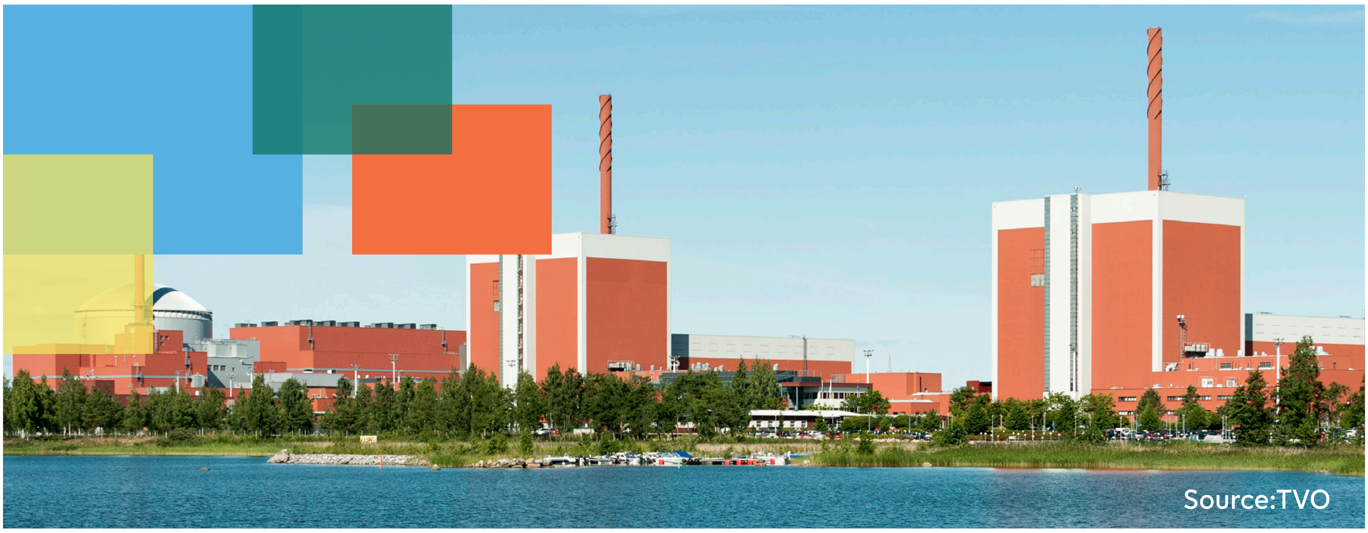

Apros utilised in many phases of nuclear power plant life-cycle Case TVO, Olkiluoto

Use of Apros at TVO is a great example how dynamic simulation can be utilised during whole lifetime of the plant. Apros has been used for several modernisation projects on the OL1 and OL2 units which are running BWR power plants delivered by Asea Atom during 1970's. Apros is also utilised preparing for the commissioning and operation of the new EPR power plant (OL3) provided by AREVA.

OL1/OL2: PROCESS ENGINEERING APPLICATIONS

TVO has used Apros simulation models since 2005. One Apros simulation model is used to simulate both OL1 and OL2 units as they are identical in design. The main application of the model has been process engineering where the biggest advantage is to analyze the effect of the subsystem level changes on the plant level processes.

Investigation of steam valve periodic test is an example about benefits that simulation brings about understanding the plant level behavior and changing the operating procedures based on accurate simulation results. Steam line control valves are tested annually in specific periodic tests at OL1 and OL2. During the periodic test the operating power of the plant were originally lowered to 60% of the nominal power. With dynamic simulations TVO was able to test and prove new procedures where periodic tests were executed on higher power level. To simulate the dynamics of the periodic tests the model needs to contain integrated model of the whole BWR-typed reactor water-steam process and control circuits for reactor power, turbine power and steam control valves. The simulation results confirmed that steam valve control circuits could be tested in higher reactor power level. The increase in operating power level for periodic test has annually positive impact on electricity production of both units.

Renewal of condenser and ejector systems is example of utilizing Apros simulation model to support and speed-up the problem solving process. Too high condenser pressure were detected in plant start-up after condenser and ejector renewal at OL2. The high pressure was detected only when using the second line of the 2 identical and redundant ejector lines. If only the second ejector line was in use the reactor power were limited to 70% so the risk of major production losses were present. Physical investigation of the problem was limited because systems are part of contaminated primary circuit. The ejector line was modelled in detail based on the measurements data and configuration from the first ejector line.

