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## **Simulators for Loviisa Automation Renewal Project**

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### **Abstract**

Simulators have been extensively used in the renewal of I&C systems of Loviisa Nuclear Power Plant in order to assure safe and economical modernization project. In all there are four types of simulators to be used in the project: engineering simulator, development simulator, testing simulator and training simulator. This presentation will give an overview of each simulator, their use and future plans.

### **Background**

Loviisa Nuclear Power Plant is located in Southern Finland approximately 100 kilometers east from Helsinki. The plant includes two VVER-440 type reactors commissioned in 1977 and 1980. The plant is owned and operated by Fortum. The goal is to operate the plant at least 50 years. The plant has now operating license until 2027 and 2030.

The original analogue I&C systems of Loviisa plant will be renewed by digital I&C. The project has been started in 2005. The contractor is Areva Siemens Consortium. The renewal will be done in stages. The first stage includes a representative part of both safety classified and non safety automation. The first renewal stage has been commissioned in Loviisa Unit 1 in 2008. The phasing of the project means that the control room will also gradually change so that the hardwired desks and panels and the current process computer system are replaced by display based Human Machine Interface (HMI) of Areva Teleperm XS (TXS) and Siemens SPPA T2000 (T2000). In TXS HMI is based on a Qualified Display System (QDS). In T2000 the interface is the OM690 display system. Also large screen displays are widely used.

Loviisa Power Plant has a full scope training simulator that has been commissioned in 1980. The simulator has to be upgraded to represent each forthcoming renewal stage one year before the new I&C will be introduced at the plant. Stimulated HMI and virtual automation will be introduced at the simulator. The process models will be upgraded by APROS [1] models in the later stages.

### **Use of Simulators**

Simulators have been extensively used in the Loviisa Automation Renewal Project (LARA). Operators are trained on the full scope training simulator. Simulators are used to test and validate new control room design and HMI systems. Simulator is used to perform closed loop testing of digital I&C at the factory. New operating

instructions are tested and validated. Simulation is also used to test and improve plans to modify existing control and automation logics.

### **Engineering simulator**

Intention in LARA project is to keep the functionality of the process controls and logics unchanged as far as reasonable. However some process upgrades will be made and some I&C functions will be changed to achieve even higher safety. Such modifications have been analysed in advance using the engineering simulator. Documentation and plans of some systems are not directly reproducible in the new digital I&C. In those cases simulator has been used to develop and test new plans. For example initial data for programming existing reactor power control system in the new digital I&C has been developed and tested using process simulation.

The engineering simulator uses APROS Simulation Software and Loviisa Plant application model. The model has been originally designed for power upgrading project and later extended for development and analysis of new emergency operating instructions. The model has been extensively validated and it has been and is currently used for safety analysis. The engineering simulator is running in standard Windows PC or laptop.

### **Development simulator**

By the end of LARA project the control room of both Loviisa units will be completely modernised. Because of such a huge and stage wise change in the working environment of the operators it was seen necessary to build a dedicated simulator for control room and HMI design.

Development simulator was taken into operation in year 2003 in a limited scope. Thereafter it has been frequently enhanced by new systems. Since summer 2008 development simulator has reached full configuration. The simulator is located in Fortum's Keilaniemi office in Espoo, Finland.

Development simulator includes stimulated HMI of Areva TXS system namely QDS and stimulated HMI of Siemens T2000 system namely OM690. In addition the simulator includes virtual automation of TXS and T2000 systems. Virtual automation is interfaced to APROS process simulator [1] and instructor's station. The process computer system (PCS) by ABB, currently operational at the plant, is stimulated. In the plant, PCS system is used to monitor the process and operations are done via hard panels. In development simulator there are no hard panels however PCS system has been enhanced to enable operations thus replacing functionality of the panels. On course of LARA project PCS system will be gradually replaced by OM690. In the simulator large screen display is presented by data projectors. New reactor protection system (RPS) manual back up panels are simulated using data projectors and touch sensitive screens. The new RPS system is still under design and will be commissioned at the plant in a later stage.



*Picture 1. Development simulator in May 2009. Operator desk and large screen displays are on the right. In the back two large touch screens simulating hard wired panels of new reactor protection system and four QDS displays are presented.*

In LARA project stage 1 development simulator has been used to develop, test and prevalidate HMI displays. The new control room layout including HMI displays are developed in Finland by Fortum's staff. Prevalidation of displays is performed in co-operation with plant operators, designers and independent assessors. Once HMI displays are tested and prevalidated in the simulator environment they are transferred to the automation suppliers for integration into new I&C at the factory.

