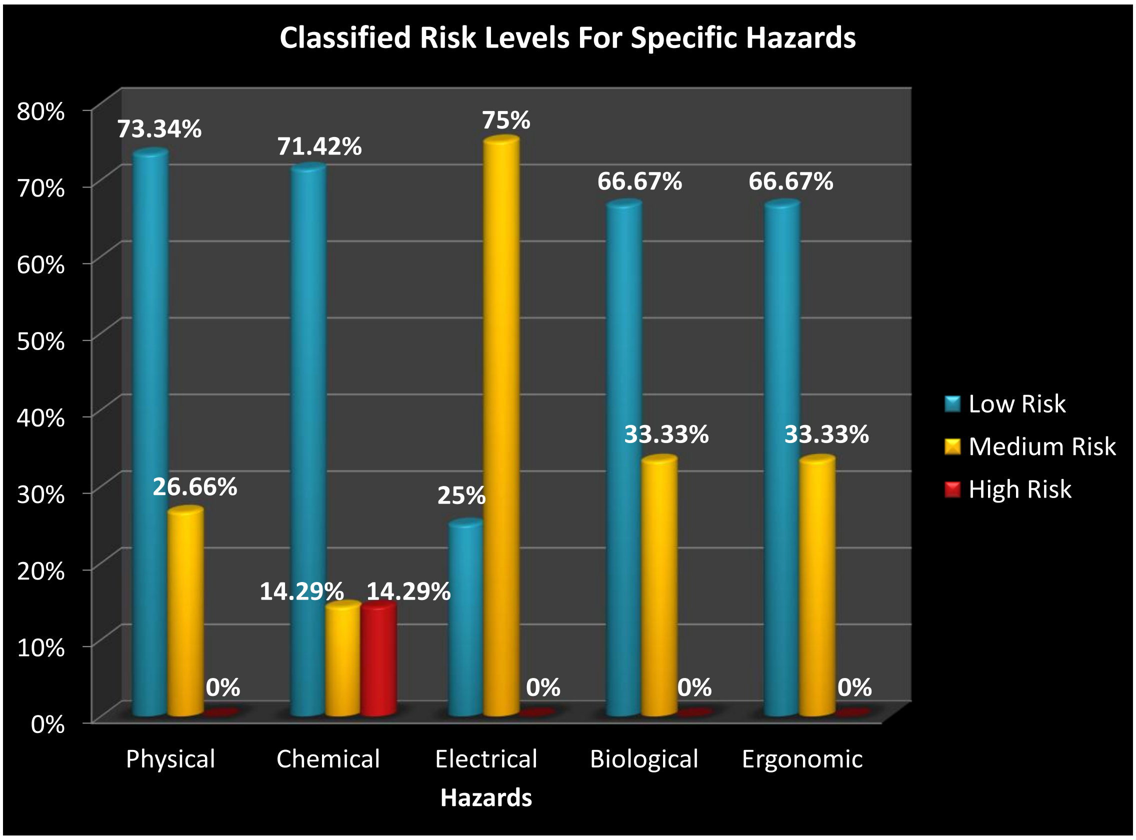


Figure 4.3: Classified three risk levels result for five main hazards in JOR hydroelectric power generation plant

According to Figure 4.3, the result of classified risk levels for each specific hazard in the Sultan Yusuf Hydroelectric Power generation Plant indicates 73.34% low risk, 26.66% medium risk and no high risk from the total 36.58% of physical hazard, chemical hazard with 17.07% of total hazard and 71.42% of this amount of hazard is in low risk condition, 14.29% belong to medium risk and 14.29% of high risk, is one of the main important hazard in purpose study area. The electrical hazard allocate 9.76% of total hazards presented as a lowest hazard in JOR hydroelectric power plant including 25% of low risk, 75% of medium risk and 0% of high risk in the system; 21.96% of biological hazard with 66.67% of low risk, 33.33% of medium risk and 0% of high risk was identified and finally ergonomic hazard with 66.67% of low risk, 33.33% of medium risk and no high risk from the total 14.63% of hazard. Generally above data present all hazards and their classified levels of risks in the Sultan Yusuf hydroelectric Power generation Plant.

4.3 WASTES – RELATED RISKS AT SULTAN YUSUF HYDROELECTRIC POWER GENERATION PLANT (JOR POWER STATION)

Regarding the study conducted through survey and interview, waste is everything that has negative impact on environment (water and soil quality, surrounding fauna and flora ecosystem) and human health in the JOR hydroelectric power station. Industrial waste is defined as waste generated by manufacturing or industrial processes, and it is divided into hazardous and non-hazardous waste. Industrial waste may be toxic, combustible, corrosive or reactive. A comprehensive observation in this study showed the type of waste in the Sultan Yusuf hydroelectric power generation plant included contaminated rags such as lubrication oil, grease and unused battery, used bulk, as well as clinical wastes. The result in Table 4.25 shows the main wastes and their hazards which identified in the JOR hydroelectric power station.

The above wastes were distinguished as main wastes in JOR power station, therefore management and safety department designed and have been implementing the waste management procedure to be guide during disposal the domestic and scheduled wastes. The procedure was developed refer to the scheduled waste regulation 2005 under Environmental Quality Act. In this study waste management is utilized to reduce risk by control wastes in Sultan Yusuf hydroelectric power generation plant (JOR Power Station).

Table 4.25: Wastes-related hazards in the JOR power station

Waste	Activities	Hazards
Lubrication oil	Produced from the cooling system and transformer in the hydroelectric power station	Chemical hazard such as water and soil contamination in environment, biological hazard for employees who come in contact with the chemical component.
Grease	Mostly used in the crane system, forklift, transformer, switchyard and reclamation or repairing of different parts of machinery.	Chemical hazard such as eyes and skin contamination, physical hazard by falling down the employees cause by slippery floor.
Battery	A magnetic field is maintained in the windings of the rotor in the generator; the power for this field is provided by banks of lead- acid or caustic- filled nickel cadmium batteries. Also the storage of usage and unused battery can cause hazards.	Chemical hazard such as soil contamination, explosion and biological hazard such as inhalation problem, itching and skin corrosion
Used Bulk	Keeping unnecessary or used materials such as wires, lamps, timber also the out of service of mechanical, electrical and their auxiliary equipments.	Physical hazard for example body injury, damaging the process and running equipment, taking space.
Clinical waste	Any waste that is generated in the diagnosis, treatment, or immunization of JOR power station stuff and those people who involved with power plant.	Biological hazards by air contamination, disease spread by direct or in direct contact, leaking leachate cause soil and water contamination.

