Lessons learned from application of the Swedish regulations for decommissioning of nuclear facilities - The regulator´s perspective

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ABSTRACT

The paper presents an overview of the Swedish regulations for decommissioning of nuclear facilities. It describes some of the experiences that the Swedish Radiation Safety Authority has gained from the application of these regulations. The focus of the present paper lies on administrative aspects of the care and maintenance operation and on the safety related documentation that has to be prepared before dismantling commences. Lessons learned during recent years will be considered when revising the regulations for decommissioning. Also these lessons learned will help to streamline the administration of the large NPP decommissioning projects that are anticipated to commence in Sweden in the near future.

Introduction

In Sweden, a nuclear reactor is expected to pass through the four phases normal operation, shutdown operation (until all nuclear fuel has been removed from the facility), care and maintenance, and "dismantling and demolition" of the facility (hereafter denoted dismantling). The same applies for other nuclear facilities, except for shutdown operation.

Regulations for decommissioning of nuclear facilities were developed in Sweden in the years 2000-2005, in connection with the shutdown of several nuclear reactors. The regulations were further developed around 2010 after the formation of the Swedish Radiation Safety Authority (SSM). In recent years the regulations have been applied on several different decommissioning projects in Sweden. This paper gives an overview of the regulations and the projects, and describes some of the experiences that have been gained from the application of the regulations. The focus of the paper lies on administrative aspects of the care and maintenance operation and on safety related documents before dismantling commences. Several lessons have been learned that will be considered in an ongoing revision of the regulations, which has been initiated by the SSM.

Swedish regulations for decommissioning of nuclear facilities

Decommissioning of nuclear facilities is regulated by a series of statutory provisions, which are included in, or based on the Act on Nuclear Activities [1], the Radiation Protection Act [2] and the Environmental Code [3]. There are also specific acts concerning funding for decommissioning. Funding aspects are however not included in this paper.

Decommissioning is defined as measures adopted by the license holder after the final shutdown of a facility in order to partly or fully dismantle and demolish the facility and to reduce the amount of radioactive substances in soil and any remaining buildings to levels that enable the release of the site from regulatory control.

Generally, any nuclear activity is subject to licensing. Specifically, the operation of a nuclear facility requires two different licenses; one according to the Act on Nuclear Activities [1] and one according to the Environmental Code [3]. In Sweden, unlike in many other countries, no new license is needed according to the Act on Nuclear Activities for decommissioning of the facility. Instead,

decommissioning activities are regarded as obligations that are included in the license for operation of the facility. However, for nuclear reactors, a specific authorisation for decommissioning is needed according to the Environmental Code.

According to the Act on Nuclear Activities [1], a license holder for nuclear activities is responsible for ensuring that all measures are taken in order to maintain safety, taking into account the nature of the operation and under what circumstances it is conducted, ensure safe management and disposal of nuclear waste generated from the operation and nuclear material derived from the operation that is not reused, and ensure safe decommissioning of facilities in which the operation has been discontinued until such date that all operations at the facilities have ceased and all radioactive waste has been disposed of.

Also, according to the Radiation Protection Act [2], a license holder for nuclear activities shall take all measures that are necessary for radiation protection of people and the environment.

The Act on Nuclear Activities [1] puts additional requirements on license holders of nuclear power plants. They must together:

- establish a program for the safe handling and disposal of spent fuel and nuclear waste and for decommissioning and dismantling of the nuclear power plants and related facilities for management of spent fuel and nuclear waste,
- plan and carry out the research and development (R&D) that is needed in order to realise the program for waste management and decommissioning.

The Environmental Code [3] defines several important principles that the implementer must comply with, e.g. best available technique (BAT).

An Environmental Impact Assessment (EIA) is to be submitted together with an application for an authorisation of environmentally hazardous activities, i.e. for the decommissioning of nuclear reactors.

These general requirements and obligations are supplemented by a more detailed Regulatory Code (SSMFS) issued by the Swedish Radiation Safety Authority (SSM) and, if needed, license conditions that the authority may specify in individual cases.

The requirements in the general regulations on safety and protection [4] and several other regulations issued by the SSM are applicable during decommissioning regarding e.g. the availability of qualified staff and financial resources, provisions with respect to operational radiation protection, discharges, unplanned and uncontrolled releases, provisions with respect to radioactive waste, and provisions with respect to emergency preparedness.

