



## Instructor Station for Apros Based Loviisa NPP Training Simulator

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**Abstract**—At the moment Loviisa Nuclear Power plant (NPP) is going through an Instrumentation and Control (I&C) renewal project. Changes are made in several stages over several years. Alongside the plant changes the training simulator of the plant will be updated in stages so that it will be similar to real plant. One part of the training simulator project is to upgrade the process simulator and its Instructor station. This paper presents the developed new Instructor station application.

Instructor station is used to design, monitor and analyze

simulation model goes through rigorous testing after changes has been made to it.

### I. INTRODUCTION

At the moment Loviisa NPP is going through an instrumentation and control (I&C) renewal project that was started in year 2005. For the time being, availability of the plant have been very good, even if the

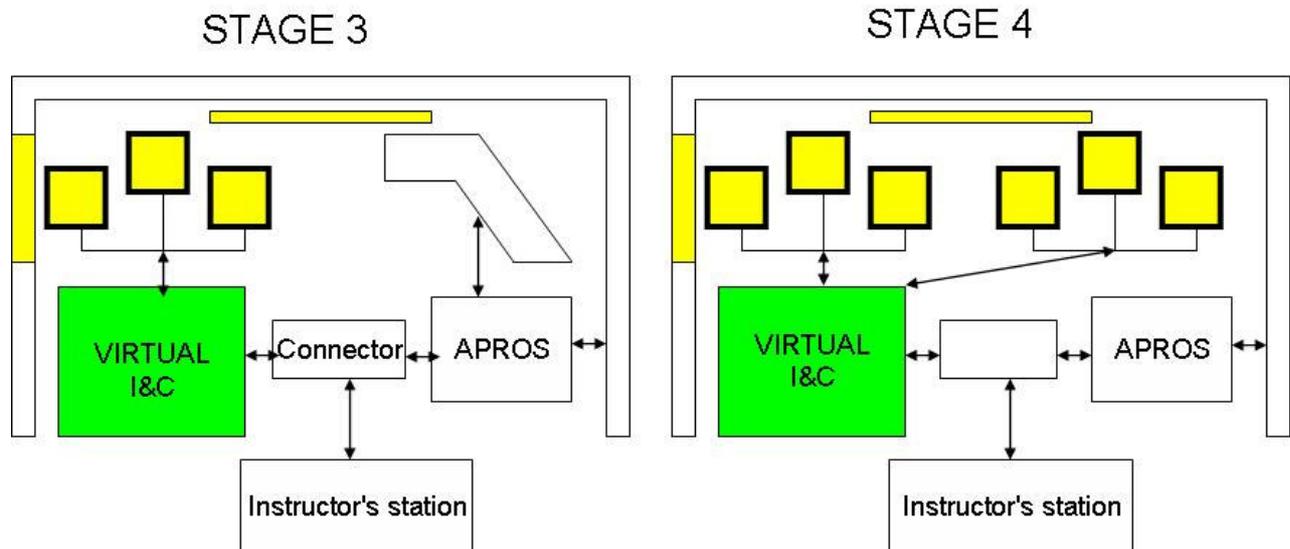


Fig. 1. Training simulator in stages 3 and 4.

the course of the training session. New tool has been especially developed to enable varying configurations that contain several different components. It has also usages beyond training. Similar features are also helpful e.g. when testing the I&C system before installation or when

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plant has been in operation over 30 years using mostly original I&C systems. However, large scale I&C renewal project is needed to guarantee good availability of the

plant until the end of the plant lifetime. I&C renewal will be carried out in four stages so that the installations are done during the normal annual outages. The last two stages are presented in Fig. 1.

Alongside I&C renewal Loviisa NPP training simulator will be renewed and old process simulator software will be replaced by APROS based training simulator. Renewal of training simulator will follow the stages of the I&C renewal. NPP control room is also changing e.g., current panel based operator interfaces will be partly replaced by monitor based interfaces. Before the changes are made to real plant they are done to the simulator to train the operators in advance.

One part of the training simulator renewal is to develop a new instructor station that can meet the requirements of the simulator training during and after the automation renewal. In this paper new instructor station called Training Station is introduced.

## II. BACKGROUND

Over the years, several projects concerning simulation assisted working methods during the whole life-cycle of the process plant has been gone through.

Simulation has been used in the e.g. for safety analysis, tuning controllers, planning the plant hardware changes and operator training. In some cases simulators have been used for testing the automation system against the simulator.

Traditionally simulator is planned from the scratch for one purpose only, even if it would be highly beneficial to use once developed model to as many purposes as possible. Some of the needs are fulfilled by just using a single simulation tool, but quite often several simulation tools are needed simultaneously to get realistic behavior of the whole plant including process, electrical and automation systems. If there is more than one simulator involved, it comes important that we've ways to establish efficient communication between the simulation system components and that we've some component that controls the whole simulation system (Simulation control program). In optimal configuration all the parts of the simulation system have similar efficient interface for data transfer and interface, which Simulation control program can use to give commands (Simulation control interface).