Based on flowchart in Figure 4.4, and initial interview the JOR power station has provided a classified system to identify, manage and control wastes by starting to identify waste from waste generators as well as segregating waste into hazardous and non-hazardous components.

Hazardous waste is considered as scheduled waste, therefore the type of schedule waste should be identified and as an announcement, notified to department of environment (DOE), inventory of hazardous component help to better storing of materials. Store of hazardous component in JOR power station is in suitable and safe area with minimum risk for system and environment. The store should be safe, limited, labeled and the containers have to be durable. Disposing of scheduled waste is the next stage of managing hazardous components, disposing of schedule waste from the plant should be in high level of standard, the contractor, facilities and transportations have to have valuable license follow scheduled waste regulation 2005 under the Environmental Quality Act, provided information and issue consignment note of hazardous component for transporting, beside observation and assist the consignment during the loading were the main important parameters that were considered. Sultan Yusuf hydroelectric power generation plant (JOR Power Station) has cooperated with *Kualiti Alam* Sdn Bhd to manage, control and reduce the impact of scheduled waste on environment and human life.

Non-hazardous waste is the waste that is not considered as a scheduled waste in JOR hydroelectric power generation plant, the normal waste collected in an area by the name of scrap yard. In the store, waste is segregated and sold to scrap merchant to recycle and those part of wastes that are not recyclable are considered as rubbish by approving from the site and dispose as normal waste.

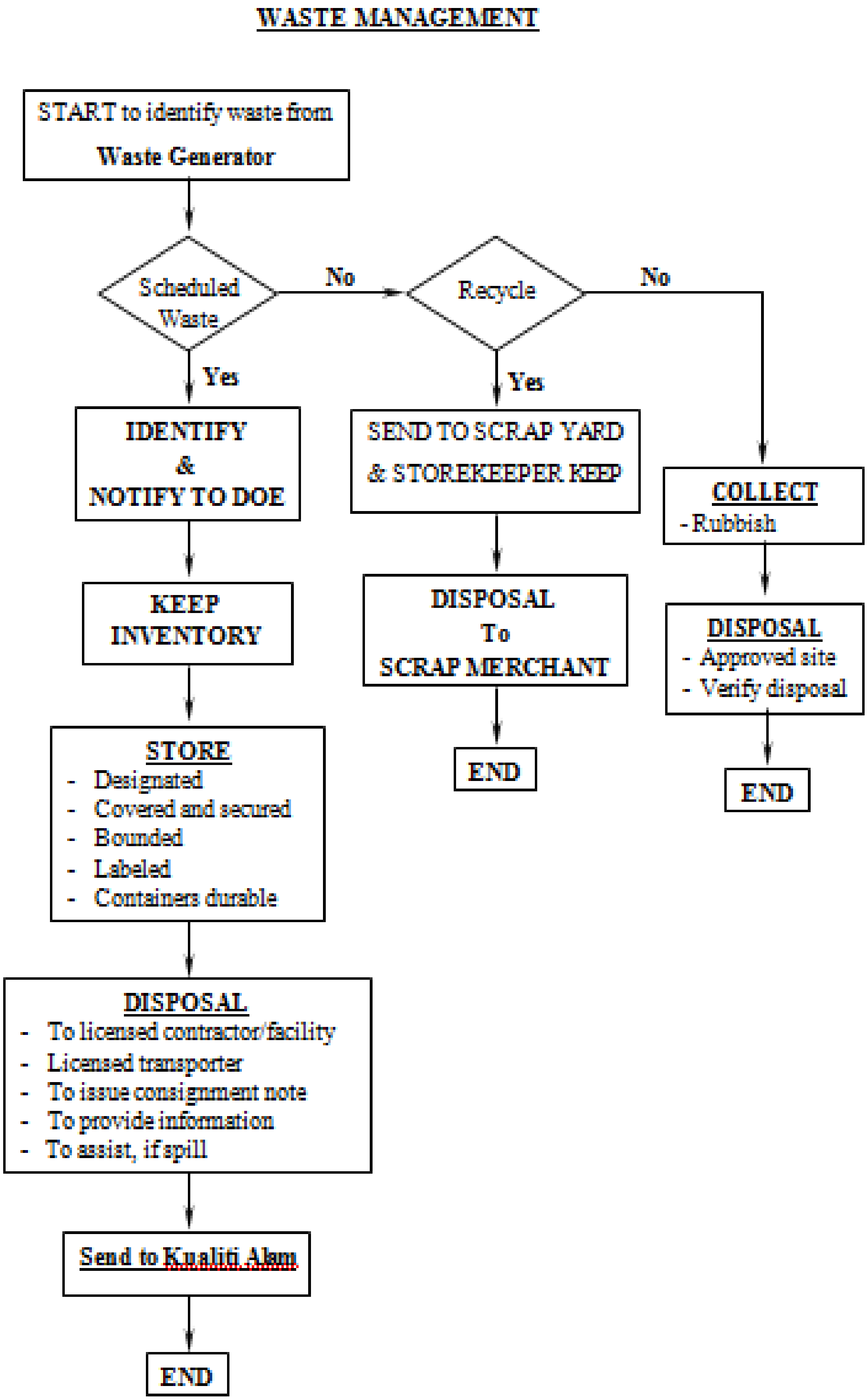


Figure 4.4: Waste management flow chart in JOR hydroelectric power station

4.4 EVALUATION OF RISK CONTROL ON SULTAN YUSUF HYDROELECTRIC POWER GENERATION PLANT (JOR POWER STATION)

Followed by inspection and general interview in JOR hydroelectric power station risk control is implemented according to Guidelines for hazard identification, risk assessment and risk control (HIRARC) 2008. The safety officer has responsibility to audit and conduct survey from the whole system every month and ask report of the process to relevant person, close communicate with employees, regularly meeting with the head manager and manager of human resources and quality to discuss the main issue of hazard and problem in system that can cause hazard as well as applying the different variety of controlling method such as elimination, substitution**,** engineering, administrative and personal protective equipment control, also safety officer should apply the new method of control with updating information from OSHA and TNB headquarter safety department.

The purpose of the risk control in Sultan Yusuf hydroelectric power generation plant is to ensure that risk control methods and activities are conducted according to safety plan and systematic manner to reduce the risk and less residual impact of hazard on environment, equipment and employees.