Chapter 9 of the general regulations [4] sets out a number of specific requirements relating to the preparation of decommissioning during normal operation, the early phases of decommissioning and the dismantling and demolition of the facility:

- A preliminary plan for the future decommissioning of the facility is to be compiled before construction of a facility. The decommissioning plan shall at any stage of the life cycle of the facility contain, inter alia, a description of the facility and the anticipated inventory of radioactive materials at the time of future shutdown, a description of the prerequisites for planning of decommissioning (such as waste handling facilities and repositories), and of the planned decommissioning activities, with time frames and a description of the anticipated end state;

- Nuclear safety and radiation protection aspects of future decommissioning shall be taken into account during the construction of a facility and when changes are made in an existing facility;
- The preliminary plan shall be kept up to date during the operation of the facility and reported to the SSM every ten years. The plan shall at any stage of the life cycle of the facility contain the information that can be made available;
- During the operation of a facility, observations and events that have significance for planning and execution of decommissioning shall be documented on an ongoing basis;
- When a decision has been made on final shutdown of a facility within a certain period of time, the licensee shall conduct an integrated analysis and assessment of how nuclear safety shall be maintained until shutdown of the facility. An analysis and assessment of organisational changes after shutdown and of personnel requirements during decommissioning shall also be conducted. The analyses, assessments and measures emanating from these shall be documented and reported to the SSM;
- Within a year after the final shutdown, the decommissioning plan shall be updated and supplemented, and shall include a description of which parts of the facility and which equipment will be required during decommissioning as well as which preparatory actions that are planned to be undertaken before dismantling will commence;
- Before dismantling of the facility may commence, the updated decommissioning plan shall be further developed and reported to the SSM. Also, the safety analysis report (SAR) of the facility shall be updated and adapted to the planned decommissioning activities. The SAR shall be subject to internal safety review by the license holder and the report shall be reviewed and approved by the SSM before dismantling may commence;
- The decommissioning project may include a series of well specified work packages or subprojects. In this case a review of the planned activities and of any additional safety or protection measures shall be performed by the licensee and submitted to the SSM before the work package or subproject is initiated. After the work package or subproject is completed, a report on the execution of the work and measures shall be submitted to the SSM;
- Considerations, measures taken and results of measurements shall be documented on an ongoing basis during decommissioning; and
- A decommissioning report on the actual execution of the decommissioning work, with descriptions of the experience gained and of the final state of the facility, shall be compiled and submitted to the SSM after the dismantling and demolition work is completed.

Recent and on-going decommissioning projects

In Sweden, there are currently ten reactors in operation at three nuclear power plant sites (Oskarshamn, Ringhals and Forsmark). In October 2015 the utility OKG formally announced that the Oskarshamn unit 2, a Boiling Water Reactor (BWR), will not be restarted. It has been offline since 2013 due to a major upgrade project. Also an earlier policy decision on the shutdown of Oskarshamn unit 1 (BWR) between 2017 and 2019 was confirmed. In April 2015 Vattenfall, the majority owner of the Ringhals nuclear power reactors, announced its intention to shutdown of the oldest two units in 2019 (unit 2, a Pressurized Water Reactor) and 2020 (unit 1, BWR), respectively, about five years earlier than planned. Vattenfall currently develops plans to organise the decommissioning of its nuclear reactors in a separate business unit.

The two BWRs in Barsebäck were already permanently shut down in 1999 and 2005, respectively, according to political decisions. The license holder and operator Barsebäck Kraft AB did prepare the

facility for a 10 plus years period of care and maintenance pending dismantling by off-site shipment of fuel, downsizing of the organisation, adjustment of the supervision and maintenance activities, and energy saving measures. Primary system decontamination of both units was performed during 2007-2008. Processing of the wastes from operation and system decontamination is proceeding until 2016.
At the end of 2015 a project for the segmentation and interim storage of reactor internals on the site has been started. In the 2020s it is planned that the reactor internals will be transferred for further interim storage in a separate part of the national repository for low- and intermediate level waste in Forsmark (SFR), once the extension of this facility is completed. The final destination of these wastes will be the national repository for long-lived low and medium level waste, SFL, which is planned to be in operation in 2045. Projecting of the dismantling of the plant is planned to start in 2018 and start of the dismantling work in 2023. Free release of the buildings are planned to take place during 2027 and after that conventional demolition will start. It is intended that the project will reach its final end state 2029-2030, with release of the site.

