Strålsäkerhetsmyndigheten
Swedish Radiation Safety Authority

2020 STATUS REPORT – SWEDISH NATIONAL ACTION PLAN

Response to ENSREG's request within the European Stress Tests, March 2020

Stockholm, March 2020

Abstract

The Swedish national action plan was first issued in December 2012 and was reviewed and revised in December 2014 and December 2017. This report describes the current status of the actions included in the Swedish national action plan and shall not be seen as a self-standing document but rather a complement to the Swedish national action plans of 2012, 2014 and 2017.

Following the severe accidents which started in the Fukushima Dai-ichi nuclear power plant, the European Council of 24/25 March 2011 requested stress tests to be performed on all European nuclear power plants. The Swedish national action plan is part of these stress tests and was developed with the aim to manage all plant weaknesses identified by the EU stress tests as well as by other forums such as the second extraordinary meeting under the Convention on Nuclear Safety.

In general, the Swedish national action plan required investigations to be performed with the aim to determine and consider the measures needed, including how they should be implemented and the appropriate time schedule for these technical and administrative measures. According to the Swedish national action plan, all necessary actions resulting from the investigations, such as technical and administrative measures shall be fully implemented before the end of 2020.

SSM has continuously performed reviews and follow-ups on the licensee actions concerning the Swedish national action plan. Due to a high degree of complexity, the majority of the necessary technical and administrative measures identified by the investigations required a relatively long time for implementation.

All measures in the Swedish national action plan have been completed in accordance with the given time schedule. The only remaining measure is the Independent Core Cooling system (ICCS) at all sites, which will be implemented by the end of 2020. The installation of the ICCSs are the most important measures required for the six plants that will continue operation after 2020.

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1. Introduction

1.1 Background

Following the severe accidents which started in the Fukushima Dai-ichi nuclear power plant, the European Council of 24/25 March 2011 requested stress tests to be performed on all European nuclear power plants. The Council invited the ENSREG, EC, and WENRA to develop the scope and modalities for the stress tests. WENRA drafted the preliminary stress test specifications in April 2011. On 24 May 2011 full consensus of ENSREG and EC was achieved. The stress tests and peer review focus on three topics which were directly derived from the preliminary lessons learned from the Fukushima disaster as highlighted by the IAEA missions following the accident and reports from the Japanese Government. Natural hazards, including earthquake, tsunami and extreme weather, the loss of safety systems and severe accident management were the main topics for review.

SSM submitted the final national stress test report on 31 December 2011 (1). The peer review was completed with a main report that includes final conclusions and recommendations at a European level and a report that includes specific conclusions and recommendations for Sweden. The report was approved by ENSREG and the EC on 26 April 2012 (2). In a joint ENSREG/EC statement the stress test report was accepted and it was agreed that an ENSREG action plan would be developed to track implementation of the recommendations. As part of the ENSREG action plan each national regulator was expected to generate a country-specific action plan. In December 2012 the Swedish Radiation Safety Authority issued the Swedish national action plans (3), and in December 2014 a reviewed and revised Swedish national action plans (4) was published. This was followed by new updated Swedish national action plans in December 2017. The present report is the third follow-up report of the Swedish national action plan.

1.2 Brief description of the Swedish national action plan

The Swedish national action plan consists of measures identified during the EU stress tests as well as by other forums such as the second extraordinary meeting under the Convention on Nuclear Safety. The Swedish national action plan is, for topic 1-3 (Chapter 1-3), in many ways comparable to the list of identified measures in the ENSREG report, *Compilation of recommendations and suggestions – Peer review of stress tests performed on European nuclear power plants* (5), but also includes specific measures identified in the Swedish national stress test report (1) and the Swedish peer review report (2), as well as other measures identified by the licensees outside of the scope of the stress tests or identified by other fora, such as the second extraordinary meeting under the Convention on Nuclear Safety (6) Measures presented under topic 4-6 and in the additional topics and conclusions (Chapter 4-7) in the Swedish national action plan, have mostly been identified based on Swedish and international operating experience, recent safety analyses, R&D results and findings, and experience gained from emergency preparedness exercises.

In the development of the Swedish national action plan, safety improvements already planned or implemented due to other circumstances, were considered. These measures include measures required and implemented according to the Regulatory requirements on modernization and the requirements regarding severe

accident conditions introduced following the TMI accident in the United States in 1979, as well as measure taken at Swedish nuclear power plants as an immediate consequence of the Fukushima accident. Further information on the Swedish nuclear power plants modernization programs, the Swedish requirements regarding Severe accidents and the measures taken at Swedish nuclear power plants as an immediate consequence of the Fukushima accident, is provided in the Swedish national action plan, 2012 (3), 2014 (4) and 2017(15).

In general, the Swedish national action plan identifies investigations whose aim is to determine and consider whether further measures are necessary, how such measures should be implemented as well as the time schedule for implementations. The measures listed in the Swedish national action plan were scheduled in three different categories, 2013, 2014 and 2015, corresponding to the year when the measures were expected to be completed. This categorization was based on an assessment of the urgency of the implementation of the measures as well as of the complexities of these measures. For measures that required investigations to be performed, the deadline given in the Swedish national action plan referred to the completion dates for the investigations, not including the time required for implementing any technical or administrative measures that these investigations might identify.