Safety is a priority for the plant and there is monthly monitoring by the safety officer, safety attitudes are in acceptable level amount the workers by looking to the number of accident which happened for employees, controlling method is working well, because most of employees use PPE during the work, all machinery and equipment are guarded and were working in good condition which shows the engineering control is going well, all important and sensitive places and facilities are labelled and safety signs/ warnings are posted where appropriate; these demonstrated that administrative control is applied. According to McManus (2011), most of the controlling method focus on Personal Protective Equipment, Engineering and administrative controls in hydroelectric power plants. For example oil and lubricants are chemical components that can cause chemical hazards in most hydro electric power plants with direct and indirect contact to workers; therefore applying PPE for employees is the best controlling method which can suggests to increase workers safety. Battery explosion is the other chemical hazard that can happen in electrical part of hydroelectric power generation plants, it can cause by short circuit across terminals in bank of batteries and exposure to liquid and aerosol of the electrolyte. So, one of the main control methods for this hazard is an engineering control by fixing shielding of battery terminal and no insulated conductors to make suitable barrier. Administrative control is the last common important control methods, basically this control method relevant to safety officer and the person who has knowledge about the whole system and regulation to better understand and implement. Noise pollution is the common types of biological hazards in generator hall in hydroelectric power stations which can cause by steady-state noise from generators and other relevant auxiliary equipments, therefore applying noise control technology by controlling the noise level, give awareness to workers and prepare medical surveillance for employees are some example of administrative control methods (McManus, 2011). Comprehensive training program in JOR hydroelectric power station with implementing for all employees is as a safety week program per year, meanwhile new worker has orientation week to familiarize themselves with the system especially their workplace, and management also send expert staff for training organized by TNB headquarters. Education is the other important parameter in JOR hydroelectric power station that helps to reduce and control risk by increasing employees' knowledge about safety in general and control method in specific; employees should be aware of why they should follow the safety program; what are the advantages of safety program as well as controlling method for the system and their life; how employees can communicate with the safety officer regarding their work; how can employees get to know and understand the new concepts of regulations before doing any training on that; these are some parameters to be applied to education in the plant.

Keeping the control measurement documents in safety department of JOR hydroelectric power station is the other effective activity according to the control method. In order to keep accurate records, all reporting systems are developed, implemented and maintained, therefore maintaining risk control measures and re-control of the system requires adequate inspection, maintenance and monitoring procedures to ensure that the controlling system applied for initial hazard is secure and continued in the power plant. Generally keeping accidents and control methods document help the safety officer to implement the effective control method that is close and applicable in the system and environment for the best result and mitigation.

4.5 GENERAL DISCUSSION

In comparing with the HIRARC guidelines from the department of occupational safety and health, of the Ministry of Human Resource of Malaysia and Law of Malaysia Act 514, OSH Act 1994, the Sultan Yusuf Hydroelectric Power generation Plant is under safe condition.

As results showed that the high level of risk was only 2% in the plant; this was a minimum level, hence the safety department was satisfied with the situation. The maximum of 66% of low level of risk was regarded as manageable and more reduction may be unnecessary. If the risk can be resolved fast, however, control actions should be instituted and be properly documented.

Regarding the safety study in the plant, some duties are incumbent on the manager and staff to apply the HIRARC well. The General Manager shall ensure that HIRARC has been carried out periodically for all facilities, equipment, services and new process/project involving all staff, contractors, sub-contractors, visitors and trainees. The Safety Coordinator is responsible for co-ordinating, preparing and updating the HIRARC Document in cooperation with other section representatives, while the Safety Committee shall discuss the HIRARC and report to the Chairman of the Safety Committee any significant risk in the quarterly Safety Committee meeting; besides that, all employees must be in close communication with their supervisor and plant safety officer for effective HIRARC implementation.

Regarding the literature most hydroelectric power plants have similar hazards which can cause more or less costly damage. According to Lamark et al. (1998), failure can happen in the generator’s stator winding which depends on the machine age, types of installation, rated voltage, design, running conditions and maintenance, but according to data collection at the proposed study plant, JOR power station does not have this problem and it back to their regular control system of the stator wings that reduced the possibility of occurrences to cause severe damage. The other common important hazard in most hydroelectric power plants are failure in switch control room and control equipment of the power generation plant, the primary electrical system from the generating unit to the transformer and external grid is highly vulnerable to short-circuit in large plants. Electrical short circuits may cause substance damage; conduct survey in JOR hydroelectric power station showed the plant is not exempted from this type of hazards, hazard due to not cutting off the power supply in the event of overloading and short circuit damaging the transformer, bushing, wires and make cost, and electrical shock hazard for workers, therefore the safety department applied engineering control by providing high maintenance and administrative control with checking the system and giving awareness and enough information to employees to prevent and reduce the amount of this type of common hazard in the proposed study area. ASCE (2007), explored oil contamination and emergency access as other main important hazards that can create risk in every hydroelectric power generation plant; most hydroelectric plants are facing oil and lubrication contamination in the system. According to inspection in JOR power station leaking of lubrication and oil supply in cooling system, sometimes in transformer section and shifting chemical material into the injection container causes environmental pollution, water contamination and chemical hazards for those involved with the system, but the management and safety committee of the plant followed the OSHA standard by doing high maintenance of machinery, administration control by providing suction tool and monthly inspection to reduce the hazard and keep it at an acceptable level.

Generally to ensure that the safety program is running well in hydroelectric power station it is important to have a well established maintenance and supervision program. Modern power plant control and automation systems give optimized mechanical and electrical components in planning, operation and maintenance, for new projects and also for renovated substations (Brauner, 1995). Stations need renovation if very old, are short of replacement parts or if they suffer frequent breakdown, as a low outlay will lead to improved effectiveness and high production.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This study was aimed at determining the factors that influence safety in Sultan Yusuf Hydroelectric Power plant (JOR power station) in relation to the adopted safety procedures and encountered problems to evaluate and control risks.

According to the study, the HIRARC in JOR hydroelectric power station carried out for all activities, facilities, equipments, services and employees to identify hazards, assess the risk level and find the best way to control, as well as, effect a waste management system to reduce the impact of hazards on the plant. HIRARC must be done prior to modifying or introducing new ways of working, work materials, new processes or machines.

