Summary Report – Nuclear Projects 2025

Energiforsk Nuclear Portfolio

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Content

Preface

This document contains brief introductions to all projects that were finalized and/or published in Energiforsk Nuclear Portfolio Programs during the year 2025.

The Energiforsk Nuclear Portfolio consists of seven different R&D programs - Concrete, Outlook & technology, ENSRIC (I&C issues), GINO (Grid interaction), Vibrations, Polymeric materials and Digitalization.

The introductions on project reports include information on:

- General background on the purpose of the study
- Why the issue is important for nuclear power plants
- Results and conclusions

The complete reports can be found on the respective program web page, which can be found by navigating to www.energiforsk.se and chose Forskning -> Kärnkraft (Swedish webpage) or English -> Research -> Nuclear Power (English webpage).

Please note: the project report introductions have been produced using co-pilot. They are intended to give brief introductions to promote further reading, not to constitute complete summaries of each report.

1. Nuclear Power Concrete Technology

1.1 Project reports

1.1.1 2024-1022 Nonlinear Ultrasonic Evaluation for Corrosion Assessment of Steel Plates Embedded in Concrete

Project finished in 2024 but published in 2025.

The study investigates whether nonlinear ultrasonic methods can detect and assess corrosion in steel plates embedded in concrete, aiming to improve nondestructive evaluation techniques for nuclear-related concrete structures.

Corrosion in containment liner plates can threaten leak-tightness and structural integrity in nuclear power plants, making early, reliable detection essential for long-term safety and life-extension of aging reactors.

Experiments showed nonlinear ultrasonics can detect severe corrosion, delaminations, and foreign materials. Combined linear and nonlinear imaging improved damage assessment, though further testing on realistic large-scale structures is needed.

The study was performed by Markus Nilsson of Lund University.

1.1.2 2025-1102 Shear Force Capacity of Existing Concrete Slabs

The study examines shear and punching shear capacity in existing reinforced concrete slabs, comparing historical and modern design codes to understand discrepancies and factors influencing structural capacity.

Accurate shear capacity assessment is critical in nuclear facilities because aging slabs, upgrades, and evolving design standards affect structural safety, reliability, and the ability to demonstrate code compliance.

Results show older codes often overestimate shear capacity, while Eurocode 2 provides more conservative predictions; punching shear capacities vary by method, emphasizing code differences and the need for careful evaluation.

The study was performed by Lamis Ahmed at Vattenfall Power Solutions.

1.1.3 2025:1123 Wood-induced corrosion on steel plates embedded in concrete

The study investigates how wood in contact with embedded steel plates can initiate corrosion by forming active/passive cells, aiming to understand early-stage mechanisms and influencing factors.

Wood-induced corrosion threatens the integrity of steel liners in reactor containments, posing safety risks and complicating maintenance in nuclear facilities.

The study shows corrosion occurs when wood is moist, voluminous, well-pressed against steel, and electrically connected to an external cathode; initiated cells may stabilize or fade depending on conditions.

The study was performed by Jonas Engblom, Bertil Sandberg and Johan Ahlström at RISE.

1.1.4 2025-1130 Determination of stresses in grouted strands of a reactor containment by a destructive test method

The study investigates stresses in bonded prestressing tendons from the decommissioned Barsebäck reactor containment using destructive testing to better understand long-term behaviour and performance of grouted strands.

Accurate tendon stress assessment is crucial because prestressed containments rely on tendon forces to maintain structural integrity and leak-tightness during accidents such as loss-of-coolant events.

Measurements showed tendon stresses could be reliably estimated by instrumentation and strand cutting, and Barsebäck's tendons exhibited only minimal prestress loss, indicating favourable material conditions and limited long-term degradation.

The study was performed by Peter Lundqvist of Vattenfall and Manouchehr Hassanzadeh of Sweco.

1.2 Other activities

1.2.1 Kraftindustrins Betongdag 2025

The annual Kraftindustrins Betongdag (Power industry Concrete Day) was arranged in March in Älvkarleby, in cooperation with the Energiforsk Concrete in Hydropower applications Program.

Among the presentations were a GAP-analysis of the 2nd generation Eurocode for concrete dams, Actions to reduce climate imprint of wind turbine foundations, as well as the three first projects listed under 1.1 above.