In the Swedish national action plan, SSM primarily chose to define crosscutting and comprehensive measures applicable to all Swedish reactors. Assessments in terms of detailed measures for individual reactors has been part of the work ensuing after the preparation of the Swedish national action plan.

During the implementation of the Swedish national action plan, a step-wise review process has been applied. The first step was to establish and review the site-specific action plans. The second step was, and still is, the review of the licensees implementations. Prior to the implementation of any technical and administrative measures, SSM performs reviews and regulatory supervision in accordance with normal procedures for plant improvements. In some cases the investigations required by the Swedish national action plan concluded that no further technical and administrative measures were needed.

1.3 Brief description of the Swedish nuclear power plants

Since the Swedish national action plan was issued in 2012 and reviewed in 2014 and 2017 three Swedish nuclear power plants, Oskarshamn 1, Oskarshamn 2 and Ringhals 2 have been permanently shut down. It has also been decided by the owner Vattenfall AB to permanently shut down the reactor Ringhals 1 in 2020.This means that there are currently 7 nuclear power reactors in operation in Sweden; five BWR and two PWRs. All the BWRs were designed by the domestic vendor ASEA-Atom (later ABB Atom, now Westinghouse Electric Sweden AB) and all the PWRs by Westinghouse (USA). The oldest BWR has external main recirculation loops while the other four units have internal recirculation pumps with no large pipes connected to the reactor pressure vessel below core level. The BWR containments are all of the PS-type and various layouts of the vent pipe configuration and pressure suppression pools. All PWRs are 3-loop standard Westinghouse design reactors.

Ever since taking the plants in operation, measures to increase the level of safety at Swedish nuclear power plants have gradually been taken in accordance with new knowledge and experience. Such new knowledge and experience has emerged from lessons learned from events, incidents and accidents, from research, from safety analyses and from new reactor designs. International incidents and accidents such as the TMI nuclear accident in 1979 as well as domestic incidents such as the "strainer event" in Barsebäck 2 in 1992 and the electric power system event at Forsmark 1 in 2006, have had a major influence on these measures. An important example of such a measure is the requirement to perform PSR, first introduced in Sweden already in the early 1980s as a result of the TMI nuclear accident. The requirements regarding these reviews have developed over the years and are now quite similar to those recommended in the IAEA Safety Standards. Other examples are the updated and extended Swedish regulations on design and construction of nuclear power reactors which were issued in 2005 and have resulted in extensive back-fitting and modernization programs for all Swedish NPPs. Additionally, insights from the European stress tests have identified further areas of improvement have been implemented to strengthen the robustness of Swedish nuclear power reactors.

1.4 Structure of the report

The 2014 update of the Swedish national action plan was divided into five parts. Part one covered the areas considered in the EU stress tests, part two other issues, part three national conclusions and generic activities, part four summary of implementation and part five progress on implementation and update of the Action Plan.

The present report has a simplified structure relative to the 2012 and 2014 reports, similar to the 2017 report, focusing on the progress on implementation of the measures (Chapter 2). Thus, it does not repeat previous descriptions of the various measures. More details regarding each measure is given in the Swedish national action plans 2012 and 2014.

This report shall not be seen as a self-standing document but a complement to the Swedish national action plans issued 2012 (3).

In the current report, a description of the ICCS has been included in chapter 2 and the answers to the items listed below have been updated, mainly by referring to the description:
T1.RA.2, T1LA.9, T2.LA.2, T2.LA.3, T2.LA.11, T2.LA.16, T2.LA.17, T3.LA.1, T3.LA.2, T5.RA.1, T5.RA.2, T6.LA.1, T6.LA.2, T6.LA.3, T6.RA.. T6.RA.7 G.RA.1.

2 Implementation of the technical and administrative measures

In the following sections the progress on the measures included in the Swedish national action plan are described. Further technical and administrative measures identified and considered as needed by the completed investigations are also described.

2.1 Implementation of the ICCS

The most important and powerful measure in the Swedish national action plan is the implementation of the Independent Core Cooling system (ICCS). Other important technical measures are the implementation of a more robust cooling of spent fuel pools and a more robust supply of emergency power. The ICCS was not an explicit part of the first version of the NAcP, but was foreseen as a consequence of the results of the analyses, studies and investigations requested in the NAcP 2013. The ICCS will provide alternative core cooling if the ordinary safety systems are unavailable in a situation with design extension conditions.

SSM issued in December 2014 an injunction requiring the installation of the ICCS, as a condition for operation after 2020. This applies to six reactors, since three of the Swedish reactors have been permanently shut down and Ringhals 1 will be shut down at the end of the year.

The main basic design requirements for ICCS are:

– Extended Loss of AC Power, ELAP (for 72 hours)

– Loss of Ultimate Heat Sink, LUHS (for 72 hours).

The ELAP and LUHS events are assumed to coincide with, or be the consequence of, severe external events (beyond the ordinary design base), including various electrical disturbances. These events should have an exceedance frequency of 10^{-6} per annum, without the need for manual action the first 8 hours.

