Strålsäkerhetsmyndigheten
Swedish Radiation Safety Authority

2021 FINAL REPORT –
SWEDISH NATIONAL ACTION PLAN

Response to ENSREG's request within the European Stress Tests, January 2022

Stockholm, January 26, 2022

Abstract

The present report constitutes the final report of the Swedish National Action Plan (NAcP).

All measures in the NAcP have been completed in accordance with the original given time schedule, meaning that all identified measures were fully implemented by the end of 2020, following the Independent Core Cooling System (ICCS) installations. The ICCS is a major safety enhancing technical measure that was required to be in place by the end of 2020 at all Swedish NPPs that continued operation after 2020. The ICCS provides core cooling that is completely independent from previously existing CC systems in terms of power supply and water source. It is also significantly more robust and built to handle extended loss of power supply and ultimate heat sink.

The installation of the ICCS is the most extensive single measure in the Swedish NAcP. As it necessarily required a relatively long time for design and implementation, SSM also decided on transitional measures to be implemented by 31 December 2017. These measures were completed for all NPPs in accordance with the decisions, with solutions that primarily focused on actions that provided, with limited modification and without fulfilling robustness requirements, a substantial increase of the safety level.

The Swedish NAcP was first issued in December 2012 and was reviewed and revised in December 2014, December 2017 and March 2020. This report is the final update of the Swedish NAcP describing the status of all actions included in the plan.

In general, the Swedish NAcP required investigations to be performed with the aim to identify necessary technical and administrative measures, how they should be implemented as well as appropriate time schedules for the implementation of these measures. All actions resulting from these investigations were fully implemented by the end of 2020.

SSM has continuously performed reviews and follow-up on the licensee actions concerning the Swedish NAcP. Due to the high degree of complexity, the majority of the necessary technical and administrative measures identified by the investigations included in the Swedish NAcP were implemented after 2015.

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 was to reinforce independence, to increase diversification, to increase separation, and measures performed to fulfil the requirement to withstand extreme external events. This created a good basis for meeting many of the requirements linked to the experience after the nuclear accident in Fukushima. Hence, the completion of the then still ongoing safety modernization programme was a top priority in parallel with the completion of the stress test activities.

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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. It was also decided that a follow-up of the NAcPs should be compiled and evaluated every 3 years, starting in 2014. In December 2012 the Swedish Radiation Safety Authority issued the Swedish NAcP (3), and in December 2014 a reviewed and revised Swedish NAcP (4) was published followed by a new revision in December 2017 and March 2020. The present report is the final report of the Swedish NAcP.

1.2 Brief description of the Swedish NAcP

The Swedish NAcP consists of measures identified during the EU stress tests as well as by other fora such as the second extraordinary meeting under the Convention on Nuclear Safety. The Swedish NAcP 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). However, it 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 NAcP, 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 NAcP, 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 very extensive Swedish nuclear power plants modernization programs (2006-2014), 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 NAcP, 2012 (3) and 2014 (4).

In general, the Swedish NAcP identifies investigations whose aim it was 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 NAcP 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 NAcP 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 NAcP, 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 NAcP.

During the implementation of the Swedish NAcP, 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 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 NAcP concluded that no further technical and administrative measures were needed.

1.3 Brief description of the Swedish nuclear power plants

Since the first Swedish NAcP was issued in 2012, four Swedish nuclear power plants, Oskarshamn 1, 2 and Ringhals 1, 2 have been permanently shut down. This means that there are currently 6 nuclear power reactors in operation in Sweden; four BWRs and two PWRs. 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 four remaining BWRs 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 short circuit in the 400 kV substation that affected the electric power system 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 that were issued in 2005. These regulations 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 that have been implemented during the latest years, to strengthen the robustness of Swedish NPPs.

In October 2014, SSM announced a two-stage set of safety upgrades of the core cooling at Sweden's operating nuclear power reactors. As an intermediate step, by the end of 2017 all reactors were required to have independent systems to ensure that power and water are available for emergency cooling for a period of 72 hours. This requirement could be met by means such as mobile diesel generators and external water storage. By the end of 2020, the regulator required the plants to install a system for independent core cooling (ICC), i.e., a "robust permanent installation that includes power supply and systems for pumping of water and an external water source independent of those used in existing emergency cooling systems." The system must also be able to handle extreme external influences, such as significantly stronger weather conditions, seawater levels and earthquakes than the existing safety system. The installation of such systems required engineering deep within the reactor building and potentially its primary coolant circuit.