The two material test reactors in Studsvik (one tank type and one mobile pool type) were permanently shut down in 2005. The reactors were dismantled in 2015. Draining of the pool is planned to start in early 2016 and the dismantling of the biological shield is planned to be undertaken between 2016 and early 2017. Decommissioning of other parts of the facility is planned to be carried out in parallel with these activities. According to the current time schedule dismantling activities will continue until 2019 to achieve an end state with the buildings prepared for free release.

The pressurised heavy water reactor in Ågesta was permanently shut down 1974. Two steam generators were dismantled and waste treated in Studsvik in the early 1990s. Currently, preparations are being made for radiological characterisation and for decommissioning, intended to begin in 2020.

Decommissioning of some minor old nuclear installations in Studsvik has recently been performed by the licensee AB SVAFO. Two old underground silos for liquid intermediate level waste have been decontaminated and partially dismantled. The remaining underground structures and the building foundation were released from regulatory control by decision of the SSM in April 2015.

The uranium mining and milling facilities in Ranstad were constructed and operated in the 1960s. In total, about 200 tons of uranium were produced. At a later stage, parts of the facility were used for extraction of uranium from waste originating from nuclear fuel fabrication. The uranium open-cast mine and mill tailings deposits were restored and covered in the 1990s. Currently, decommissioning of the remaining facility is proceeding. The former mineral processing plant has been dismantled and demolished after approval by the SSM. Currently, clean-up and dismantling of plant equipment is carried out as part of the preparation for further decommissioning activities for remaining nuclear installations in Ranstad, mainly the leaching plant. Certain waste from these activities is being transported to a treatment facility and landfill site for hazardous waste, after clearance by the SSM. Decommissioning activities will continue until 2017.

Adaptation of the safety analysis report for care and maintenance operation

As described above, the regulations for decommissioning of a nuclear power reactor assume a period of care and maintenance operation before dismantling activities start. This period starts when all the spent nuclear fuel has been removed from the facility. As during shutdown operation, certain preparatory activities for the dismantling of the facility may be performed during this period. At this point exemptions from certain requirements (related to the no longer existing nuclear core; safety classification of structures, systems, components, and devices; necessary control programs and intervals) can be made as these are no longer relevant for nuclear safety of the reactor. This adapted set of requirements is reflected in a renewed SAR and Operational Limits and Conditions for the management of its operation. The SSMFS 2008:1 requires in Chapter 9 section 5 that the SAR for care

and maintenance operations fulfills the same formal criteria, i.e. concerning structure and content, as the SAR for normal operation. It shall contain no less than the following information: site, design rules, facility and functional description, radioactive substances, radiation protection, operation of the facility, analysis of operational conditions, references, and drawings. Furthermore, functions necessary for safety, protection and security during the subsequent dismantling phase shall also be described.

The SSM's current requirements are only in part adapted to the care and maintenance operation of a nuclear power plant. As it has been announced that four reactors are to be shut down in the coming years in Sweden, the SSM saw a need to provide the licensees with guidelines on how to interpret the current requirements when revising the SAR for the care and maintenance phase. The guidelines were completed in 2015. Examples of requirements no longer relevant during the care and maintenance are:

- safety functions and systems related to reactivity control, protection of the primary system integrity, emergency core cooling, residual heat removal, and the containment function,
- the main and emergency control rooms, and
- surveillance programs for the reactor pressure vessel and primary circuit.

The authority expects that the licensees will apply for exemptions from all requirements that are no longer of importance for nuclear safety or security. The guidelines should enable transparent, uniform and efficient handling of such applications. Also reviewing up to four SAR for care and maintenance operation during a relatively short period of time becomes more feasible for the SSM if the licensees follow the guidelines.

Required documents and approvals before dismantling

Before dismantling of the facility may commence, the licensee must present the following documents to the SSM, of which some must be approved by the authority

- Final decommissioning plan,
- Safety analysis report for dismantling (to be approved by the SSM),
- Waste management plan and waste type descriptions (to be approved by the SSM), and
- General data according to Euratom Article 37 (to be submitted to the European Commission).

These documents are described below, together with some issues that have been identified by the SSM.

Final decommissioning plan

The final decommissioning plan shall describe and motivate the planned decommissioning activities. It shall contain the following information, some of which may be presented on a broad level, with reference to other reports, such as the SAR or the waste management plan.