Most of the installation work is finished, parts of the systems have been tested and the operator training is ongoing. The system will be in operation in late 2020 at all reactors, in accordance with injunction from 2014.

ICCS will be a part of the fulfilment of the security requirement at Forsmark and Ringhals.

Forsmark NPP

In Forsmark the ICCS will be placed in a new building with its own water source for Forsmark 1 and 2, adjacent to the reactor building of Forsmark 1. The power supply will be galvanically separated from the plant's regular electrical power system via a motor-generator set. The water source will be sufficient for 24 hours of operation for Forsmark 1 and 2, or for 72 hours for one of the units. In case of operation for both units, additional water sources are available to make operation for 72 hours possible. The pump capacity is sufficient to supply water to the RPV at full pressure. Forsmark 3 will have its own new building.

Decay heat will be removed from the containment after about 8 hours of ICCS operation, by transporting steam to the multi venturi scrubber.

If needed, there is an additional possibility to utilize mobile equipment to supply more water, and thereby use the ICCS for a longer period than 72 hours.

Ringhals NPP

All features of the ICCS, including supportive functions, are housed in a separate building, one for each unit.

The main features of the Independent Core Cooling system are as follows:

- Providing feedwater to the steam generators (normal operation)
- Providing boron and make-up to a closed reactor coolant system (normal operation)
- Providing borated make-up for feed-and-bleed for an open reactor coolant system (shutdown mode)

The ICCS building has a separate electrical power supply system, galvanically, functionally and physically separated from the regular electrical power system. The galvanic separation is achieved by a motor-generator set. The electromagnetic design of the building structure and shielding of cables ensure that no electrical disturbances (conductive or radiative) can affect the ICCS.

Oskarshamn NPP

The ICCS function comprises a new low pressure make-up system with a direct diesel-driven pump, also giving electrical support. The primary water source is the central handling pool at the reactor service floor. The available amount of water is sufficient for continuation of core cooling for 40 hours. After 40 hours, make-up water for the central service pool is taken from the fire water tanks, which will last for another 32 hours.

The ICCS has its own diesel generator set that can recharge the dedicated batteries for the ICCS and energize the battery-backed busbars after the initial 8 hours. Residual heat is released through the multi-venturi scrubber system.

Detailed descriptions of each measure in the following sections are found in the Swedish national action plans issued 2012 (3).

2.2 Natural hazards

2.2.1 Actions performed by the licensees

In this section, the status for each measure related to natural hazards performed by the Swedish licensees (LA) is given. Further technical and administrative measures needed are also described.

T1.LA.1 - Seismic plant analyses
Completed for all NPPs. Further studies regarding the structural integrity of the reactor containments, scrubber buildings and fuel storage pools have been performed. The analyses showed that those structures can withstand an earthquake significantly stronger than the "Swedish E-5-earthquake". For the ICCS to be installed by 2020 earthquakes with the exceedance frequency of 10^{-6} per annum shall be considered for the design.

T1.LA.2 – Investigation regarding secondary effects of an earthquake

Completed for all NPPs. A more detailed analysis of earthquake induced flooding has been included in the analyses regarding secondary effects. In addition, seismic induced fires have been analysed. Minor weaknesses have been addressed.

T1.LA.3 – Review of seismic monitoring
Completed for all NPPs. Seismic monitoring systems are installed at all Swedish sites. The licensees have reviewed the procedures and training program for seismic monitoring and implemented the revised procedures and programs.

T1.LA.4 – Investigation of extreme weather conditions
Completed for all NPPs. The analyses, and in some cases corresponding administrative and physical improvements, shows that the NPPs can handle extreme weather with the exceedance frequency of 10^{-5} per annum. For the ICCS to be installed by 2020 extreme weather with the exceedance frequency of 10^{-6} per annum shall be considered for the design.

T1.LA.5 – Investigation of the frequency of extreme water levels
Completed for all NPPs. The analyses and in some cases corresponding administrative and physical improvements shows that the NPPs can handle extreme water levels with the exceedance frequency of 10^{-5} per annum. For the ICCS to be installed by 2020 extreme water levels with the exceedance frequency of 10^{-6} per annum shall be considered for the design.

T1.LA.6 - Flooding margin assessments
Completed for all NPPs. Analyses of incrementally increased flooding levels beyond the design basis and identification of potential improvements have been performed. These analyses included capability to mitigate internal and external flooding events. Weaknesses have been addressed and physical measures have been taken at some plants.

T1.LA.7 – Evaluation of the protected volume approach
Completed for all NPPs. Based on performed stress tests, measures have been taken at some plants.

T1.LA.8 – Investigation of an improved early warning notification
Completed for all NPPs. The licensees have introduced instructions for the control room staff to check the weather forecast with the Swedish Metrological and Hydrological Institute (SMHI) once per shift. The instructions include a check regarding possible effects of extreme weather conditions at the NPPs and the consideration of suitable mitigating measures.

T1.LA.9 – Investigation of external hazard margins
Completed for all NPPs. The analyses and in some cases the corresponding administrative and physical improvements show that the NPPs can handle external hazard with the exceedance frequency of 10^{-5} per annum. For the ICCSs to be installed by 2020 extreme external hazards with the exceedance frequency of 10^{-6} per annum shall be considered for the design, see chapter 2.1.