The risk of identified hazards from the Sultan Yusuf hydroelectric Power generation plant activities and services are assessed and estimated against likelihood (frequency) and severity (impacts) to find out different levels of risk. However, the general risk assessment which was conducted in the Sultan Yusuf hydroelectric Power generation Plant showed the station is in safe condition with 66% of low risk, 32% of medium risk and only 2% of high risk; therefore the outcomes of a risk assessment are inventoried for action, to devise, maintain or improve controls. In view of the above, this study therefore concludes that common hazards in JOR power station were identified as physical hazard (36.58%) such as, falls from height or slips and trips, chemical hazard (17.07%) for example, expose to acids, lubricants and asbestos, electrical hazard (9.76%) for instance, contact direct or in direct of employees with the high voltage

electricity and it radiation or failing circuit breaker, biological hazard (21.96%) such as, bacterial infection, aerosols and ergonomic hazard (14.63%) mainly musculoskeletal.
In conducting the assessment of risk, the factors of existing risk controls pertaining to those hazards are considered / whichever higher. The risk evaluation process shall determine whether the level of risk is acceptable or unacceptable and also indicated the types of necessary action required to manage workplace hazard.

Finally, suitable approaches to improve risk control in the Sultan Yusuf hydroelectric Power generation Plant has been selected by taking Personal Protective Equipment, Administrative, Engineering, Isolation and substitution controls to reduce significant hazards, control residual impact and increase safety at plant as elaborated in details in chapter 4. Meanwhile safety policy has a role in JOR power station to prevent and control the hazard by applying training, education program and keeping all classified documents related to safety and health. Furthermore waste management is another method that can help to identify risks by cause wastes to control and reduce the hazardous and non- hazardous wastes in JOR power station which was implemented following the Scheduled Waste Regulation 2005 under the Environmental Quality Act. The risk level upon completion of their OH&S Management Program during annual document review to ensure the effectiveness of the program. HIRARC will be reviewed and updated annually during document review session to ensure the effectiveness of the system. Meanwhile Sultan Yusuf hydroelectric Power generation Plant (JOR Power Station) is committed towards in safety and health, which is reflected in their certifications, namely MS 1722:2005, OHSAS 18001, MS ISO 14001:2004 and MS ISO 9001:2000. With these accreditations, JOR power station management hopes to improve and keep the station in high quality of standard to provide a safe working environment.

RECOMMENDATIONS

The present study has shown how the HIRARC model can be implemented in a hydroelectric power plant to keep the plant in low risk and safe condition. The following recommendations are given in two parts.

The first part is recommended to help for future evaluation of hazard and risk in the study area and any other hydroelectric power plant.

1. To implement different methods of hazard identification such as fault tree analysis, event tree analysis as well as hazard and operability study (HAZOP) to increase the accuracy of identifying hazards in the study area.
2. To apply HIRARC model separately for each unit of the hydroelectric power generation plant to assess and get more details of risks for each specific section, it helps to enhance the validity of evaluation hazards and risks in the plant.

The second part is proposed to improve safety and health in the study area and similar plants.

1. The most important issue in safety program is the lack of effective and coherent programs in creating safety culture. Hence, workers have an important role in the success and the development of safety activities. Therefore, without establishing a safety culture, achieving the objective is impossible. Different training methods are necessary in JOR power station to increase the motivation of the workers towards safety. Besides, performing more educational programs for workers in plant is also recommended.
2. Monitoring control can be a good way to re-observe, check and control the system with applying monitoring control project management, monitoring controlling process and monitoring control surveillance. Manger and safety officer can be sure the system, environment and employees are in a safe condition and follow safety

and health regulations, if HIRARC is applied well, identified hazards are under control and mitigated enough; therefore running the system will be cost effective.

3. Updating and improving the safety program is the other effective way to keep the plant safe. Regarding system upgrading, when changing part of the process and plant facilities, the manager and safety officer should be diligent to implement the new safety programs which take in to account the probability of new hazards that can occur in the plant.

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APPENDICES

(Appendix A)

HIRARC FORM									
Company				Conduct by: (name , designation) Date :(from…..to….)					
Process/ Location									
Approved by: (Name, designation)									
Date				Review Date:			Next Review Date:		
1. Hazard Identification				**2. Risk Analysis**				**3. Risk Control**	
No.	Work Activity	Hazard	Which can cause/effect	Existing Risk Control (If any)	Likelihood	Severity	Risk	Recommended Control Measures	PIC (Due date/ status)
1									
2									
3									
4									
5									

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(Appendix B)

Hazard Identification Checklist

HAZARDOUS CHEMICAL EXPOSURES	Y	N	Comment
4. Are employees aware of the potential hazards involving various chemicals component?			
5. Is employee exposure to chemicals kept within acceptable levels?			
6. Are all employees required to use personal protective clothing and equipment when contact chemicals (i.e. gloves)?			
7. Where needed for emergency use, are respirators stored in a convenient, clean and sanitary location?			
8. Are respirators intended for emergency use adequate for the various uses for which they may be needed?			
9. Are employees prohibited from eating in areas where hazardous chemicals are present?			
10. Is personal protective equipment provided, used and maintained whenever necessary?			
11. Are there written standard operating procedures for the selection and use of respirators where needed?			
12. If you have a respirator protection program, are your employees instructed on the correct usage and limitations of the respirators?			

13. Are the respirators NIOSH approved for this particular application?			
14. Are they regularly inspected and cleaned sanitized and maintained?			
15. If hazardous substances are used in your processes, do you have a medical or biological monitoring system in operation?			
16. Are you familiar with the Threshold Limit Values or Permissible Exposure Limits of airborne contaminants and physical agents used in your workplace?			
17. Have control procedures been instituted for hazardous materials, where appropriate, such as respirators, ventilation systems, handling practices, and the like?			
18. Do you use general dilution or local exhaust ventilation systems to control dusts, vapours, gases, fumes, smoke, solvents or mists which may be generated in your workplace?			
19. Is ventilation equipment provided for removal of contaminants from such operations, and is it operating properly?			
20. Do employees complain about dizziness, headaches, nausea, irritation, or other factors of discomfort when they contact and working with chemical component?			
21. Is there a dermatitis problem--do employees complain about skin dryness, irritation, or sensitization?			

