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Technical note

HAZOP application for the nuclear power plants decommissioning projects

Sigitas Rimkevičius, Mindaugas Vaišnoras *, Egidijus Babilas, Eugenijus Ušpuras

Lithuanian Energy Institute, Breslaujos 3, LT-44403 Kaunas, Lithuania

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ABSTRACT

Decommissioning of nuclear facilities involves different types of activities, tools, equipment and systems. There is a potential for a wide range of radiological and industrial accidents during various stages of a decommissioning project creating risk for workers and the environment. The occurrence of accidents is possible due to many different operations involving movement and handling of large pieces of equipment and contaminated items. In addition, size reduction and decontamination processes are capable of producing hazards. One of the first steps in developing a safety assessment for decommissioning activities is the identification of hazards that can affect workers, members of the public and the environment during decommissioning activities, and then to identify engineered and administrative control measures to prevent, eliminate or mitigate the hazards and their consequences. Fault and hazard identification can be undertaken in several ways using a range of tools and techniques, including Hazard and Operability Study (HAZOP).

The paper will mainly focus on the application of HAZOP technique for identification of the hazards raised due to dismantling and decontamination activities at the Ignalina NPP, as well as at feasibility study for the management of Bohunice V1 NPP primary circuit components.

1. Introduction

The decommissioning of nuclear facilities requires adequate planning and demonstration that dismantling and decontamination activities can be conducted safely. Existing safety standards require that an appropriate safety assessment be performed to support any activities related to the sitting, operation, modifications and decommissioning of nuclear facilities. The main purpose of the safety assessment is to demonstrate that residual risks have been reduced to As Low As Reasonably Achievable (ALARA) and to nationally prescribed safety criteria. Dismantling and decontamination activities at any nuclear facilities significantly increase radiological and non-radiological hazards to workers, public and the environment.

All relevant hazards (e.g., sources of harm) to workers, the public and the environment should be considered in the decommissioning safety assessment, including (International Atomic Energy Agency, 2009):

- Radiation exposures, for example, external exposure from direct radiation and other radiation sources (including criticality), internal exposure due to inhalation, ingestion or cuts and abrasions, and loss of containment leading to the uncontrolled release of radionuclides.
- Toxic and other dangerous materials, for example, asbestos, flammable materials, carcinogens, chemicals used for decontamination purposes.
- Industrial hazards, for example, dropped loads, work at heights, fires, high temperatures, high pressures, noise, dust and asbestos.

According to IAEA safety guide WS-G-5.2 (International Atomic Energy Agency, 2009), a systematic approach should be taken for

Abbreviations: ALARA, As Low As Reasonably Achievable; AWT, annular water tank; D & D, dismantling and decontamination; ECCS, Emergency Core Cooling System; EU, European Union; FEU, fume extract unit; HAZOP, hazards and operability assessment procedure; HEPA, high efficiency particulate air filtration system; IAEA, International Atomic Energy Agency; INPP, Ignalina Nuclear Power Plant; LEI, Lithuanian Energy Institute; MFU, mobile filtering unit; MLW, medium level waste; NPP, nuclear power plant; PCC, primary circuit components; PPE, personal protection equipment; RIS, reactor internal structures; RPV, reactor pressure vessel; SG, steam generator; SJR, Safety Justification Report; SQEP, suitably qualified and experienced personnel; VVER, from Russian: water–water energetic reactor.

* Corresponding author.
E-mail address: mindaugas.vaisnoras@lei.lt (M. Vaišnoras).

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the identification of hazards on the basis of the description of the facility and decommissioning activities. The following steps should be applied in an iterative manner to identify accident scenarios that could lead to the exposure of workers and members of the public or could have adverse consequences for the environment (International Atomic Energy Agency, 2009):

- Identification of hazards and initiating events: The activity and location of the radioactive source term at the facility should be considered together with any additional hazards, arising from decommissioning activities or processes, and initiating events that create the potential for causing harmful consequences for workers, the public or the environment should be identified.
- Hazard screening: The hazards identified should be quantified and screened for in order to direct the safety efforts towards all the significant and relevant hazards and initiating events for a facility.
- Identification of scenarios: The safety analysis should identify all relevant scenarios arising either from decommissioning activities or accident situations, in which the screened hazards could be realized.