T1.LA.10- Develop standards to address qualified plant walk-downs
Completed for all NPPs. Extensive efforts have been undertaken to manage resistance to earthquakes and other external events. As part of this, a walk-down methodology has been defined and documented, and walk-downs have been

performed. The licensees use the deterministic method represented by SMA (Seismic Margin Assessment), based on guidelines in the EPRI NP-6041 SL

2.2.2 Actions to be performed by the regulators

The following section describes the status for each measure related to natural hazards performed by the Swedish regulatory body (RA).

T1.RA.1 - Research project regarding the influence of paleoseismological data
Completed. Results presented in SSM technical report 2017:35.

T1.RA.2 - Estimation of extreme weather conditions
SSM shall initiate a study to better estimate extreme weather conditions. The study will be performed as a research project in cooperation with the licensees. The project has not yet been initiated. Furthermore, SSM follows international research findings regarding extreme weather conditions as a member in OECD/NEA working group on external events (WGEV).

2.3 Design issues

2.3.1 Actions to be performed by the licensees

The following section describes the status for each measure related to Design issues performed by the Swedish licensees (LA). Further technical and administrative measures needed are also described.

T2.LA.1 – Implementation of the demonstrations of design basis in SAR
Completed for all NPPs. Included in the Safety Analysis Reports for all Swedish NPPs

T2.LA.2 – Define design basis for alternate cooling and alternate residual heat removal
Completed for all NPPs. The ICCS decision states that Loss of Ultimate Heat Sink (LUHS) 72 hours is a design basis. The licensees have also performed strengthening of existing alternate cooling and alternate residual heat removal. In some cases, the strengthening will be a part of the ICCS-solutions, see chapter 2.1.

T2.LA.3 - Primary and alternative AC power supplies and AC power distribution systems
Completed for all NPPs. The ICCS decision states that Extended Loss of AC Power (ELAP) for 72 hours is a design basis. All licensees have already performed strengthening of the electrical power supply. In some cases, the strengthening will be a part of the ICCS-solutions, see chapter 2.1.

T2.LA.4 - Reassess DC power supplies and DC power distribution system
Completed for all NPPs. The licensees have analysed the actual battery capacity available with existing loads. The analyses shows that there are considerable margins of the batteries at some of the plants. For the remaining plants, measures have been taken to expand the battery capacity in existing battery systems.

Alternatively an application of load shedding or a combination thereof have been installed.

T2.LA.5 - Reassess the integrity of the primary system
Completed for all NPPs. For the PWRs the integrity of the primary system has been further evaluated and reassessed for prolonged extreme situations resulting from natural phenomena and other events. This included reassessment of the primary pumps seals, which will be replaced at the latest in 2020.

T2.LA.6 - Reassess the operability and habitability of the Main and Emergency Control Rooms as well as emergency control center
Completed for all NPPs. Operability and habitability of both the main and the emergency control rooms as well as of the emergency control center have been further evaluated. Some weak points have been identified and addressed. For example, the inner roofs in the control rooms have been strengthened to withstand strong earthquakes.

T2.LA.7 - Reassess the instrumentation and monitoring
Completed for all NPPs. For dose monitoring, see T3.LA.4. For core cooling and residual heat removal, see T3.LA.2. For spent fuel pools see, T2.LA.8, and T3.LA.3.

T2.LA.8 - Reassess the integrity of the spent fuel pools
Completed for all NPPs. The integrity and robustness of the spent fuel pools during prolonged extreme situations have been further evaluated and reassessed. The assessments have defined technical and administrative measures to be addressed, e.g. regarding strengthening of the instrumentation and of the water supply to the fuel pools.

T2.LA.9 – Evaluate the need for mobile equipment
Completed for all NPPs. New mobile equipment has been identified as necessary for all plants for prolonged extreme situations. The needed mobile equipment is in place.

T2.LA.10 – Reassess and update equipment inspection programs
Completed for all NPPs. Plans have been developed to ensure that the procedures for inspection and maintenance are incorporated in ordinary activities, both for equipment that existed before the Fukushima accident and equipment acquired as a result of the stress tests.

T2.LA.11 - Reassess and update training programs
Training programs are reassessed when new equipment and new administrative measures are in place. The training is ongoing as a result of the new installations connected to the ICCS, see chapter 2.1.

T2.LA.12 - Evaluate the need for consumables
Completed for all NPPs. The licensees have evaluated and assessed the technical and administrative measures needed to ensure adequate accessibility during all potential situations.

The conclusions drawn are that the review carried out by all facilities for fuel supplies and consumables do fulfil the requirement.

T2.LA.13 - Evaluate the need for resources
Completed for all NPPs. This issue is handled within the framework of actions in response to the requirements of the emergency regulations, SSMFS 2014: 2.

T2.LA.14 - Evaluate the accessibility of important areas
Completed for all NPPs. The licensees have conducted a review of existing emergency operating procedures with bearing on accessibility of important areas. This has resulted in an updating of the instructions in the Emergency Operating Procedures.