1.3 Chairperson reflections: Christian Bernstone, Concrete program Chair

In the report series, **Markus Nilsson's work on nonlinear ultrasound for detecting corrosion in embedded liner plates** is a good example of the useful work that is being done in the program. The work demonstrates how corrosion products on liner plates produce strong nonlinear responses and can thereby reveal damage that is otherwise difficult to detect through the missile shielding provided by concrete. The method is still at an early stage of

development, but there is clear potential that is fully aligned with the industry's need for improved NDT methods for reactor containments.

2. Energiforsk Nuclear Safety Related I&C, ENSRIC

2.1 Project reports

2.1.1 2025:1114 Process for Managing Ageing of I&C Equipment

The report develops a best-practice process for managing ageing and obsolescence of safety-related I&C equipment in Nordic nuclear power plants, based on literature reviews and interviews.

Ageing I&C systems threaten safe, reliable long-term operation, especially as Nordic plants operate beyond original lifetimes; effective ageing management is essential to prevent failures in safety-critical functions as well as in systems important for continuous operation.

The study proposes a generic lifecycle-integrated process covering scoping, monitoring, assessment and mitigation. Key conclusions highlight grouping components, strong supplier dialogue and integrating ageing management into existing routines.

The study was performed by Gabriel Aspegren and Emelie Gaveberg at Solvina AB.

2.1.2 2025:1136 Cyber Security for Operational Technology

The study aims to provide Nordic nuclear operators with practical guidance for strengthening cyber security in operational technology by mapping regulations, assessing standards, and gathering cross-industry lessons to support safer digitalised operations.

Cyber security is vital for nuclear power plants because increasing digitalisation, evolving threats and regulatory demands require robust protection of control systems to ensure safe, reliable, and resilient plant operation.

The study concludes that strong governance, systematic use of standards, supply-chain control, continuous improvement, and an OT-security checklist are essential for effective protection and alignment with future regulatory expectations.

The study was performed by Maria Alsterskär, Johan Ander, Fredrik Ekelund and Torsten Engström at Sweco Sverige AB.

2.2 Other activities

2.2.1 Workshop on competence for analogue I&C equipment

A closed workshop for experts employed by the nuclear power plants, with the purpose of candidly discussing and benchmarking issues around employing and keeping competence on old or even obsolete technology.

2.3 Chairperson reflections: Emil Ohlson, ENSRIC Chair

The issue with both keeping and developing competence within the nuclear I&C area is one of the biggest challenges we have at the plant. To have a common understanding and plan within the Nordic Nuclear community is key in dealing with this issue. The discussions, presentations, and ideas we had at the **Workshop on competence for analogue I&C equipment** could really make a difference going forward. To get valuable contacts to peers at other plants was also a big positive outcome of this workshop.

3. Grid Interaction with Nuclear Power Plant Operations, GINO

3.1 Project reports

3.1.1 2025-1083 Robustness indicators for power systems

The study set out to develop simple, meaningful indicators that describe power system robustness by analysing how preconditions, unplanned events and operator measures lead to observable outcomes such as frequency and voltage quality.

Robustness is important for power systems serving nuclear power plants because stable frequency and voltage are essential for secure operation, especially as the Nordic grid transforms with more variable energy sources.

The results show a general framework for selecting robustness indicators and demonstrate its application to frequency and voltage. The study concludes that a small, clear set of indicators can effectively track long-term trends.

The study was performed by Camille Hamon, Gustav Elfving, Erica Lidström and Simon Lindroth at Sweco Sverige AB.

3.1.2 2025-1090 Voltage dip transients and auxiliary equipment in nuclear power stations

The study investigates how voltage-dip transients from transmission-grid faults arise, propagate, and affect auxiliary equipment in nuclear power plants, aiming to improve understanding and develop recommendations for increased equipment robustness.

These transients, oscillations that occur at the beginning and ending of voltage dips, are important because they can amplify within plant systems, potentially disrupting converters and protection functions essential for nuclear safety, posing operational and reliability risks.

Results show that transient characteristics vary widely with fault type and location, and that the magnitude of the oscillations may be larger at the equipment terminals than in the grid. The study concludes that transients require greater attention and further research.