> Apros has been valuable tool for TVO in many projects and investigations. From our perspective, the strength of Apros is detailed plant scale process and automation modelling. At Olkiluoto 1 and 2 units, we have used Apros as engineering tool. We have chosen Apros because of reliable support and user-friendly modelling environment.
>
> Mikko Leminen, Nuclear Safety Engineer, TVO

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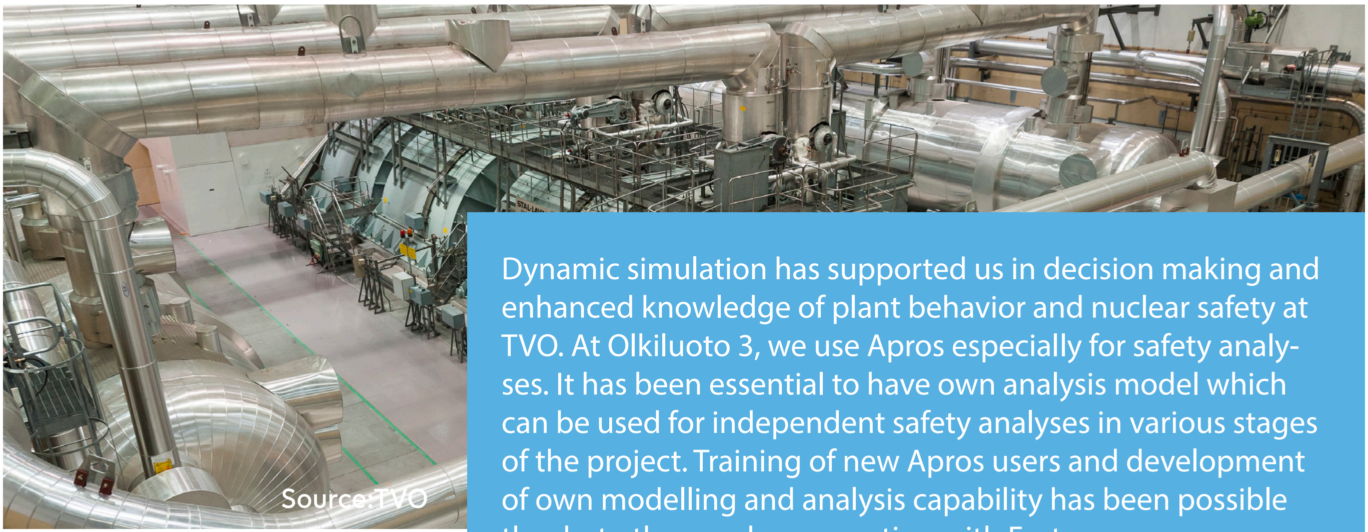

Dynamic simulation has supported us in decision making and enhanced knowledge of plant behavior and nuclear safety at TVO. At Olkiluoto 3, we use Apros especially for safety analyses. It has been essential to have own analysis model which can be used for independent safety analyses in various stages of the project. Training of new Apros users and development of own modelling and analysis capability has been possible thanks to the good co-operation with Fortum.

Mikko Leminen, Nuclear Safety Engineer, TVO

The possible reasons for faulty behavior (high amount of non-condensable gases after ejector) were investigated by making configuration changes to the model so that the simulation results would correspond the measurements from the second ejector line. Simulations assumed higher bypass flow in ejector which was confirmed in physical inspections. In addition to problem solving the Apros model was used to validate other process changes in ejector systems and to analyze the procedures for creating the condenser's vacuum. Simulations demonstrated possibilities to shorten the time to vacuum creation in start-up which results higher annual production capacity. All these measures supported the project staff in decisions and fastened the problem solving process significantly.

OL1/2 simulation model have been also utilized for example in following cases:

- Analyzing the concept and commissioning of new forward pumping system pumps
- Investigation of reactor pressure vessel level measurement system
- Commissioning of new 2-stage reheating plant
- Tuning of generator cooling control system

The comprehensive simulation model of OL1 and OL2 contains the boiling water reactor, turbine plant, containment, safety automation, control systems and plant electricity grid. Through-out the projects and investigations the simulation results have been compared with the plant measurement data, including start-up and shut-down states, with very good accuracy. Main goal for the simulation model in the future will be continuing the support for process and automation modernization projects with up to date model. The usage of the model will be broaden also to safety analyses with integration of the multichannel reactor model which enables the loss of coolant analyses.

OL3: SAFETY ANALYSES AND COMMISSIONING

With the new EPR unit (OL3) the need for a detailed Apros model was seen in very early phase of the project. The first OL3 safety analysis with Apros was executed in 2008 and proved that the model can successfully simulate a Large Break Loss of Coolant Accident (LBLOCA). The model has been actively updated and it has similar scope as OL1 and OL2 models including all the essential systems for analysis needs. For safety analysis purposes the model contains 3D and multichannel core models. Multichannel core is utilized in loss of coolant analyses and the 3D neutronics core model allows the examination of asymmetric behavior inside the pressure vessel and primary loops for example in reactivity analysis. In 3D core model all the core flow channels are individually modelled which enables higher accuracy for the simulations. 3D core model is used also to simulate the LBLOCA accident and results have agreed to the plant suppliers safety analysis.

The simulation model has been used to wide range of internal design based accident analysis, investigation of plant level commissioning tests and model is validated against the plant supplier reference data. Furthermore, the model has had a role in the training of safety engineers and many Master of Science theses have been written about OL3 model development and analysis cases. In the future the simulation model will be developed and updated for safety analysis purposes but still remaining the best estimate configuration. Best estimate configuration ensures also the capabilities of engineering analysis for primary and secondary circuit systems.

Dynamic simulation enables safety analysis, strengthens the operating organisation's understanding of the process behavior in all plant states, provides data for project planning, commissioning and problem solving, and reinforces the validity of the suppliers' data and decisions.

In partnership with VTT

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