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A HIRARC model for safety and risk evaluation at a hydroelectric power generation plant

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ABSTRACT

There are many formal techniques for the systematic analysis of occupational safety and health in general, and risk analysis in particular, for power generation plants at hydroelectric power stations. This study was initiated in order to create a HIRARC model for the evaluation of environmental safety and health at a hydroelectric power generation plant at Cameron Highlands in Pahang, Malaysia. The HIRARC model was used to identify the primary and secondary hazards which may be inherent in the system which were determined as a serious threat for plant operation and maintenance. The primary tools of the model consisted of, generic check-lists, work place inspection schemes which included task observation and interview, safety analysis as well as accident and incident investigation. For risk assessment, the Likert scale was complemented by the severity matrix analysis in order to determine the probability and extent of safety and health at the study power generation plant. These were used to identify and recommend control measures which included engineering and administrative aspects as well as the use of personal protective equipment (PPE). A total of forty-one important hazard items were identified in the system at target power generation plant. These hazards were mainly identified by means of checklists which were sourced from literature and subsequently customized for the current purpose. Risk assessment was conducted by initially classifying the hazards into three levels such as Low, Medium and High. Generally 66% of the hazards identified were at low risk, 32% at medium and 2% at high risk. This indicated that there was sufficient awareness and commitment to safety and health at the study power station. Meanwhile the Power Station was also certified by MS 1722:2005, OHSAS 18001, MS ISO 14001:2004, MS ISO 9001:2000 and scheduled waste regulation 2005 which give credibility to the current study in creating a working model which may find widespread application in the future.

1. Introduction

1.1. Background

Hydroelectric power generation plants are becoming increasingly popular in many parts of the world. This may be attributed mainly to the rapidly decreasing conventional energy resources which have been used extensively through time. There is also a need to look for green, clean and renewable energy sources with respect to the requirements of environmental issues. Although risks from dams are seldom encountered perhaps due preventive measures but the implications are of a 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 the dedication of dam owners (Bowles, 2001).

In order to maintain the safety and health of employees working in hydroelectric power stations it is absolutely essential to have a safety management system (SMS) in place. With respect to this a policy involving the identification and evaluation of major hazards is necessary in order to implement steps for identifying the risk elements during usual and special operations and to predict the likelihood and severity. The safety management system involves choosing risk analysis methods and their outcome 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 criteria underlying risk for making decisions (Bowles, 2001).

According to the Department of Occupational Safety and Health of Malaysia (DOSH) an occupational safety and health policy involves a written document expressing an organization's

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dedication to employee health, wellbeing and safety. It is a basis for efforts made to ensure a proper workplace environment. This policy must encompass all the organization's activities related to 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).

1.2. Research purpose

The HIRARC model consists of a comprehensive series of phases for the identification of hazards, assessment of risk and the determination of control measures for the implementation of safety and health in the operations (Insert Fig. 1 here). An important element of risk assessment is the identification of existing hazards, evaluating the probability or chance of occurrence and recommending relevant controls. The hazards in hydroelectric power generation plants are quite varied and have a significant effect on employees, facilities and the environment. Hence the current study was undertaken to identify the hazards, estimate the risks and determine control measures based on the data collected in order to derive a comprehensive HIRARC model for the study power generation plant in Cameron Highlands in Pahang, Malaysia.

1.3. Related literature

Kim Froats and Tanaka (2004) found 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 hydroelectric power plants are often set aside for recreation. The recreational uses should be weighed against the risks and hazards of strong currents, rising water levels and rugged topography. Although hydroelectric generating stations account for only a minority of these accidental deaths, it is imperative for operators to ensure that public safety issues are addressed.

Numerous generic risk evaluation methods are available for determining the extent of risk. However, 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. According to Au Yong and Hui Nee (2009) as far as hydroelectric power stations are concerned each facility can include the following structures which may have a direct relation to hazards in the plant: a) head pond b) water conveyance structure to include dam

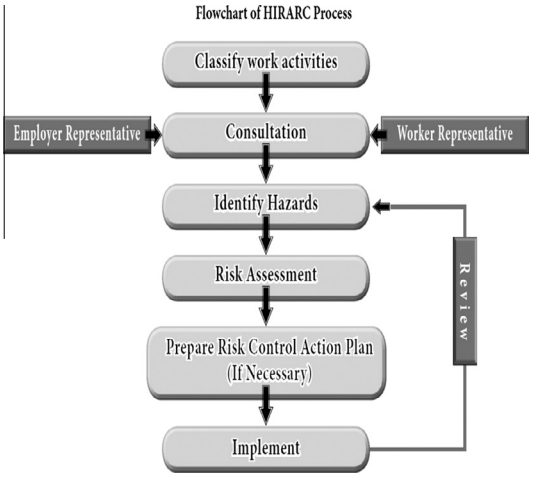

Fig. 1. Hazard identification, risk assessment and risk control model. *Source:* Department of Occupational Safety and Health Malaysia (2008).

structure, power intake canal, overflow spill walls, stop log sluices and sluice gates c) spillway d) powerhouse tail-race and e) downstream.

Among the variety of hazards associated with hydroelectric power generation plants, some are common to all employees while others are limited only to those working with or maintaining electrical or mechanical equipment (McManus, 2011). 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, and
- Fire in the machine hall or other engine rooms.

Thus, in order to ensure the safety of hydroelectric power plant operations, maintenance and supervision programs should be included in the safety and health management plans. These should include 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 which are common today, evaluations are generally carried out according to schedule, hence placing a higher demand on the reliability of control and safety measures. Early automatic detection of some incidents such as flooding is very difficult in unmanned facilities. Table 1, indicates a risk exposure matrix for a hydroelectric power plant (Lamark et al., 1998). Smith (2000) explained that ongoing hazard monitoring and effective control measures are essential for ensuring a continuous improvement process in occupational safety and health.

Although, data on safety and health in hydroelectric power stations are highly specialised and focused, information from diverse disciplines with actual and potential applications to causal modeling for the HIRARC model was reviewed. In this study the HIRARC model proposed by the National Institute of Occupational Safety and Health (NIOSH) of Malaysia was used to investigate the safety and health in the study hydroelectric power generation plant, in Cameron Highlands, Malaysia.

2. Work operations

2.1. The power station

According to McManus (2011) a hydroelectric generating station has a dam that traps a large quantity of water, a spillway for controlled release of 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 causes 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 river bed. This optimizes height while ensuring controlled water flow.