The study was performed by Math Bollen and Abdallah Ammar Hoseny Uosef at Luleå University of Technology

3.1.3 2025-1091 Trends of frequency deviations

The study investigates two decades of Nordic grid frequency data to understand long-term trends and how these deviations relate to system stability and nuclear power plant operation.

Stable frequency is crucial for nuclear plants because deviations can affect equipment performance, and component lifetime, especially during large grid disturbances or rapid power imbalances.

Results show improved frequency quality in recent years, limited correlation between low inertia and poorer frequency quality, and no reported wear-and-tear issues in nuclear plants caused by frequency deviations.

The study was performed by Viktorija Dudjak, Jonas Persson and Markus Björklund at Vattenfall Research & Development.

3.1.4 2025-1107 Exchange Strategies for Power Electronics in Rectifiers and UPS System for NPP

The study investigates how obsolete power electronics can be replaced with modern technologies to maintain safety, reliability, and compliance in nuclear power plant auxiliary systems.

Reliable auxiliary power is vital for nuclear plants because failures in rectifiers, converters, or UPS units can compromise safety systems, especially during grid disturbances, transients, or loss of off-site power events.

The results show that modern solutions improve efficiency but introduce new challenges in robustness and qualification. Conclusions emphasize predictive maintenance, redundancy, careful design validation, and gradual transition to ensure safe long-term operation.

The study was performed by Yubo Song, Huai Wang and Frede Blaabjerg at Aalborg University

3.1.5 2025-1118 Impact of over-frequency events on Nordic NPPs

The study investigates how increasing over-frequency events in the Nordic power system may affect nuclear power plants, using simulations to understand system behaviour under different HVDC-related and system split disturbance scenarios.

Over-frequency events are important because sudden power imbalances or system splits can cause rapid frequency rises that stress turbines, protection systems, and safety-critical equipment in nuclear power plants.

The results show that NPPs can handle most HVDC-related disturbances, but extreme system-split scenarios may exceed design limits. Conclusions highlight the need for monitoring, scenario analysis, and improved coordination with grid operators.

The study was performed by Matilda Arvidsson, Andreas Benjaminsson, Lucas Finati Thomée and Daniel Karlsson at DNV

3.1.6 2025-1145 Fast Frequency Support Impact On Nuclear Generation

The study examines how Fast Frequency Support from HVDC links influences frequency stability and rotor-angle stability in the Nordic power system, focusing on interactions with nuclear power plant generator dynamics.

This issue is important because nuclear units provide large inertia and essential stability services; unintended control interactions could affect electromechanical oscillations, damping, and overall robustness during major frequency disturbances.

Results show droop-based support improves frequency damping without harming nuclear stability, while synthetic inertia generally performs well but can reduce damping in stressed, weak-grid conditions, requiring careful tuning and coordination.

The study was performed by Danilo Obradović at RISE Research Institutes of Sweden.

3.2 Other activities

3.2.1 Project presentation webinar

A webinar with presentations of all projects listed above except the last was held on the 22nd of May.

3.2.2 Annual GINO seminar – joint with Vibrations 2025

The seminar was a full-day event, held at the SSM offices in Stockholm. Presentations included Lina Bertling Tjernberg (KTH) on System services, Robert Eriksson (UU) on Forced oscillations, Omar Juarez Moreno (SvK) on the ENTSOE report on the Iberian incident, as well as project presentations from the GINO and Vibrations programs.