22. Have you considered the use of an industrial hygienist or environmental health specialist to evaluate your operation?			
23. If internal combustion engines are used, is carbon monoxide kept within acceptable levels?			
24. Is vacuuming used, rather than blowing or sweeping dusts whenever possible for clean up?			
25. Is Asbestos a hazard in powerhouse area?			
26. Have you faced with any Battery Explosion products during the process?			
27. Does Coating Decomposition products make hazard (e.g., copper, lead)?			
28. Is there any gas emission by arcing in the rotor and other electrical equipment (e.g., ozone)?			
29. Do disturbances of lubrication and oil supply in turbine can rapidly lead to water and cause hazard?			
ELECTRICAL	**Y**	**N**	**Comment**
1. Do you specify compliance with OSHA as a requirement for all contract electrical work?			
2. Is there any simple access to high voltage switchyards or control areas?			
3. Are all electrical power tools, leads and portable electrical equipment tagged and inspected follow the Hydro Equipment Safety regulations?			
4. Do the employees have knowledge of the electrical device and their function?			

5. Is there a hazard due to direct contact of persons with live parts?			
6. Is there a hazard due to contact of persons with parts which have become live under faulty conditions (indirect contact)?			
7. Is there a hazard due to proximity to live parts under high voltage?			
8. Is there a hazard posed by electrostatic charges?			
9. Is there a hazard due to thermal radiation (heat) or the projection of molten particles from short circuits, overloads etc.?			
10. Is there any Electrical Safety Training for employee and all people who engaged with process?			
11. Are electrical enclosures such as switches, receptacles, junction boxes, etc., provided with tight-fitting covers or plates?			
12. Are all flexible cords and cables free of splices and taps?			
13. Are employees instructed to make preliminary inspections and/or appropriate tests to determine what conditions exist before starting work on electrical equipment or lines?			
14. When electrical equipment or lines are to be serviced, maintained, or adjusted, are necessary switches open, locked-out and tagged whenever possible?			
15. Are portable electrical tools and equipment grounded or have double insulation?			
16. Is sufficient access and working space provided and maintained around all electrical equipment to permit safe operations and maintenance?			
17. In wet or damp locations, are electrical tools and equipment appropriate for the use or location or otherwise protected?			

18. Are metal measuring tapes, ropes, handlines or similar devices with metallic thread woven into the fabric prohibited where they could come in contact with energized parts of equipment or circuit conductors?			
19. Are there any potential electrical hazards for machine hall?			
20. Is there any failing of bushing device during the operation?			
21. Is there any hazard due to circuit breaker not cutting off the power supply in the event of overload?			
22. Is there any firing hazard cause by over using of generator copper coil during the operation?			
23. Are there accident caused by arc temperature, or arc brightness and hit by the lid during its removal in transformer?			
24. Is there any explosion and mechanical hazard due to high voltage and low maintenance in transformer?			
25. Is there any Failure in the stator winding of the generator cause by deterioration mechanism?			
26. Do the cables and their auxiliary power system face with cutting or firing hazard due to low maintenance and overloading of the cables?			
27. Is there any heating losses hazard (Dissipation factor) on the environment and the workers cause by ageing or low maintenance of insulation system in switchyard?			

28. Does high voltage electricity and it radiation in switchyard area have negative impact on the environment and employees?			
29. Are mechanical and corrosion failures cause hazard in relays and contactors?			
Mechanical	**Y**	**N**	**Comment**
1. Is there a training program to instruct employees on safe methods of machine operation?			
2. Is equipment and machinery securely placed and anchored, when necessary to prevent tipping or other movement that could result in personal injury?			
3. Is a crane preventive maintenance program established?			
4. Is the load chart clearly visible to the operator?			
5. Is an audible warning device mounted on each crane?			
6. Is sufficient illumination provided for the operator to perform the work safely?			
7. Are cranes of such design, that the boom could fall over backward, equipped with boom stops?			
8. Does each crane have a certificate indicating that required testing and examinations have been performed?			
9. Is each overhead electric hoist equipped with a limit device to stop the hook travel at its highest and lowest point of safe travel?			

10. Are close-fitting guards or other suitable devices installed on hoists to assure hoist ropes will be maintained in the sheave grooves?			
11. Is it prohibited to use chains or rope slings that are kinked or twisted?			
12. Are operators instructed to avoid carrying loads over people?			
13. Are all hooks equipped with spring-loaded safety clips to prevent accidental load release?			
14. Are only employees who have been trained in the proper use of hoists allowed to use them?			
15. Is there any hazard for employee due to fixing or maintenance of draft tube (e.g., drowning)?			
16. Is there any Flooding hazard for Machine Hall and other Room for Machinery Equipment caused by natural catastrophes, dam breaks or overflow?			
17. Is turbine scroll case checked frequently to prevent probably leaking from the seam, lap joint or welded part cause by high pressure of water?			
18. Can leakage and disturbances in oil and lubrication system cause hazard in cooling system?			
19. Is there any collapse hazard in power house access gallery cause by landslides, sinkholes, and ground settlement?			
20. Can electric power to each machine be locked-out for maintenance, repair, or security?			
21. Are rotating or moving parts of equipment properly guarded to prevent physical contact (e.g., generators, turbines, moving chains and gears)?			

22. Are machinery guards secure and arranged so they do not offer a hazard when in use?			
23. Is there suitable ventilation system to gather the dusts, vapors, or gases in machine hall or access gallery to be controlled, and convey them to a suitable point of disposal?			
24. Is there any hazard in turbine shaft due to cavitation on shovels or moving fast (e.g., breaking or firing)?			
25. Do Disturbances of lubrication, oil supply and water pressure can rapidly lead to damage of the turbine bearing due to the huge pressure on the bearing?			
26. Is there any mechanical failure for generator due to low maintenance and overloading?			
27. Is there any collapsing hazard in all power generation house tunnels area cause by swelling clay, ageing or water pressure?			
28. Do damaging and fails to run in ducts and fans in ventilation system can cause hazard in confine space?			
29. Is high sedimentation cause hazard for cooling system and turbine bearing?			
Ergonomic	Y	N	Comment
1. Do workers perform tasks that are externally paced?			
2. Are workers required to exert force with their hands (e.g., gripping, pulling, pinching)?			
3. Do workers use hand tools or handle parts or objects?			