The identification of initiating events and the analysis of their evolution should be carried out using an appropriate technique. A wide range of different methods, such as Hazards and Operability Study (HAZOP), Failure Mode and Effect Analysis (FMEA), Fault Tree Analysis, are used for the hazards identification and analysis (Hashemi-Tilehnoee et al., 2010). In the nuclear industry HAZOP method is used rather often (Jeong et al., 2008; John, 1988). The HAZOP method is a formal, systematic, and critical approach to identifying the qualitative potential of hazards and operating problems associated with an existing or new system or piece of equipment, caused by deviations from the design intent, and their resulting consequential effects (Kletz, 1997; Hyatt, 2004).

The paper discusses hazard identification approach (HAZOP) used for decontamination and dismantling (D & D) projects at the Ignalina NPP related to the dismantling and decontamination of the equipment located in buildings 117/1 and V1. Also, the same HAZOP method was employed for hazard identification in feasibility study for management of Bohunice V1 NPP primary circuit components. The HAZOP study considered and reviewed the available potential hazard management strategies for satisfying the ALARA principle. Accumulated experience of the Lithuanian Energy Institute experts in preparation of safety analysis for operating NPP (Ušpuras et al., 2010) was successfully adopted for the development of D & D works safety assessment for NPP decommissioning.

Table 1
List of nodes for HAZOP study for Ignalina NPP D & D projects.

Node	Title
1	Plant and building preparatory work (e.g., install barriers and transfer systems, remove cladding and insulation)
2	Remove small items and small bore pipe-work from accessible areas, drives/motors
3	Remove large items (vessels) and pipe-work, remove valves from pipe-work
4	Remove filter medium
5	Size reduce large pipe-work and vessels
6	Decontamination and monitoring of cut segments and pipe-work
7	Place all waste in containers/trolleys for removal
8	Remove steel platforms, redundant electrical cabinets and cables
9	Transfer waste from building
10	Clean/decontaminate room
11	Monitor room

Further Ignalina NPP D & D HAZOP studies considered each element or sequence ("node") of the design and involved the application of Keywords.

2. Hazard identification methodology used in NPP D & D projects

The safety assessment process for decommissioning provides a basis, on which the safety of workers and the public can be ensured through the evaluation of the consequences of potential hazards and the identification of the ways they can be mitigated, so that the associated residual risks are ALARA. The safety assessment should identify necessary preventive, protective and mitigating measures and should justify that these will be suitable and sufficient to ensure safety during decommissioning, in compliance with the relevant safety requirements and criteria (International Atomic Energy Agency, 2009). The main steps of the harmonized safety assessment methodology for decommissioning are listed below:

(1) Safety assessment framework.
(2) Description of facility and decommissioning activities.
(3) Hazard analysis: identification and screening.
(4) Hazard analysis: evaluation.
(5) Evaluation of results and identification of safety control measures.

One of the first steps in developing a safety assessment for decommissioning activities is the identification of existing and future hazards (both radiological and non-radiological) that can affect workers, members of the public and the environment during decommissioning activities, and then to identify engineered and administrative control measures to prevent, eliminate or mitigate the hazards and their consequences. It is critical to the safety assessment that all reasonably foreseeable initiating events and accident scenarios are identified (International Atomic Energy Agency, 2013).

Analysis of the possible hazards, raised by the proposed D & D technology, starts before safety case development. A nuclear safety case is a set of documents that describe the radiological and non-radiological hazards in terms of a facility or site and modes of operation (including potential undesired modes) and the measures that prevent or mitigate the harm being incurred. The safety case should provide a coherent demonstration that relevant standards have been met and that risks to persons have been reduced to As Low As Reasonably Achievable. Safety assessment, an integral part of the safety case, is driven by a systematic assessment of these hazards and is an important component of the safety case (International Atomic Energy Agency, 2012). The safety analysis should identify all relevant scenarios arising either from decommissioning activities or accident situations, in which the screened hazards could be realized. It is a fundamental requirement that all reasonably foreseeable faults are identified as a part of safety case development. Hazard identification is a "comprehensive process to be applied systematically to the identification and review of the hazards presented by a facility or operation and a consideration of the ways in which risk to workers, the public and the environment due to these hazards might be realized".

Fault and hazard identification can be undertaken in several ways using a range of tools and techniques (including Hazard and Operability [HAZOP]), and it is this technique, which was applied for D & D projects at the Ignalina NPP, as well as at feasibility study for management of Bohunice V1 NPP primary circuit components.

2.1. HAZOP procedure

A Hazard and Operability Study (HAZOP) can be used at varying times during the life cycle of the process, from process development through to the closure of the plant, including hazard