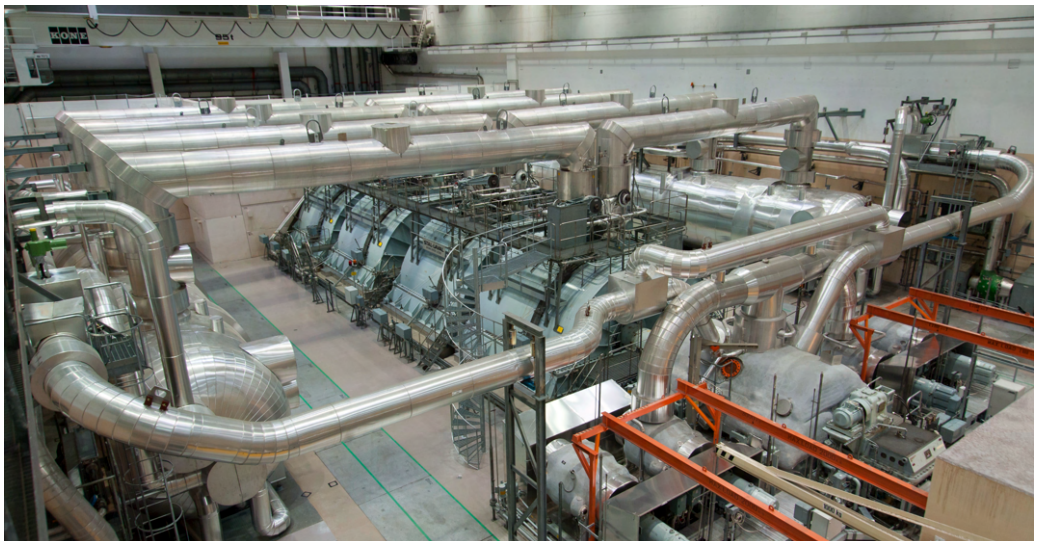
3.3 Reflections: Ari Kanerva, GINO program Steering group member

We carried out several interesting projects during 2025, but if I had to highlight one, my personal favourite would be **Impact of Over Frequency Events on Nordic NPPs**.

The work examines a phenomenon that has not been extensively studied in recent years. What I find particularly valuable is how the study brings together historical experience and simulation based analysis of potential disturbances.

This type of data is essential for nuclear power plants, as it helps ensure that our design criteria adequately address all relevant disturbance scenarios and that nuclear safety is consistently maintained. In addition, as we are currently progressing with our system modernization program, it is crucial that we define the correct requirements for the equipment. This study supports that effort very well.

4. Vibrations in Nuclear Applications



4.1 Project reports

4.1.1 2025-1084 Development of a Digital Twin for Torsional Vibrations of Turbogenerators

The study investigates whether a Digital Twin can be developed to monitor and analyse torsional vibrations in turbogenerators, aiming to improve detection of harmful vibration behaviour in nuclear power plants.

Torsional vibrations are difficult to measure yet critical to control, as undetected oscillations can damage turbines or generators, causing costly outages and threatening operational safety in nuclear facilities.

The project showed that a Digital Twin, built on finite-element modelling, measurements and calibration routines, can accurately reproduce vibration behaviour, identify parameter changes and support continuous monitoring and diagnostics.

The study was performed by Sven Herold, Hendrik Holzmann and Rainer Nordmann at Fraunhofer Institute LBF Darmstadt.

4.1.2 2025-1105 Cavitation induced vibrations in orifice plates and a partially closed valve

The study aimed to experimentally investigate cavitation and flow-induced vibrations in orifice plates and a partially closed valve to generate high-quality validation data for advanced CFD modelling.

Cavitation-induced vibrations are important for nuclear plants because they can cause fatigue, strong oscillations and erosion, threatening the integrity of piping components and increasing operational and safety risks.

Results showed strong cavitation and high vibrations for single-hole orifices, while multi-hole plates produced lower vibration levels. The partially closed valve caused wall-adjacent cavitation with higher erosion risk.

The study was performed by Kristian Angele at Vattenfall Research and Development.

4.1.3 2025-1137 Blade Vibrations in Turbines

The study aims to explain how steam-turbine blade vibrations arise, how they are influenced by design and operating parameters, and how they can be modelled, monitored and mitigated to ensure reliable turbine performance.

Blade vibrations are important in nuclear power plants because excessive oscillations can cause fatigue, cracking or blade failure, threatening turbine integrity, plant availability and overall operational safety.

The results show that vibration origins include steam-force excitations, rotor–blade interactions and aeroelastic effects, and that proper design, monitoring and mitigation measures can significantly reduce vibration risks.

The study was performed by Dr. Rainer Nordmann at the Technical University Darmstadt.