4. Do workers stand continuously for periods of time?			
5. Do workers sit for a long time without the opportunity to stand or move around freely?			
6. Do workers use electronic input devices (e.g., keyboards, mice, joysticks, track balls) for continuous periods of time?			
7. Do workers kneel (one or both knees)?			
8. Do workers perform activities with hands raised above shoulder height?			
9. Do workers perform activities while bending or twisting at the waist?			
10. Are workers exposed to vibration?			
11. Do workers lift or lower objects between floor and waist height or above shoulder height?			
12. Do workers lift, lower, or carry large objects or objects that cannot be held close to the body?			
13. Do the neck and shoulders have to be stooped to view the task?			
14. Are there sufficient rest breaks, in addition to the regular rest breaks, to relieve stress from repetitive-motion tasks?			
15. Are all seating place adjusted, positioned and arranged to minimize strain on all parts of the body?			

Biological	Y	N	Comment
1. Is there any musculoskeletal injury due to prolonged work in awkward posture?			
2. Is oxygen deficient a serious problem for employees that are working in confined space (e.g., water-conducting channels, generator and turbine machinery contain many pits)?			
3. Are there any falling and drowning hazards into fast-moving water in power house area?			
4. Is there electrocution hazard due to fixing and maintenance of electrical device for workers?			
5. Do Generating, transformer and other electrical equipment have Electromagnetic fields (including radiofrequency) on employee?			
6. Do generators and heat exchangers may discharge heated air into the powerhouse and make heat hazard for workers?			
7. Is noise level over the standard of the indoor air quality in powerhouse area (85db)?			
8. Are there any physiological and psychosocial stresses on workers due to their working position or working schedule?			
9. Is there any hazard vibration cause by powered hand tools and rotational motion of generators and turbulence of water flows transmitted through floors and walls?			
10. Are there frequently indoor air quality and industrial hygiene to check and control the air quality and worker health in power generation house?			

First-aid and fire-fighting equipment	Y	N	Comment
1. Do you have adequate first aid in powerhouse which can be used in emergency cases?			
2. Are first aid kids easy to access for every one?			
3. Do workers have training to know that how they use it in emergency cases?			
4. Are first-aid supplies replenished as they are used?			
5. Is the local fire department acquainted with the facility and its specific hazards?			
6. Are portable fire extinguishers provided in adequate number and type?			
7. Do you have a fire prevention plan?			
8. Does your plan describe the type of fire protection equipment and/or systems?			
9. Have you established practices and procedures to control potential fire hazards and ignition sources?			
10. Is your local fire department well acquainted with your facilities, location, and specific hazards?			
11. If you have a fire alarm system, is it tested at least annually?			

12. If you have a fire alarm system, is it certified as required?			
13. If you have interior standpipes and valves, are they inspected regularly?			
14. Is maintenance of automatic sprinkler system assigned to responsible persons or to a sprinkler contractor?			
15. Are fire extinguishers mounted in readily accessible locations?			
16. Are fire extinguishers recharged regularly and noted on the inspection tag?			
17. Are employees periodically instructed in the use of extinguishers and fire protection procedures?			
Methods of control	**Y**	**N**	**Comment**
1. Do you have an adequate control of those hazards that probably have happened?			
2. Have the controls solved the problem?			
3. Is the risk posed by the original hazard contained?			
2. Have any new hazards been created?			
3. Are new hazards appropriately controlled?			
4. Are monitoring processes adequate?			
5. Have workers been adequately informed about the situation?			

6. Have orientation and training programs been modified to deal with the new situation?			
7. Do your controlling methods lead to workers doing their work in a good condition without creating new hazard?			
8. Are workers under protection with the proper controlling method when they are exposing to hazard?			
9. Do the control methods reduce or omit the hazard from the work environment?			
10. Is there a proper procedure for storage and disposal of hazardous waste?			

(Appendix C)

General Work Place Inspection Checklist

INSPECTORS:	DATE:			
	(O)Satisfactory (X) Requires Action			
	Y	**N**	**Condition**	**Comments**
WORKSITE GENERAL				
1. Are Occupational Safety and Health Administration (OSHA) and state required posters displayed in a prominent location?				
2. Are safety signs/warnings posted where appropriate?				
3. Are emergency telephone numbers posted where they can be found readily?				
4. Is a first aid kit available and adequately stocked?				
5. Is a substance abuse policy in place				
6. Is the Summary of Occupational Illnesses posted?				

7. Are emergency evacuation traffic routes identified?				
8. Are all work areas clean and orderly?				
9. Are combustible scrap, debris, and waste stored safely and removed from work areas promptly?				
10. Are adequate toilets and washing facilities provided?				
11. Are toilets and wash areas clean and sanitary?				
12. Are work areas adequately illuminated?				
11. Are resources available to deal with very hot or very cold conditions (drinking water, lined gloves, insulated boots)?				
12. Are work surfaces kept dry or appropriate means taken to assure the surfaces are slip-resistant?				
13. Is metallic or conductive dust prevented from entering or accumulation on or around electrical enclosures or equipment?				
14. Are work surfaces and grip surfaces safe when wet?				
15. Do workers know the symptoms of heat cramps, heatstroke?				

TRAINING				
1. Is training provided for each person newly assigned to a job?				
2. Does initial training include a thorough review of hazards and accidents associated with the job?				
3. Is adequate instruction in the use of personal protective equipment provided?				
4. Is training for the use of emergency equipment provided?				
5. Are workers knowledgeable in the "Right to Refuse" procedures?				
WORK PROCESSES				
1. Are repetitive motion tasks properly paced and kept to a minimum?				
2. Do joint committee members have access to material safety data sheets?				
3. Are workers informed (by hazard signs and tags)?				
4. Have all trucks, forklifts and other equipment been inspected and maintained?				
5. Are lockout procedures followed?				
6. Is ventilation equipment working effectively?				
7. Is fume and dust collection hood properly adjusted?				

RECORD KEEPING				
1. Are medical records and exposure records maintained as required?				
2. Are training records maintained in accordance with OSHA requirements?				
3. Are employee records being maintained for the required time frames?				
4. Are operating permits and records up-to-date?				
5. Are procedures in place to maintain records and logs? a. Safety inspections b. Safety meeting minutes c. Accident investigations d. Emergency response drills				
FIRE EMERGENCY PROCEDURES				
1. Is there a clear fire response plan posted for each work area?				
2. Do all workers know the plan?				
3. Are drills held regularly?				