T2.LA.15 – Investigate the effects of simultaneous events affecting all reactors at the site
Completed for all NPPs. The licensees have conducted a review of existing operating procedures with focus on weather and other events that can simultaneously affect all reactors at the site. This has resulted in an update of the instructions in SAR and Operating Procedures.

T2.LA.16 – Reassess the use of severe accident mitigation systems
This is a part of the solutions for ICCS for the BWRs, which will use the severe accident mitigation systems as an ultimate heat sink. The analyses or/and technical improvements showing that this does not affect the system's primary function as a severe accident mitigation system, shall be completed by 2020, see chapter 2.1.

T2.LA.17 – Reassess the procedures and operational training
Ongoing. Procedures and operational training are reassessed when new equipment and new administrative measures are in place. See T2.LA.11.

T2.LA.18 - Evaluate the need for external support
Completed for all NPPs. The licensees have implemented and evaluated external recourses that will be needed in prolonged extreme situations.

T2.LA.19 – Reassess the risk of criticality and/or re-criticality
Completed for all NPPs. For the Ringhals PWRs re-criticality must be considered in the long-term scenario. Measures have been identified and addressed and will be performed in the ICCS project. Boron will be included in the ICCS water and new pump seals installed.

The overall probability for re-criticality that endangers the containment integrity is judged very low for the BWRs based on APRI research.

2.3.2 Actions to be performed by the regulators

No specific actions to be performed by the Swedish regulatory body (RA) have been identified.

2.4 Severe accident management and recovery (On-site)

2.4.1 Actions to be performed by the licensees

The following section describes the status for each measures related to severe accident management performed by the Swedish licensees (LA). Further technical and administrative measures needed are also described.

T3.LA.1 – Consider improvements of the capability to cool the spent fuel pool
The licensees have in a common project developed a "Position Paper" that defines requirements that shall be adopted. Improvements will be in place in parallel to the installation of Independent Core Cooling, see chapter 2.1.

T3.LA.2 – Define the design basis for an independent core cooling system
The licensees have in a common project developed a "Position Paper" that defines requirements that shall be adopted. The requirements have been accepted by the Regulary body and the independent Core Cooling systems shall be in place before the end of 2020, see chapter 2.1.

T3.LA.3 – Investigate instrumentation of spent fuel pool
Completed for all NPPs. This will be followed by introducing necessary instrumentation to monitor temperature and water level in the fuel pools in connection with the introduction of an alternative function for cooling the fuel in the fuel storage pools. See Action T3.LA.1.

T3.LA.4 – Investigate the need for measuring radiation levels
Completed for all NPPs. Recommendations on more dose rate monitors in the reactor building to support accident management have been addressed at all utilities. New monitors have been installed at the NPPs.

T3.LA.5 – Develop a plan to handle more than one affected unit
Completed for all NPPs. As a direct measure after the Stress tests, the licensees have developed training scenarios and emergency exercises in which more than one reactor at each site is involved.

T3.LA.6 – Improve the strategies for managing re-criticality
Completed for all NPPs. The licensees have conducted a review of existing emergency operating procedures with bearing on re-criticality. This has resulted in updating of the instructions in the Emergency Operating Procedures.

T3.LA.7 – Develop the strategies for managing loss of containment integrity
Completed for all NPPs. The licensees have investigated possible strategies on the loss of containment function and approaches to assess the containment damage extent. The outcome of the investigations have been incorporated in the Emergency Operating Instructions.

T3.LA.8 – Evaluate accident management programmes
Completed for all NPPs. A review of the instructions have been carried out for all utilities. Some changes have been implemented based on the findings. As the emergency preparedness organization develops, further mobile equipment are introduced and analyses are carried out. The emergency procedures are continuously developed.

T3.LA.9 – Consider an extended scope of training and drills
Completed for all NPPs. As a direct measure after the Stress tests, the licensees developed training scenarios and emergency exercises in which more than one plant at each site is involved.

T3.LA.10 – Investigate the need for a new call-in system
Completed for all NPPs. The licensees have in some cases decided to introduce enhanced call-in-systems.

T3.LA.11 – Analyze the management of hydrogen
Completed for all NPPs. An investigation regarding the handling of hydrogen (oxyhydrogen) after a severe accident is handled in a joint licensees project within the Nordic Owners group (NOG). Some potential shortcomings in the handling of hydrogen gas after a severe accident have been identified and it will be corrected at the latest 2020 by installing increased venting in identified potential shortcomings.

T3.LA.12 – Investigate the need for means to manage large volumes of contaminated water
Completed for all NPPs. Plans on how to manage large volumes are in place.

T3.LA.13 – Reassess personal safety issues
Completed for all NPPs. This issue is handled within the framework of actions in response to the requirements of the new emergency regulations, SSMFS 2014: 2.

T3.LA.14 – Secure the accessibility of the emergency control center
Completed for all NPPs. This issue is handled within the framework of actions in response to the requirements of the new emergency regulations, SSMFS 2014:2.

T3.LA.15 – Set up action plans for support to local operators
Completed for all NPPs. This issue is handled within the framework of actions in response to the requirements of the new emergency regulations, SSMFS 2014:2.