4.2 Other activities

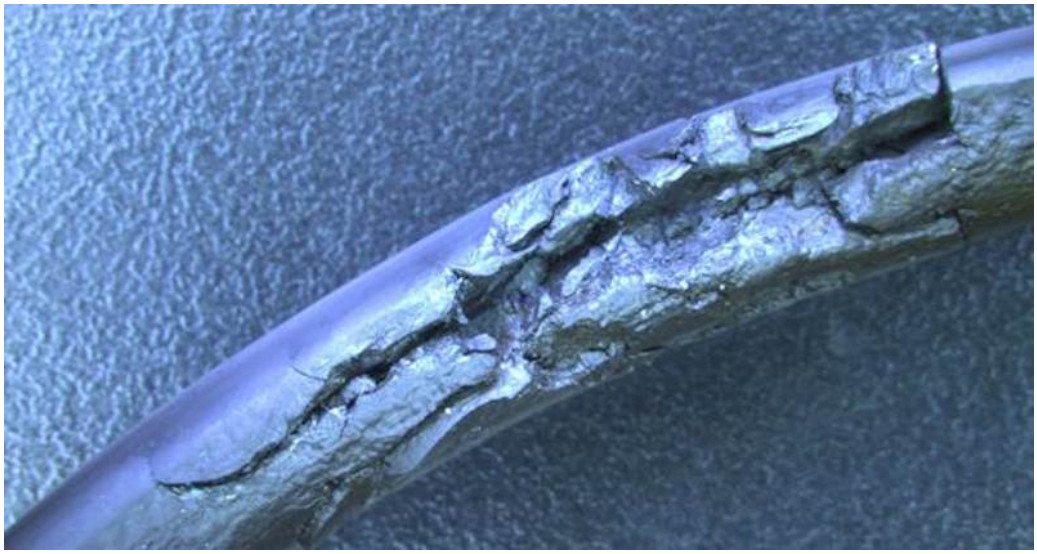
4.2.1 Annual Vibrations seminar – joint with Gino 2025

The seminar was a full-day event, held at the SSM offices in Stockholm. Presentations included Lina Bertling Tjernberg (KTH) on System services, Robert Eriksson (UU) on Forced oscillations, Omar Juarez Moreno (SvK) on the ENTSOE report on the Iberian incident, as well as project presentations from the GINO and Vibrations programs.

4.3 Chairperson reflections: Petri Lemettinen, Vibrations program Chair 2025

I think my favourite among all the interesting projects is **Blade Vibrations in Turbines**. The report connects fundamental vibration physics directly to the practical operation and monitoring of steam turbines by clearly explaining how blade vibrations are generated, how they are influenced by design and operating parameters, and what are the possibilities to monitor them during operation. A key benefit for power plants is that the report openly presents in-depth knowledge that is typically kept as turbine manufacturers know how, thereby strengthening power plant personnel's technical understanding and ability to proactively manage risks related to turbine blade vibrations.

5. Polymeric Materials in Nuclear Applications



5.1 Project reports

5.1.1 2025-1106 Thresholds for radiation sensitivity of polymers in combined radiation-thermal environments

The study investigates whether radiation-dose thresholds can be defined for polymers in combined radiation-thermal environments, enabling more focused material qualification and monitoring where radiation contributes minimally to ageing.

Understanding this is important for nuclear power plants because many essential components use polymers, and distinguishing when radiation meaningfully affects degradation supports safe long-term operation and efficient lifetime assessments.

The results show that most polymers exhibit no noticeable degradation below about 20 kGy, and that a highly conservative threshold of 1 kGy can simplify qualification, ageing evaluations and extended-use decisions.

The study was performed by Mathias C. Celina.

5.1.2 2025-1122 Examination of two In-Service-Aged PVC Cables from a Nuclear Power Plant

The study examined two PVC instrumentation cables that had operated for over 40 years to assess their condition and determine whether they could remain in service for at least 20 additional years.

This issue is important for nuclear power plants because ageing cables can stiffen, crack or fail, potentially causing electrical faults that affect safety systems and overall plant reliability.

The results showed that both cables differed in fillers but used the same DEHP plasticizer, whose loss was the main ageing mechanism. Despite this, flexibility remained sufficient for continued safe use.

The study was performed by Karin Jacobson at PDS Consulting

5.1.3 2025-1124 Cable Condition Monitoring Experiences at Nuclear Power Plants

The study aimed to gather current practices, experiences, and improvement opportunities related to cable condition monitoring in nuclear power plants, focusing on how ageing of polymeric cables is assessed and managed.

Cable ageing is an important issue because plants contain extensive cabling essential for safety and reliable operation. As nuclear fleets age and lifetime extensions are considered, systematic monitoring becomes increasingly critical.