1.4 Structure of the report

The 2014 update of the Swedish NAcP 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 is an update of the 2020 year Swedish NAcP and focuses on the final status on implementation of the measures (Chapter 2).

2 Implementation of technical and administrative measures

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

2.1 Implementation of the Independent Core Cooling

The most important measure in the Swedish NAcP is the implementation of the Independent Core Cooling system (ICCS). Other important technical measures are the implementation of more robust cooling of spent fuel pools and more robust supply of emergency power. The ICCS was not an explicit part of the first version of the Swedish NAcP , but was foreseen as a consequence of the results of the analyses, studies and investigations requested in the Swedish NAcP 2013. The ICCS will provide alternative core cooling if the normal safety systems are unavailable in a situation with design extension conditions. In December 2014 SSM issued an injunction requiring the installation of the ICCS, as a condition for operation after 2020. This condition applies to six reactors, since four of the Swedish reactors have been permanently shut down in the period between 2014 and 2020.

The main basic design requirements for ICCS are the ability to handle:

- 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, and the ICCS should operate without the need for manual action the first 8 hours. The system have been in operation since late 2020 at all reactors, in accordance with the injunction from 2014.

Forsmark NPP

ICCSs have been installed for Forsmark 1, 2 and 3. For Forsmark 1 and 2, the ICCS has been placed in a new building with its own water source adjacent to the reactor building of Forsmark 1. The power supply is galvanically separated from the plant's normal electrical power system via a motor-generator set. The water source is 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 has its own new building designed according to the same principles. 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

ICCSs have been installed for Ringhals 3 and 4. 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 water to the 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 normal 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

ICCS has been installed for Oskarshamn 3. The ICCS function comprises a new low pressure make-up system with a diesel-driven pump, also giving electrical support. The primary water source is the central fuel 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.

2.2 Natural hazards

2.2.1 Actions performed by the licensees

In this section, the final 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 installed 2020 earthquakes with the exceedance frequency of 10^{-6} per annum are 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, show that the NPPs can handle extreme weather with the exceedance frequency of 10^{-5} per annum. For the ICCS installed

2020, extreme weather with the exceedance frequency of 10^{-6} per annum is 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 installed 2020, extreme water level with the exceedance frequency of 10^{-6} per annum is 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. For the ICCS installed 2020, flooding margins with the exceedance frequency of 10^{-6} per annum is considered for the design.

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 ICCS installed 2020, extreme external hazards with the exceedance frequency of 10^{-6} per annum is considered for the design.

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 final 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
A study to better estimate extreme weather conditions has been performed as a research project by the licensees. The resulting extreme weather conditions have been used as design conditions for the construction of the ICC.

2.3 Design issues

2.3.1 Actions to be performed by the licensees

The following section describes the final 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 is a part of the ICC-solutions.

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 is a part of the ICC-solutions.

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. At some of the plants, the analyses showed that there were considerable margins in the battery capacity. 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 (PWR), which have been replaced.

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.LA2. 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 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 were identified as necessary for all plants for prolonged extreme situations. The needed mobile equipment is in place. As part of the ICCS decision, SSM decided on transitional measures to be implemented before 31 December 2017. The transitional measures were completed for all NPPs in accordance with the decisions.

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 normal 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
Completed for all NPPs. Training programs were reassessed when new equipment and new administrative measures were in place.

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 were 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 was handled within the framework of actions in response to the requirements of the new 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 related to the accessibility of important areas. This 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 uses the severe accident mitigation systems as an ultimate heat sink. Analyses or/and technical improvements showing that this does not affect the system's primary function as a severe accident mitigation system have been performed.

T2.LA.17 – Reassess the procedures and operational training
Completed for all NPPs. Procedures and operational training are reassessed when new equipment and new administrative measures are in place.