In addition to HMI design and testing the development simulator is extensively used for testing of new APROS process models that will replace current process models of Loviisa full scope training simulator. Currently the extent of APROS models is nearly full scope including primary and secondary processes, 3D reactor model and containment model. Current analogue automation systems have been simulated as well. They will be gradually replaced by virtual automation as the project advances. Electrical power system is modelled in detail and includes automation. Emergency diesel generators and their automation system are simulated as well.

Development simulator has been used for training operators to use new OM690 system before it was installed at the plant.

## Testing simulator

Testing simulator is used to perform closed loop testing of the digital I&C. Testing simulator is located in Germany in the premises of Areva and Siemens. The process models are the same as those used in the development simulator. Process models are connected to the real or virtual I&C. The safety critical automation is tested both in real hardware and virtual configurations. Utility automation is tested in virtual configuration only. Testing simulator has been operated in co-operation with Fortum and I&C suppliers and it has been used to complement other test methods in the factory acceptance tests.

In addition to the process models Fortum has developed together with VTT a software tool Testing Station to manage and execute closed loop testing. Testing Station connects to virtual I&C and process simulator and has standard simulator control features like any instructor station. Testing Station is intended to enhance dynamic closed loop testing by having features like:

- Definition of test scenarios including sequences of operations and malfunctions
- Execution and reporting of a single test scenario
- Automated execution of a series of test scenarios including reporting
- Once a set of test scenarios has been defined, it can be automatically repeated and results verified each time something in the I&C code has changed
- Comparison reports of test scenarios run with different updates of I&C application code
- Tuning of controllers

Above mentioned features make Testing Station useful for testing of process models as well. Fortum uses Testing Station for example for automated regression tests of process model updates. Series of automated testing scenarios have been used to study sensitivity of simulation results to changes in key process model parameters.

Testing Simulator has been used in LARA stage 1 to test preventive protection system, control rod control system and nuclear water treatment system. The former systems are safety classified and implemented in TXS/QDS whereas latter system is non safety and implemented in T2000. During the test field corrections were made in the logics, controllers and operator displays. In case of water treatment system virtual commissioning of T2000 I&C done at the simulator was seen very helpful and I&C application code was improved in many ways. Closed loop tests are particularly useful for detecting errors that originate from faulty initial data as these can only be found once I&C gets realistic process response. I&C application code improvements due to closed loop tests were seen to have considerable impact on commissioning of I&C in LARA project. More information will be found in a paper to be presented in summer 2009 in Tampere IFAC Symposium on Power Plants and Power Systems Control [2].

## Training simulator

Loviisa Full Scope Training Simulator (LOTS) has been upgraded for first stage of LARA project in January 2007. Training simulator has two QDS displays installed for monitoring and operation of preventive protection system and control rod control system. In addition two elements of large screen display have been installed. TXS I&C have been simulated in the process models.



*Picture 2. LOTS in January 2007 after upgrade to LARA stage 1. In the front the QDS display is installed in reactor operator's desk and in the back two large screen display elements are presented.*

In January 2007 LOTS was used to validate the new HMI systems. After that training of operators on new systems started.

New utility automation systems have not yet been installed at LOTS as in the first renewal stage they are used in the nuclear water treatment system (NWTS) that is mainly outside the scope of LOTS. NWTS operations are trained at the development simulator where those process models, virtual T2000 I&C and OM690 displays exist.

In the upcoming renewal stages LOTS will be upgraded one year before the corresponding stage is taken into operation at the plant. In the later stages the current process models of LOTS will be replaced with APROS models and new instructor's station will be introduced.

In the upcoming stages the changes will be bigger and more training days will be required. In addition simulator is needed for validation of operating instructions and

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for research and test runs. Therefore Fortum has decided to build another training simulator on site. Parts of the second training simulator are already operational at Fortum's Keilaniemi office and they are used for simulator system and process model tests. The configuration will later be moved to the site and extended to second training simulator.

### **Conclusions**

Simulators have been extensively used in the Loviisa Automation Renewal Project (LARA). Use of simulators will be intense also in the upcoming stages. In addition to upgrading Loviisa training simulator Fortum has decided to build another training simulator on site to ensure sufficient simulator time for training, validation of operating instructions, testing and research. Fortum continues work on simulators and strives for better process models and efficient tools. Experience of using simulator in control room and HMI design and closed loop I&C testing have been encouraging.

[1] <http://apros.vtt.fi/> and <http://www.apros.fi>

[2] Tahvonen et. al., Simulation Assisted Automation Testing During Loviisa Automation Renewal Project, IFAC Symposium on Power Plants and Power Systems Control, 5-8.7.2009, Tampere, Finland, to be published in 2009