T3.LA.16 – Reassess the use of containment filtered venting system in the long-term
Completed for all NPPs. Investigations and assessments of the ability to manage a severe accident have been performed by the licensees with different suggested solutions.

T3.LA.17 – Investigate long-term handling of the containment chemistry
Completed for all NPPs. Investigations and assessments of the ability to manage a severe accident have been performed by the licensees. The conclusion of the study is that none of the studied phenomena are expected to provide substantial degradation of the containment and increase the emissions. Uncertainties remain for some plants regarding the risks of corrosion and degradation of polymeric materials. Current research in these areas should be followed.

T3.LA.18 – Evaluate the need for common resources available at the site
Completed for all NPPs. The licensees have evaluated the existing shared resources on the site with different suggested solutions.

T3.LA.19 – Investigate the performance of the common system for filtered containment venting
Not applicable since Oskarshamn 1 and 2 are permanently shut down. No other plants have common containment venting.

2.4.2 Actions to be performed by the regulators

No specific actions to be performed by the Swedish regulatory body (RA) was identified.

2.5 National organizations

2.5.1 Actions to be performed by the operators or other national organizations

The following section describes the status for each measures related to the national organization are given.

T4.NA.1 – Processing the result from the evaluations of the country-wide exercise focusing on a nuclear power plant accident – SAMÖ/KKÖ
The result has been processed.

T4.NA.2 – Processing the result from the evaluations of the performances of the national organizations throughout the first month of the accident at the Fukushima Dai-ichi NPP
Findings related to responsibilities were handled within the framework of the Action Plan *"The Swedish preparedness for radiological and nuclear accidents" (2015)*. Internal development projects have been initiated at the involved authorities to increase the ability to manage a nuclear event. During 2016-2017 a working model following guidelines for effective coordination (SOL) published by the Swedish Civil Contingencies Agency (MSB) has been implemented, exercised and evaluated with good results. During this period, three different exercises were conducted involving the County Administrative Boards that have the primary responsibility for protecting the public during a NPP accident.

T4.NA.3 – Evaluation of the Swedish Defense Research Agency's (FOI) role during a radiological or nuclear emergency
The role of the Swedish Defence Research Agency (FOI) has been evaluated as part of the evaluations mentioned above in T4.NA.2. The responsibilities of FOI during a radiological or nuclear emergency include field and laboratory measurements and analysis (for example within the framework of the national expert response organisation led by SSM). FOI also gives advice to the Government of Sweden and supports SSM with assessment and prognosis in radiological or nuclear emergencies.

T4.NA.4 – A country-wide exercise focusing on a nuclear power plant accident – Havsörn
The exercise included 33 organizations and was carried out in December 2013. The scenario included an event on the NPP Forsmark, in the County of Uppsala, that escalated to a discharge. The exercise included field measurements.

T4.NA.5 – The evaluation of the exercise finished with a final report from the evaluation team – Havsörn
The County Board of Uppsala has produced the final report evaluating the exercise.

T4.NA.6 – Processing the result from the evaluations of the country-wide exercise focusing on a nuclear power plant accident – Havsörn
Most findings are handled within the framework of the Action Plan *"The Swedish preparedness for radiological and nuclear accidents" (2015)*. Various

development projects have been initiated to increase the ability to manage a nuclear event. For example, a table top (Assar) was conducted in December 2014 as a follow-up to increase the ability to handle a nuclear accident.

2.6 Emergency preparedness and response and post-accident management (Off-site)

2.6.1 Actions to be performed by the licensees

The following section describes the status for each measure related to Emergency preparedness and response and post-accident management performed by the Swedish licensees (LA). Further technical and administrative measures needed are also described.

T5.LA.1 - Clarify the responsibility for decontamination stations outside the site for personnel during shift turnovers and how equipment is to be replaced
Handled within the update of the emergency plan.

T5.LA.2 - Investigate the course of action during a long-term need for personnel
Handled within the update of the emergency plan.

T5.LA.3 - An investigation is suggested to ascertain advantages and disadvantages in replacing the present substitute Command Centre with a suitable office outside the site
Handled within the update of the emergency plan.

T5.LA.4 - It shall be investigated whether some of the functions included in the emergency preparedness organization staffing are sufficient, to sustain shifts around the clock
An investigation has been conducted and the number of persons to maintain permanent staffing around the clock in case of emergency has been established for the roles in the emergency response organization. The results have been incorporated in the emergency plan.

T5.LA.5 - Presently calling in personnel depends on a functioning GSM/Telenet. An improvement in this area shall be investigated
Handled within the update of the emergency plan in 2014.

T5.LA.6 - Identify alternative evacuation routes. Alternative collection sites shall be decided upon and incorporated in the licensee's emergency plans
These sites shall be communicated with the emergency planning at the county administration board. Handled within the framework of actions in response to the requirements of the new emergency preparedness regulations, SSMFS 2014:2.

T5.LA.7 - The Command Centre shall be connected to its own auxiliary power supply that is independent of the regular power supply at the plant site.
Auxiliary power is now in place for all the Command Centres.

2.6.2 Actions to be performed by the regulators

The following section describes the status for each measures related to Emergency preparedness and response and post-accident management performed by the Swedish regulatory body (RA).

