

Vattenfall Implements 1st-Ever Qualified AI/ML Ultrasonic Inspection at Ringhals Unit 3



Historically, ultrasonic inspections of PWR reactor upper head penetrations have been among the most data-intensive tasks in the industry. A single examination can generate more than four miles (seven kilometers) of data, requiring days or even weeks of analysis by multiple experts. The sheer volume of information makes these inspections challenging and places a heavy burden on analysts, impacting both efficiency and reliability.

EPRI's artificial intelligence/machine learning (AI/ML)-assisted analysis tool transforms these inspections by reducing the data review workload by up to 95% through automated filtering of inconsequential information and highlighting of areas that need expert attention. In the first qualified application of AI/ML in this context, Vattenfall's Ringhals team advanced the EPRI technology by completing a full-scale ENIQ qualification—similar to ASME Section XI, Appendix VIII in the U.S. The team applied existing mockups and advanced defect simulation techniques to set a benchmark for regulatory acceptance and real-world deployment of AI-driven inspection solutions.

Benefits

Vattenfall enhanced the efficiency and reliability of its ultrasonic inspections with the EPRI tool. Analysts were able to focus on critical data, reducing review time and improving examination quality. Although initial financial gains were modest, the successful qualification sets the stage for broader adoption, potentially enabling long-term cost savings and shorter outage durations. The effort also strengthened regulatory confidence in AI/ML technologies for non-destructive evaluations, paving the way for future global implementations and innovations in inspection practices.

Application

After receiving qualification from the Swedish Qualification Centre, the technology was used as part of the qualified examination of upper head penetrations during the May 2025 refueling outage at Ringhals NPP Unit 3. A second implementation at Unit 4 in July 2025 saved approximately one week of examination time. Vattenfall's operating experience continues to advance industry practice and has opened the door for global implementation of this technology.

Key EPRI products and resources used to support this effort include:

- AI-Assisted Analysis of Reactor Vessel Upper Head Penetration Ultrasonic Inspections, 3002029360
- AI Tool Developed by EPRI Significantly Cuts Analysis Time in U.S. Nuclear Plant Field Trial, 3002025510
- AI-Assisted Analysis of Ultrasonic Inspections, 3002023718
- Quick Insight Brief: Leveraging Artificial Intelligence for Nondestructive Evaluation, 3002021074
- Quick Insight Brief: Leveraging Artificial Intelligence for the Nuclear Energy Sector, 3002021067

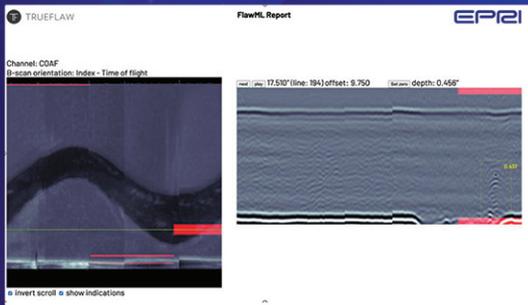


Figure 1
Displays an example of the AI/ML-enabled ultrasonic results, highlighting regions flagged for expert review during examination.



Figure 2
Illustrates human-AI collaboration, with machines handling vigilance and humans providing cognition.



Figure 3
Shows the flag rate distribution for individual UT data files analyzed. The blue bars provide the observed relative population and the orange line the cumulative population for each range of flag rate values.

| Head | Inspection | Penetrations Analyzed | Average File Flag Rate |
|------|------------|-----------------------|------------------------|
| H02 | ISI | 81 | 6.8% |
| H03 | PSI | 44 | 0.3% |
| H04 | ISI | 56 | 1.1% |
| H05 | PSI | 73 | 3.2% |
| H06d | ISI | 78 | 2.7% |
| H07b | ISI | 54 | 2.6% |

Figure 4
Indicates the number of penetrations analyzed and the average flag rate for in-service/pre-service inspections (ISI/PSI) of different reactor heads.