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Successful I&C Renewal Project of Loviisa NPP

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1. Introduction

Loviisa VVER-440 plant units were originally commissioned on 1977 and 1980. The status of instrumentation and control (I&C) systems was clarified after 30 years of operation, as manufacturing of original components and spare parts had been stopped. In early 2000s it was decided to set up an I&C renewal project to ensure licensability and high availability of the plant and to improve the maintainability by securing sufficient supply of spare parts and knowledgeable personnel until the end of plant lifetime. The renewal scope would address the most important safety and licensing questions: renewal of critical safety and safety related I&C systems with modern safety requirements, addition of new safety related and non-safety preventive functions together with relevant manual and automatic back-up systems, provision or clear separation and prioritization between the systems in different defence-in-depth levels. Digital I&C platforms were chosen for all safety, safety related and non-safety systems. Comprehensive hardwired and digital backups with diverse technology were planned for the most essential safety systems.

A full scope I&C renewal project LARA was initiated with Areva and Siemens Consortium in 2004. Since the beginning it was noticed that modernizing full scope of nuclear power plant I&C together with plenty of safety improvements brings lot of complexity and requires chunking the renewal into several stages in order to keep the scope and commissioning duration manageable. This again presented a need for numerous intermediate solutions. The first renewal stage was successfully commissioned in outages 2008, 2009 consisting of Preventive Protection System (reactor's fast and slow shutdown, control rod control and position indication), incore measurement system and normal process control systems.

The challenges faced consisted of e.g. modern requirement based design, large architecture, qualification of digital I&C and vast intermediate solutions between renewal stages. After several postponements of commissioning date for the most important 2nd renewal stage, many accruing and waiting change needs of operating plant were forced to be included in the project scope. This induced growing risks related to the estimated duration of commissioning outage and the commencing year, and no clear visibility meeting the project's original targets.

2. Second I&C renewal project ELSA

Based on the difficulties a new plan was prepared. The new ELSA I&C renewal project included substantially smaller scope, and would renew only most critical I&C systems with most essential safety improvements. Delivery limits were carefully prepared and responsibilities shared between the utility and the new supplier Rolls-Royce Civil Nuclear in an optimal manner. The project duration was kept as short as possible to minimize emerging plant change needs and thus to keep the configuration manageable. The project scope was planned to be commissioned in three consecutive outages, both plant units at the same year, with keeping regular outages durations with tolerable risk for additional delays.

Pre-approval for the planned scope and equipment was sought in the conceptual design phase from the regulator. New ELSA-R program together with program management routines were established to govern the closely related projects of the ELSA project and thus to secure successful execution of the projects. The new smaller scope also meant identification of maintenance and renewal needs for the existing and remaining I&C parts and management of them as separate spare parts or renewal projects under normal plant governance.

3. APROS® testing

Simulators were planned to be used in many areas of the ELSA project since the beginning. This was due to versatile APROS® tool and good experiences from other projects. At first all safety analyses were renewed with the new plant functional architecture. After validating the plant functionality the new I&C systems were validated against the simulated plant model. The simulation environment made validation against the simulated plant possible to be done at an early phase of the project, and to include plant operators already at this early phase. Also errors were discovered early on and the tuning of the reactor power controller was possible before commissioning. No real modifications to the systems were needed to be done at the plant.

For testing the I&C architecture in an efficient and flexible manner a completely new plan was prepared. For most extensive last renewal stage a test platform of 7 individual I&C systems was set up at the supplier's test field. In addition the supplier's separate test connection equipment the APROS simulator was interconnected with the I&C. This provided two advantages: the possibility to run test cases against the simulated plant, and emulating I&C systems in simulator environment before the software & hardware detail design of all systems was ready. First all seven I&C systems were tested with emulations. One by one after completion the real I&C systems replaced the corresponding system emulation in the test configuration, leading in the end to all the seven real I&C systems being interconnected and APROS used as a simulated plant model.

This enabled saving months from testing time of interconnected tests. The interconnection functionality between systems was possible to be tested well in advance, and only in the end when all seven systems were ready and interconnected hardwired, comprehensive testing of actual interconnections themselves was done to confirm that no differences between simulated and real environments existed.

The test platform was also used for additional functional testing based on regulator request. The test simulator made it possible run complex accident scenarios outside the planned test procedures, testing the I&C architecture and systems both in design basis and beyond design basis cases. These test cases were consisting for example of complete blackout of half of the I&C system cabinets and large common-cause failure (CCF) of actual safety class 2 safety systems together with an accident scenario. The simulation of these cases confirmed that that the diverse automatic backup system using different measurements and functions from actual safety system was able to trip the reactor. Also all the two and four redundant system architectures with separated power supplies worked as planned. These tests proved the solidity of the architecture and that the diversity was correctly applied in defence-in-depth concept.

4. Conclusions

Loviisa I&C renewal project was set up to ensure licensability and high availability of the plant and to improve the maintainability by securing sufficient supply of spare parts and knowledgeable personnel until the end of plant lifetime. The first full scope renewal project proved to be extremely challenging due to scope, safety improvements and emerging change needs. New ELSA project included substantially smaller scope, and would renew only most critical I&C systems with most essential safety improvements. The corner stones of successful implementation of ELSA on time and within budget proved to be on technical side the clear ADLAS® plant and safety documentation, utilization of APROS® simulators, meticulous definition of scope, architecture and the interfaces. From project point of view the optimized share of responsibilities, active schedule management and risk mitigation based on it, planning of licensing documentation schedule and most importantly of all a shared mindset and a common goal between Fortum and the Supplier secured the project to meet the expectations.