2.6.2.1 Actions identified in Sweden at a national level

T5.RA.1 - Up-dating and formalization of pre-defined criteria on countermeasures and the implementation of measurable operational intervention levels and routines for application of intervention levels

On 22 October 2015, the Government of Sweden commissioned the Swedish Radiation Safety Authority (SSM) to, in consultation with the Swedish Civil Contingencies Agency (MSB), relevant county administrative boards and other competent authorities and stakeholders, perform a review of emergency planning zones and emergency planning distances applying to activities involving ionising radiation. The review, presented to the Government of Sweden on 1 November 2017, encompasses overall objectives for the emergency planning, the types of emergency planning zones and emergency planning distances that should be established, reference levels that should serve as the basis for emergency planning, and dose criteria and intervention levels for different protective actions. The review considers events at, and emergency planning zones surrounding, the nuclear power plants, a fuel fabrication plant and the central interim storage facility for spent nuclear fuel in Sweden. An ongoing project, expected to be finished by the end of 2020, will cover pre-defined criteria for events related to activities and acts in emergency preparedness category IV. The project will result in a document complementary to the review (2017) and in line with the "Nordic Flagbook" (2013) "*Protective Measures in Early and Intermediate Phases of a Nuclear or Radiological Emergency, Nordic Guidelines and Recommendations*".

T5.RA.2 - SSM and the nuclear facilities are currently working towards establishing a system for electronic transmission of plant data from the Swedish nuclear power plants to SSM's Emergency Response Centre.

A system for electronic transmission of plant process parameters from nuclear power plants is now in place in SSMs emergency centre. Now focus is on implementation, education and training.

T5.RA.3 - Implementation of the revised Swedish regulation SSMFS 2008:15, SSM's Regulations concerning Emergency Preparedness at Certain Nuclear Facilities.

Implemented.

T5.RA.4 - The Nordic Flag Book
In the last quarter of 2013 the "Nordic Flagbook", "*Protective Measures in Early*

and Intermediate Phases of a Nuclear or Radiological Emergency, Nordic Guidelines and Recommendations", was completed and approved by the Director Generals of the Nordic Radiation Safety Authorities. The "Nordic Flagbook" has been translated into Swedish during 2014. See answer to T5.RA.1 for further information.

2.7 International cooperation

2.7.1 Actions to be performed by the licensees

The following section describes the status for each measure related to International cooperation performed by the Swedish licensees (LA). Further technical and administrative measures needed are also described.

T6.LA.1- -Expanding the scope of WANO Peer Reviews
Ongoing.

T6.LA.2 - Expanding the frequency of WANO Peer Reviews
Ongoing.

T6.LA.3 - Developing a world-wide integrated event response strategy
Ongoing.

2.7.2 Actions to be performed by the regulators

The following section describes the status for each measures related to International cooperation performed by the Swedish regulatory body (RA).

T6.RA.1 - Accede to the 2004 Protocol to amend the Paris and Brussels Conventions on Third Party Liability in the field of nuclear energy
Ongoing.

T6.RA.2 - Assessment and improvement of international crisis communication and information dissemination
The Swedish emergency preparedness guidelines have been updated. Sweden participates in WENRA and HERCA.

T6.RA.3 - IRRS recommendation to SSM to establish and implement guidance for dissemination of all significant operating experience and lessons learned to all relevant authorized parties
This is an ongoing process.

T6.RA.4 - Actively participate in information exchange after the Fukushima accident – International organizations
Ongoing. Sweden participates in relevant meetings and information exchange.

T6.RA.5 - IRRS-recommendation: Better ensure compliance with relevant IAEA Standards
Completed, the internal guidelines are updated and have been checked against IAEA guides and standards. This is also an important part of the on-going project to update regulations related to operating NPP:s.

T6.RA.6 - More strategic coordination and follow-up of the work in the different IAEA Safety Standards Committees
Ongoing.

T6.RA.7 - Fulfillment of WENRA reference levels (RLs)
Ongoing. New requirements that were planned to be in place 2018 are now planned to be in force at the end of 2021.

2.8 Generic actions to be performed by the regulators

Generic measures related to two or more topics that are to be performed by SSM are given in the following Section.

G.RA.1 - Implementation of the results from the analysis of long-term safety
Ongoing, including extensive review and development of existing requirements that will be completed 2021 and a new inspection program that also will be implemented 2021 (see also T6.RA.7).

G.RA.2 - Review of actions belonging to category 2013
The reports are followed up by SSM and actions are undertaken when needed.

G.RA.3 - Review of actions belonging to category 2014
The reports are followed up by SSM and actions are undertaken when needed.

G.RA.4 - Review of actions belonging to category 2015
The reports are followed up by SSM and actions are undertaken when needed.

3 Summary of the implementation and necessary technical and administrative measures

Due to the fact that the main parts of the measures in the Swedish national action plan were investigations, necessary technical and administrative measures were planned to be implemented and completed after 2015. The final date for these actions was set to 2020 in the Swedish National Action Plan. However in many cases SSM decided that necessary measure should be implemented earlier than 2020 in order to secure that the implementation took place as soon as reasonably possible without jeopardizing reactor safety.