The study found that plants use a wide range of visual, tactile, global, and local monitoring methods, often combining them for a more complete assessment. Inspections are typically systematic, and ageing data is mainly used to track trends rather than predict remaining lifetime.

The study was performed by Konsta Sipilä at VTT and Anna Bondeson at RISE.

5.2 Other activities

5.2.1 Annual Polymers seminar

The seminar was an all-day event, held in Helsinki. Presentations included Mathew Celina (Los Alamos) on Thresholds for radiation sensitivity, Michal Zavadil (UJV Rez) on testing and qualification of seals, Simone Suraci (University of Bologna) on Dielectric spectroscopy.

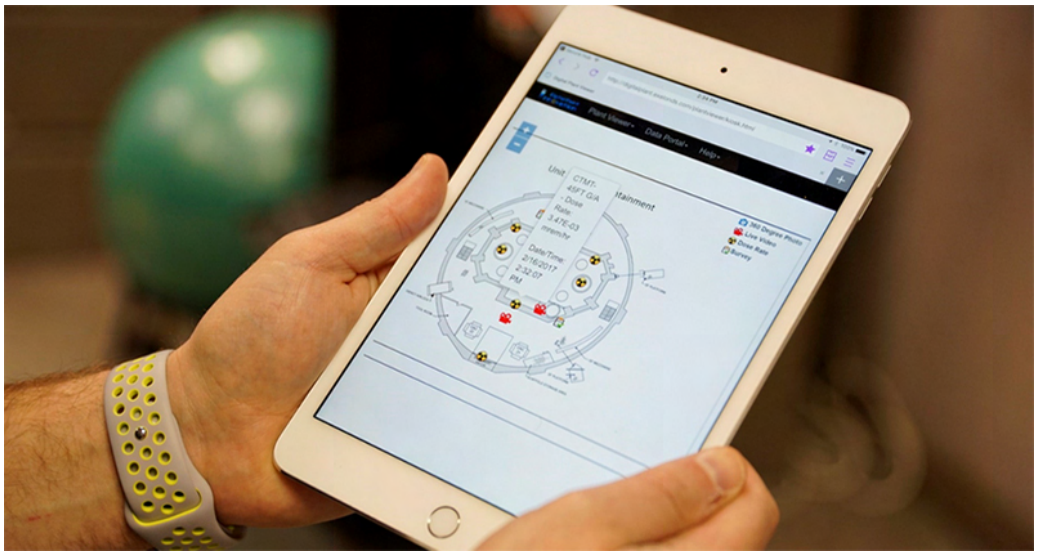
5.2.2 Benchmark visit to Krsko NPP

Thanks to a contact taken at the Polymers seminar, a group consisting of one delegate from each of the participating companies were able to perform a benchmark study visit at Krsko NPP and learn about the different methods for testing, evaluation and qualification that have been in use.

5.3 Chairperson reflections: Patrik Rydberg, Polymers program Chair 2025

One of my highlights was the **benchmarking with Krskó NPP**, where we got insights into how they are dealing with an aging facility with a focus on cable management. Ducovany and Temelin from the Czech Republic also participated in the benchmarking exercise where we were able to exchange experiences and lessons learned. The exchange of information benefited all participants in the benchmarking, both those who have been involved for a long time and those who are just starting their journey in the field of cable aging or polymeric materials in nuclear power plants.

6. Digitalisation in Nuclear Power



6.1 Project reports

6.1.1 2025-1091 On-Premise AI Solutions for Nordic Nuclear Applications

The study examines the feasibility of implementing on-premise AI solutions tailored to Nordic nuclear power plants, focusing on secure deployment of language and vision-based AI systems.

AI is important for nuclear plants because large document volumes, strict safety regulations, and sensitive data require secure, efficient tools for analysis, decision support, and operational improvement.

The results show strong potential for on-premise AI, including LLMs and computer vision, while highlighting challenges in data security, hardware needs, and model selection. A pilot study proposes a secure semantic search engine.

The study was performed by Leon Sütfeld and Andreas Thore at RISE Research Institutes of Sweden.

6.2 Other activities

6.2.1 Digitalization newsletter

The program finances a monthly newsletter about digitalization news in the nuclear industry, produced by Fortum. The newsletter has approximately 300 subscribers.

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