4. Are fire extinguishers chosen for the type of fire most likely in that area?				
5. Are there enough extinguishers present to do the job?				
6. Are extinguisher locations conspicuously marked?				
7. Are extinguishers properly mounted and easily accessible?				
8. Are all extinguishers fully charged and operable?				
9. Are special purpose extinguishers clearly marked?				
MEANS OF EXIT				
1. Are there enough exits to allow prompt escape?				
2. Do employees have easy access to exits?				
3. Are exits unlocked to allow egress?				
4. Are exits clearly marked?				
5. Are exits and exit routes equipped with emergency lighting?				
6. Are doors that are required to serve as exits designed and constructed so that the way of exit travel is obvious and direct?				
7. Are exit doors openable from the direction of exit travel without the use of a key or any special knowledge or effort, when the building is occupied?				

LIGHTING				
1. Does lighting produce glare on work surfaces?				
2. Is the level of light adequate for safe and comfortable performance of work?				
3. Is emergency lighting adequate and regularly tested?				
4. Is emergency lighting provided, with an independent power source which activates automatically when normal lighting fails?				
MACHINE GUARDS				
1. Are all dangerous machine parts adequately guarded?				
2. Do machine guards meet standards?				
3. Are lockout procedures followed when performing maintenance with guards removed?				

TOOLS AND MACHINERY				
1. Are manufacturers' manuals kept for all tools and machinery?				
2. Do power tools conform to standards?				
3. Are tools properly designed for use by employees?				
4. Are defective tools tagged and removed from service as part of a regular maintenance program?				
5. Are tools and machinery used so as to avoid electrical hazards?				
6. Is proper training given in the safe use of tools and machinery?				
CONFINED SPACES				
1. Are entry and exit procedures available and adequate?				
2. Are emergency and rescue procedures in place (e.g. trained safety watchers)?				
3. Is adequate ventilation provided prior to and during confined space entry?				
4. Is the atmosphere inside the confined space frequently tested or continuously monitored during work?				
5. Is adequate illumination provided in confined spaces?				

6. Is approved respiratory equipment required if the atmosphere inside the confined space cannot be made acceptable?				
7. Is there an assigned safety standby employee outside of the confined space, whose sole responsibility is to watch the work in progress, sound an alarm if necessary, and render assistance?				
8. Is each confined space checked for decaying vegetation or animal matter, which may produce methane?				
9. Is the confined space checked for possible industrial waste, which could contain toxic properties?				
HOUSEKEEPING				
1. Is the work area clean and orderly?				
2. Are floors free from protruding nails, splinters, holes and loose boards?				
3. Are aisles and passageways kept clear of obstructions?				
4. Are permanent aisles and passageways clearly marked?				
5. Are covers or guardrails in place around open pits, tanks and ditches?				
6. Are appropriate and convenient storage racks provided for tools, raw materials, parts and products?				

7. Are oil spills and other 'slips, trips and falls' hazards promptly cleaned up or removed?				
8. Are there enough waste receptacles or containers of adequate size?				
9. Is there provision for proper drainage of waste water or other liquids?				
SOUND LEVEL/NOISE				
1. Are noise levels being measured using a sound level meter or an octave band analyzer and records being kept?				
2. Have you tried isolating noisy machinery from the rest of your operation?				
3. Have engineering controls been used to reduce excessive noise levels?				
4. Where engineering controls are determined not feasible, are administrative controls (i.e., worker rotation) being used to minimize individual employee exposure to noise?				
5. Is there an ongoing preventive health program to educate employees in safe levels of noise and exposure, effects of noise on their health, and use of personal protection?				
6. Is the training repeated annually for employees exposed to continuous noise above 85 dBA?				
7. Have work areas where noise levels make voice communication between employees difficult been identified and posted?				

8. Is approved hearing protective equipment (noise attenuating devices) available to every employee working in areas where continuous noise levels exceed 85 dBA?				
9. If you use ear protectors, are employees properly fitted and instructed in their use and care?				
10. Are employees exposed to continuous noise above 85 dBA given periodic audiometric testing to ensure that you have an effective hearing protection system?				
11. Is protection against the effects of occupational noise exposure provided when sound levels exceed those of the Cal/OSHA noise standard?				
EMPLOYEE FACILITIES				
1. Are facilities kept clean and sanitary?				
2. Are facilities in good repair?				
3. Are cafeteria facilities provided away from toxic chemicals?				

PERSONAL PROTECTIVE EQUIPMENT				
1. Is required equipment provided, maintained and used?				
2. Does equipment meet requirements and is it reliable?				
3. Are protective gloves, aprons, shields, or other means provided?				
4. Are hard hats provided and worn where danger of falling objects exists?				
5. Is appropriate foot protection required where there is the risk of foot injuries from hot, corrosive, poisonous substances, falling objects, crushing or penetrating actions?				
6. Are approved respirators provided for regular or emergency use where needed?				
7. Is all protective equipment maintained in a sanitary condition and ready for use?				
8. Where special equipment is needed for electrical workers, is it available?				
9. When lunches are eaten on the premises, are they eaten in areas where there is no exposure to toxic materials or other health hazards?				
10. Is personal protection utilized only when it is not reasonably practicable to eliminate or control the hazardous substance or process?				
11. Are warning signs prominently displayed in all hazard areas?				

(Appendix D)

Interview Questions

We can assure you that anything you say to us is confidential and anonymous.

ATTITUDES TOWARD SAFETY

1. Who has the responsibility for safety at the power generation house? (Is it the responsibility of the company and individual worker?)
2. What are the general attitudes towards safety at power generation house?
3. Does safety sometimes get in the way of getting the job done?
4. Is safety a priority all of the time or only until you get busy in which other things take priority?
5. Do you encourage your colleagues/workmates to work safely?
6. Do you think to update and employ better safety in your work place?
7. Do you believe all accidents are preventable?
8. Where / when do accidents usually occur?
9. Do you believe that people who work to procedures will always be safe?
10. What are the common injures at your work place (power generation house)?

SAFETY PROGRAMME

1. Can you explain the safety program in power generation house for us?
2. What safety mechanisms presently exist? (e.g. policies, weekly safety meetings)
3. How are they working? Are they successful? (Strengths & Weaknesses)
4. What improvements do you think could be made to the program?
5. How are you involved in safety at power generation house?
6. After an accident occurs is the company more concerned with apportioning blame than future prevention?

7. How is the reporting of minor injuries and near misses affected by the safety program?
8. Does safety manager/supervisor remind employees of safe working practices regularly?
9. Is your safety plan following the OSHA program? Is it sufficient? Why /Why not?
10. Does industrial hygiene control your company health and safe program? Why /Why not?