Documentation of the facility

- Actual facility description with drawings.
- Operating data, operating experience and events of importance for safety and protection during decommissioning.
- A description of the radioactive inventory in the facility.

Prerequisites for planning

- A description of available or planned systems for management and disposal of the radioactive waste arising in connection with decommissioning.
- A description of the ultimate objective of decommissioning.

- A description of planned dates for the start and end of different stages of the dismantling activities, with justification.

Decommissioning activities

- A description of the planned activities from commence of dismantling until decommissioning is completed. The division into work packages or subprojects shall be described. The planning shall be based on an analysis of different options for conduct of decommissioning.
- A description of the planned organisation, the management and control of the decommissioning activities as well as an estimate of the number of staff and its competence at different stages.
- An analysis and assessment of the risks and potential radiological consequences of the planned activities.
- Estimated radiation doses to personnel and estimated releases of radioactive substances to the environment.
- A description of the planned management of radioactive materials and waste.
- A description of how the end state of the facility will be verified.

As implied by these requirements, the decommissioning plan should be based on a thorough understanding and knowledge of the facility, its operation and the inventory of radioactive (and other hazardous) substances. It should also consider the boundary conditions for the decommissioning project, such as the availability of different kinds of resources during the life-time of the project. Furthermore, the decommissioning plan needs to be based on a thorough understanding of the practical decommissioning tasks, i.e. which activities need to be performed at what point of the project and an assessment of the corresponding risks.

The decommissioning plan should also form the basis for elaborating more detailed descriptions of procedures for characterisation, dismantling, waste management, safety, protection and security etc. Ideally, the final decommissioning plan should not need any revision, but in reality later revisions might become necessary, due to changes in boundary conditions for the decommissioning project or due to unexpected issues within the project (e.g. unexpected contamination).

Safety analysis report for dismantling

According to the regulations [4], the safety analysis report is the central document that must be approved by the authority before dismantling may commence. However, in the current SSMFS requirements it is neither well specified to what level of detail the licensee shall describe and analyse the planned activities nor how the planned safety and protection measures need to be described and motivated in the SAR. Even though a thorough radiological characterisation and planning of dismantling activities should be performed in advance, the SSM acknowledges that the full decommissioning project cannot be planned in detail before dismantling commences, due to practical reasons or due to the fact that detailed characterisation might not be possible or feasible before some initial preparation or dismantling activities have been performed. It is therefore anticipated in the regulations that more details will be considered and described by the licensee in advance of each work package or subproject within the decommissioning project (e.g. dismantling of the reactor pressure vessel, the biological shield, and the primary system). Alternatively, the licensee may adopt the SAR for a specific dismantling stage or period of time only. This approach requires a SAR revision and new approval from the SSM before entering the next stage or time period. Although this gives the dismantling project flexibility, it also causes a substantial administrative burden both for the licensee and the authority due to the number of documents that are produced and submitted for review.

The SSM plans to prepare guidelines on this issue as different licensees have taken different approaches depending on preference and/or interpretation of the current regulations.

Waste management plan and waste type descriptions

A waste management plan shall be submitted with the SAR for dismantling and demolition. The plan shall describe the waste that is expected to arise during the project and the waste streams to intermediate storage facilities or final repositories. The waste streams shall be selected based on safety considerations, optimisation of radiation protection and application of BAT. For waste that is planned to be stored longer than 5 years on site or to be directly disposed of in a final repository for radioactive waste, the licensee must present so called waste types descriptions, which describe typical waste packages and the methods for ensuring that they fulfill the waste acceptance criteria of the repository. Since the waste management plan shall be enclosed to the safety analysis report it must also be approved by the authority before dismantling may commence.

From the review of waste management plans for decommissioning projects and from supervision of decommissioning projects, the SSM has observed the following:

- In some cases, the existence of certain waste types has been overlooked by the licensees. The underlying reason has been insufficient characterisation of the facility, or of existing inventories of operational waste.
- Not all applicable requirements have been identified and considered early in the waste management planning process. An example is waste containing uranium, where safeguard requirements apply. This has complicated the authorisation procedures for both the licensee and the authority.
- The development of waste type descriptions has in some cases not been sufficiently prioritised by the licensee, which partly can be explained by the lack of waste acceptance criteria for waste repositories that are still in the planning or licensing stage. The lack of waste type descriptions means that the waste management will suffer from less well-defined boundary conditions. This may lead to improper treatment or unnecessary handling of the waste at later stages.