3.1 Relevant outcomes of studies and analyses identified in the NAcPs, and completed since the 2014 workshop

The licensees have completed all analyses/studies/investigations that were requested in 2013, 2014 and 2015. In order to further raise the level of safety, SSM issued in December 2014 an injunction requiring the installation of ICCS. The system is activated if the other cooling systems fail to function in connection with an accident. The installation of an ICCS is a condition for operation after 2020.

The main basic design requirements for ICCS are ELAP (Extended Loss of AC Power) or LUHS (Loss of Ultimate Heat Sink) for at least 72 hours, in combination with extreme events with an exceedance frequency of 10^{-6} per annum, without the need for manual measures for the first 8 hours.

3.2 Good practices and challenges identified during the implementation so far

The installation of the ICCS is the most extensive single measure to be introduced connected with the National action plan. Due to the fact that it necessarily would require a relatively long time for the final full scope implementation, SSM decided on transitional measures to be implemented before 31 December 2017. The transitional measures have been completed for all NPPs and will be reviewed by SSM in early 2018.

Since the time is very limited for designing and installing such an extensive system, it was necessary for SSM to define the requirements on the basic design criteria early. There has also been a successful strategy from the licensee side with a joint group including members from all licensees and the owners. The group, KSKG, identified critical key issues that needed to be solved or clearly described in the requirements. A series of meetings were held between SSM and KSKG to assure the understanding of the requirements.

The transitional solutions installed by 2017 have primarily focused on actions that provided, with limited modification, a substantial increase of the safety level. Because of different generations and different designs of the Swedish NPPs, the transitional solutions are different. The measures are based on the results from the Stress tests and PSA studies have verified their importance. For most of the plants,

the transitional solutions have focused on increasing the independence of the emergency power for the existing core cooling systems.

Finally, it is worth stressing as another important success factor the comprehensive safety modernisation carried out at Swedish NPPs between 2006 and 2014 as a result of the updated design regulation SSMFS 2008:17. The main areas for the safety modernization has been to reinforce independence, diversification, to increase separation and measures performed to fulfil the requirement to withstand extreme external events. These measures have created a good basis for meeting the requirements linked to the experience after the nuclear accident in Fukushima.

A general challenge worth mentioning is that many questions in NAcP have a relatively open formulation, i.e. "an investigation shall be performed", "a study shall be performed", "… shall be further analysed and reassessed", etc. The fact that all licensees have identical questions to address in the NAcP has stimulated cooperation and dialogue, which is positive.

The fruitful exchange of opinions and discussions of possible solutions and gained benefits has made it possible to choose the most important solutions first. In addition, the use of PSA to point out the most relevant measures to be performed has shown that the SSMFS 2008:17 requirements have increased the safety at the NPPs.

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List of Acronyms

AC	Alternating Current
APRI	Accident Phenomena of Risk Importance
ATWC	Anticipated Transient Without all Control rods
ATWS	Anticipated Transient Without Scram
BWR	Boiling Water Reactor
CNS	Convention of Nuclear Safety
DBE	Design Base Earthquake
DBF	Design Base Flooding
DC	Direct Current
EC	European Commission
ENSREG	European Nuclear Safety Regulators Group
EU	European Union
EXWE	Extreme Weather
F1	Forsmark unit 1
F2	Forsmark unit 2
F3	Forsmark unit 3
FOI	The ministry of the environment and the Swedish defense research agency
HERCA	Heads of European Radiological Competent Authorities
IAEA	International Atomic Energy Agency
ICC	Independent Core Cooling
ICRP	International Commission on Radiological Protection
INRA	International Nuclear Regulators Association
IRRS	Integrated Regulatory Review Service
ISP	The Swedish Agency for Non-Proliferation and Export Controls
LOCA	Loss Of Coolant Accident
MSB	The Swedish civil contingencies agency
MTO	Man-Technology-Organization
MVSS	Multi-Venturi Scrubber System
NPP	Nuclear Power Plant
NUSSC	The Nuclear Safety Standards Committee
O1	Oskarshamn unit 1
O2	Oskarshamn unit 2
O3	Oskarshamn unit 3
OECD/NEA	The Nuclear Energy Agency (NEA) within the Organization for Economic Co-operation and Development (OECD),
PS	Pressure Suppression

PSA	Probabilistic Safety Assessment
PSR	Periodic Safety Reviews
PWR	Pressurized Water Reactors
R1	Ringhals unit 1
R2	Ringhals unit 2
R3	Ringhals unit 3
R4	Ringhals unit 4
RASSC	Radiation Safety Standards Committee
SAFIR	The Finnish research programme on nuclear power plant safety
SAM	Severe Accident Management
SAR	Safety Analyses Report
SBO	Station Black Out
SKI	Swedish nuclear power inspectorate
SMA	Seismic Margin Assessment
SMHI	The Swedish Meteorological and Hydrological Institute
SSM	The Swedish radiation safety authority
TMI	Three Mile Island
TRANSSC	The Transport Safety Standards Committee
UD	The ministry for foreign affairs
WANO	The World Association of Nuclear Operators
WASSC	Waste Safety Standards Committee
WENRA	Western European Nuclear Regulators' Association