ATTITUDES TOWARD THE PROGRAMME

1. Have you had any cases of near miss? Was it reported? Why / Why not?
2. Do you think management is committed to safety and is it sufficient?
3. How can management be committed?
4. What do you think management/employees think of the safety program?
5. Is enforcement applicable to force workers follow to safety program?

INCENTIVES

1. What rewards do you have to encourage safety work practice?
2. How appealing are these to you?
3. Is company has a plan to increase the safety attitude amount the workers?
4. Have you encouraged your employees to discuss any safety concerns they may have and ask them to offer any ideas for safety improvement?
5. What do you think is the general opinion?

SAFETY AWARENESS/TRAINING

1. Is it important for everyone to have regular safety updates?
2. How is the need for safety communicated?
3. How was the safety program communicated?
4. Is the training received enough?
5. What can be improved?

MISCELLANEOUS

1. Have you had any other experience to increase safety in your company?
2. Do you think everyone is aware of safety requirements?
3. Is signage adequate?
4. What is the plan for implementation of safety program?
5. What are the main challenges to implement the safety program in power generation house?

(Adapted from Cox, S. & Cox. T. 1996, *Safety Systems and People*, Butterworth-Heinemann,Cornwall, Great Britain, p. 328, *Journal of Management Practice Volume 1, No. 1 1999)*

(Appendix E)
Sample Job Hazard Analysis Form

Job Title:	**Job Location**	**Analyst**	**Date**
Task	Task Description:		
Hazard Type	Hazard Description		
Consequence	Hazard Controls		
Rational or Comment:			

Occupational health and safe administration, US department of labor.OSHA 3071(2002). Job Hazard Analysis. Retrieved from http://www.osha.gov/Publications/osha3071.pdf.

(Appendix F)

ACCIDENT INVESTIGATION FORM

Name of Safety Representative________________________ Date ________

1. DETAILS OF INJURED PERSON

Name____

Department____

Job title____

Approximate length of service____

Approximate length of time on current job ______________________________

2. DETAILS OF ACCIDENT

Briefly describe the circumstances leading to accident________________________
____
____

Describe equipment/processes being used (if any)____________________________
____
____

Describe any circumstances that may have contributed to the accident___________
____
____

3. DETAILS OF INJURY

What type of injury or ill health was sustained or is suspected?
____
____

What part of the body was injured?
____
____

Was First Aid or medical attention provided? ______________________________

If so, was it prompt? ____

If not, why not? (e.g. was there any problem arising from the lack of trained people or resources to treat the victim) ____

How long is the person who suffered the injury likely to be out of work?

____

4. ENVIRONMENTAL CONDITIONS

What were conditions like prior to the accident occurring? (e.g. noise, temperature, lighting, dust, fumes, housekeeping, etc.)___________________________________

____

5. TRAINING/EXPERIENCE

What level of training did the worker receive?

____

____

Was he/she told of the hazards, safety features and/or means of protection?

____

____

How experienced was he/she?

____

____

Was there anyone present to provide instruction or assistance?

____

____

http://www.unitetheunion.org/pdf/AccidentInvestigationForm.pdf

(Appendix G)

Classified risk levels for specific hazards in JOR Power Station

Type of Hazard	Risk level & Categories			Risk Percentage		
	Low	Medium	High	Low	Medium	High
Physical	11	4	0	73.34	26.66	0
Chemical	5	1	1	71.42	14.29	14.29
Electrical	1	3	0	25	75	0
Biological	6	3	0	66.67	33.33	0
Ergonomic	4	2	0	66.67	33.33	0

Total Hazards: 41

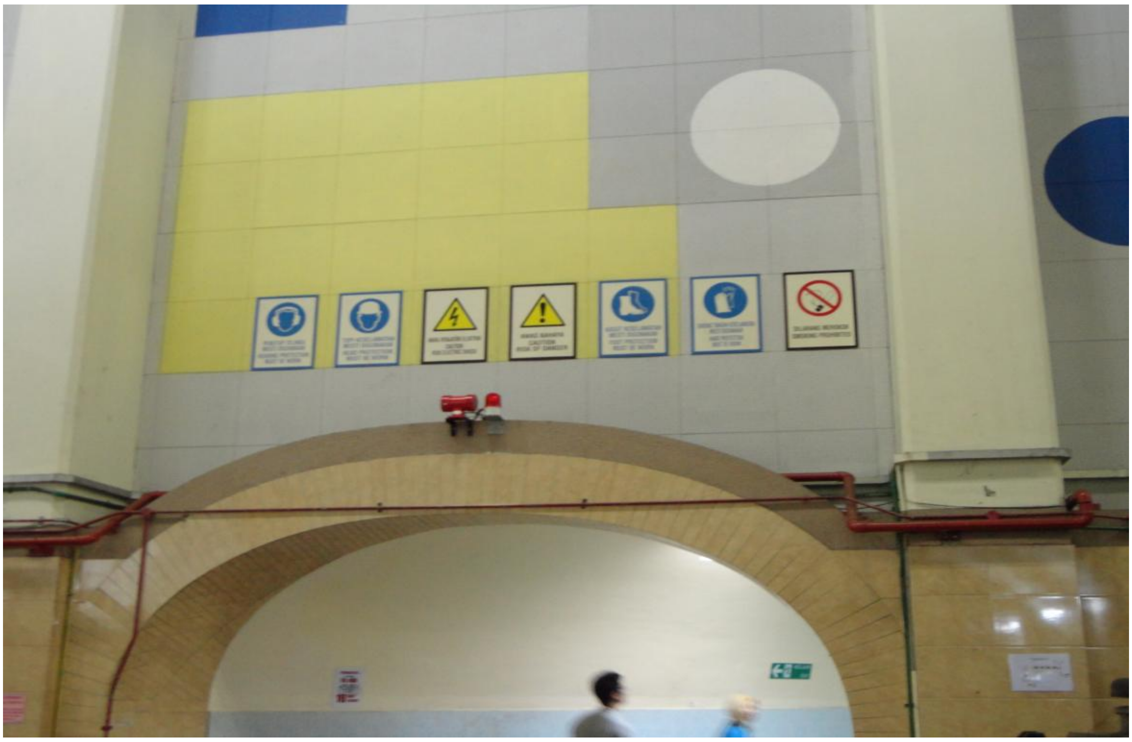
(Appendix H)

JOR Power Station

Jor underground power station hall entrance

Jor underground power station hall access tunnel

Jor underground power station hall



The symptoms of safety follow OSH regulation at JOR power station

The symptoms of safety follow OSH regulation at JOR power station