T2.LA.18 - Evaluate the need for external support
Completed for all NPPs. The licensees have implemented and evaluated external recourses that are 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 were identified and addressed and were considered in the ICCS project. Boron is included in the ICC water and new pump seals have been installed.

The overall probability for re-criticality that endangers the containment integrity is judged very low for the BWRs based on research performed within the long term Swedish program APRI (Accident Phenomena of Risk Importance).

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 final 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.

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.

T3.LA.3 – Investigate instrumentation of spent fuel pool
Completed for all NPPs. This has been addressed 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 relevant for re-criticality. This has resulted in updating of 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 for managing loss of containment function and approaches to assess the extent of containment damage. 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 will be introduced as needed and analyses 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 licensee project. Some potential shortcomings in the handling of hydrogen gas after a severe accident have been identified and have been corrected by installing increased venting in identified potentially vulnerable locations.

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 were performed by the licensees with different suggested solutions. Implementation of the ICCS, which takes into account the filtered venting system for residual heat removal, also resulted in more detailed analyses.

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 lead to 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 is 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 final 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) have been implemented, exercised and evaluated with good results. During this period, three different exercises were conducted involving the County Administrative Boards, which have the primary responsibility for protecting the public during a NPP accident.

T4.NA.3 – Evaluation of the Swedish Defence 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 final 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 required 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 final 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. In 2020, the Swedish Radiation Safety Authority (SSM) published a report on the planning basis for activities and acts in emergency preparedness category 4 (SSM 2020:15). The report covers pre-defined criteria on countermeasures and the implementation of measurable operational intervention levels and routines for application of intervention levels for nuclear or radiological emergencies. The report will be published in English during 2021. The reports complements earlier reports for facilities in emergency preparedness category I, II and III.

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.

The system is installed.

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

The regulation has been 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" was translated into Swedish during 2014.

2.7 International cooperation

2.7.1 Actions to be performed by the licensees

The following section describes the final status for each measure related to International cooperation performed by the Swedish licensees (LA).

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 final 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.

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. The new regulations will come into force in March 2022.

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

T6.RA.7 - Fulfilment of WENRA reference levels (RLs)
Ongoing. New regulations will come into force in March 2022.

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
Completed, Extensive review and development of existing requirements were completed 2018 and a new inspection program was also implemented 2018.

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

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

G.RA.4 - Review of actions belonging to category 2015
The reports are followed up by SSM and actions have been taken 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 NAcP consisted of 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 NAcP.

3.1 Relevant outcomes of studies and analyses identified in the Swedish NAcP, 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 a system for Independent Core Cooling (ICC). The ICCS is activated if the other cooling systems fail to function in connection with an accident. The installation of an ICCS was a condition for operation after 2020.

The main basic design requirements for the 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

The installation of the ICCS is the most extensive single measure that have been introduced connected with the Swedish NAcP, due to the fact that it necessarily required a relatively long time for the final full scope implementation, SSM also decided on transitional measures to be implemented before 31 December 2017. The transitional measures were completed for all NPPs in accordance with the decisions.

Since the time was very limited for designing and installing such an extensive system as the ICCS, it was necessary for SSM to define the requirements on the basic design criteria early. There was also 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 mutual understanding of the requirements.

The transitional solutions installed by 2017 primarily focused on actions that provided, with limited modification, a substantial increase in the safety level. Because of different generations and different designs of the Swedish NPPs, the transitional solutions were different. The measures were based on the results from the Stress tests and PSA studies have verified their importance. For most of the plants, the transitional solutions 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 (originally SKIFS 2004:02). 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 created a good basis for meeting the requirements linked to the experience after the nuclear accident in Fukushima. Hence, the completion of the then still ongoing safety modernization programme was a top priority in parallel with the completion of the stress test activities.

A general challenge worth mentioning is that many questions in the Swedish 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 had identical questions to address in the Swedish NAcP stimulated cooperation and dialogue, which was positive.

The fruitful exchange of opinions and discussions of possible solutions and gained benefits 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 also contributed to increase 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
ICCS	Independent Core Cooling System
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
RPV	Reactor Pressure Vessel
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