General data according to Euratom Article 37

According to article 37 of the Euratom Treaty, "each Member State shall provide the Commission with such general data relating to any plan for disposal of radioactive waste in whatever form as will make it possible to determine whether the implementation of such plan is liable to result in the radioactive contamination of the water, soil or airspace of another Member State". According to a recommendation issued by the Commission [5], general data shall be provided for the dismantling of nuclear reactors (except research reactors of less than 50 MWth), mixed-oxide fuel fabrication plants and reprocessing plants. According to the recommendation, dismantling comprises disassembling, cutting and demolition of contaminated or activated components, systems and structures including their packaging and transfer off-site. The recommendation also specifies the information that should be included in the general data. The information is to a large degree the same as the information to be included in the safety analysis report, with a focus on waste streams and normal and accidental releases to the environment.

The general data should be submitted to the Commission not less than six months before "any authorisation for the discharge of radioactive waste is granted by competent authorities". This has been interpreted as the approval by the SSM of the safety analysis report for dismantling. In order to be able to consider review comments delivered by the Commission on the general data, the SSM awaits any such opinion before approving the safety analysis report.

In order to develop the general data, good knowledge of the radioactive inventory is needed, which in turn puts requirements on radiological characterisation of the facility. Depending on the quality of the report and on the opinion from the Commission, the Article 37 procedure may have an impact on the schedule of the decommissioning project.

Discussion and summary of lessons learned from supervision of preparation of decommissioning projects

According to the Act on Nuclear Activities [1] all requirements for a nuclear power reactor do formally apply during the care and maintenance period, as well, although all spent nuclear fuel has been removed from the facility. Therefore the licensee could apply for exemptions from those requirements which they do no longer consider applicable for the facility at its current stage. The SSM has in 2015 issued guidelines for the interpretation of these requirements.

There are several interlinks and overlaps between the different documents that shall be submitted to the SSM and, in some cases, approved by the SSM before and during dismantling. For example, the characterisation of the facility (concerning radioactive substances and hazardous substances as well as other features of importance) forms a common basis for all the documents. Thus, if new knowledge is gained, e.g. concerning the radioactive inventory or waste management, one or several of the documents needs to be revised. Experience has shown that it is practically impossible to keep all documents up to date and consistent at all times. This difficulty needs to be acknowledged and dealt with in an organised way, both by the licensee and by the SSM. The structure of the documents should be prepared with this is mind and there need to be arrangements in place to manage the information on which plans and assessments are based. The possibility, in the Swedish regulations, to provide safety justifications gradually throughout a decommissioning project aims to reduce the requirement to continuously update a safety assessment covering the whole project.

Further, experience has shown that the decommissioning plan becomes more or less obsolete once the SAR and waste management plan has been approved. Thus, as long as the overall plan is not changed, there is no need to revise the decommissioning plan, even if the underlying data or other specific features change.

One particular issue is how to interpret the term ”dismantling” and to specify which activities may be conducted by the licensee before approval of the SAR for dismantling. For the application of both the Swedish regulations on decommissioning and article 37 of the Euratom treaty, the SSM has interpreted “dismantling” as disassembling or segmentation of major contaminated or activated components or structures. For example, disassembling and segmentation of internal parts of a reactor vessel may not be commenced without notification of general data according to Euratom article 37 and approval by the SSM of a SAR for dismantling. On the other hand, according to practice, the SSM has acknowledged that the following can be regarded as preparations for dismantling

- replacement or upgrade of safety related equipment,
- removal of spent nuclear fuel and other radiological sources from the site,
- adaption of the organisational structure and number of employees,
- management of operational waste and removal of loose objects,
- radiological characterisation of systems without safety importance, including taking samples,
- removal of contaminated, non-safety related components for reuse in other nuclear facilities,
- removal of non-contaminated, non-safety related components and structures,
- system decontamination with subsequent waste treatment, and
- removal of minor amounts of insulation, e.g. asbestos, from non-safety related systems.

As half of the Swedish nuclear fleet will be shut down within the coming four years many challenges await all parties involved: the licensees, the waste management system, the financing system, and the SSM.

References

[1] The Act on Nuclear Activities (1984:3).
[2] The Radiation Protection Act (1988:220).
[3] The Environmental Code (1998:808).
[4] The Swedish Radiation Safety Authority's Regulations concerning Safety in Nuclear Facilities, SSMFS 2008:1.
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