Simulator system usage scenarios have similarities and it makes sense to use same tool for various purposes. In the earlier project Fortum Nuclear Services and VTT Technical Research Centre of Finland have developed Testing Station software for simulation assisted automation testing. Testing Station can be used to control simulation and execute predefined test runs automatically.

It can also be used to collect and analyse test results. After Apros simulation software is connected to virtual automation, Testing Station can be used to manage and control execution of tests. Run and freeze commands can be given as well saving and loading initial condition can be done collaborate to all components. Testing Station has been used successfully in simulation assisted automation testing in Loviisa I&C renewal project (See [2]). This tool has been basis for Instructor station presented in this paper.

It can be pointed out that there are several features and functions implemented in Testing Station that are helpful also in operator training. This is the main reason why Training Station software was decided to create on top of Testing Station. This way the developments done in Testing Station can be utilized also in Training Station. Common features implemented already in Testing Station did give a good starting point for Training Station but also the needs special for training must to be taken into account.

Finally the tool developed suits also for other purposes. At the moment it is used for validating the simulation model after the changes and executing regression analysis cases.

## III. LOVIISA NPP TRAINING SIMULATOR

### A. Main components

Main components and used communication interfaces of the final simulator system are presented in Fig. 2. Instructor station is controlling the whole system that contains simulators and operator interfaces.

Full scale NPP training simulator consists of several components from different suppliers. In Loviisa NPP training simulator Apros is used to model the process. The virtual copy of the automation system used in training simulator is created by the automation supplier. Also the old panels and the old process computers are involved in several stages of the training simulator renewal.

Simulators include Apros for modeling the process and TXS and T2000 emulators for modeling automation system. Operator displays include QDS, hardware panels, PMS and OM690. Communication interfaces include proprietary interfaces like Apros communication library (ACL) and more widely used interfaces like OPC.

### B. Loviisa NPP training simulator in I&C renewal project

During the first stage of I&C renewal project only limited functions including safety-classified and non-safety classified functions are renewed. The second stage covers safety-critical systems i.e. reactor and plant protection systems. In stages 1 and 2 old Loviisa training simulator LOKS will be updated to changes done in the plant. In Stage 3 of I&C renewal whole I&C systems of the primary circuit will be renewed. Stage 3 will be large

and also very challenging for the training simulator because in this stage old simulation software will be replaced by APROS. In this stage also Training Station will be taken into use. In Stage 3 training simulator is a mixture of old and new automation, displays and panels. Also this thing makes stage 3 challenging.

In addition to training given to operators simulators are utilized extensively in I&C renewal project also in engineering and testing. In all cases a APROS model that is developed during simulator renewal project is used.

### C. Apros

Simulation model describing the process will be developed using APROS (Advanced PROcess Simulator). It is the simulation software created by Fortum and VTT Technical Research Centre of Finland for full-scale modeling of dynamic processes such as nuclear and combustion power plants and pulp and paper mills. Also automation an electrical systems can be modeled using comprehensive model library. Models are one-to-one analogous with concrete devices. Solution algorithms are hidden to components and needed calculation level objects are generated automatically when process level components are created through graphical user interface. If needed, also users own modules can be included in the calculation.

APROS thermal hydraulic model library contain several different thermal hydraulic models e.g. one dimensional water/steam/gas flow, single phase flow, containment and one for the steady-state flow with tank dynamics. Different models can be mixed to the same APROS model.

As a result of versatile functionalities APROS has the simulation environment that meets all the requirements for the testing, design, analysis and training simulator applications. It has been used successfully in many solutions for instance in training simulators [5] and in simulator assisted automation testing [6].

Apros provides interfaces typically needed in training simulators. These interfaces include starting and stopping of the simulation, saving and loading models and issuing malfunctions.

## IV. TRAINING STATION

### A. Background

Training Station development project was started in year 2007 in co-operation with Fortum Nuclear Services and VTT Technical Research Centre of Finland. The goal of the project was to develop a new instructor station to Loviisa NPP training simulator. In stage 3 of I&C renewal the new Apros based training simulator and new instructor station will be taken into use in Loviisa NPP training simulator.

When a software tool designed for simulator assisted automation testing is taken as the basis the first thing is to define how existing features should be modified and what kind of new features are needed to manage the training sessions.

The new instructor station is designed to replace an existing instructor application that has been in use for a long time. The current instructors know the old application and its strengths and weaknesses very well. This provides good possibility to get input for the new Instructor Station. These instructors will also be primary end users of the new Instructor station. During the development of the new Instructor station the meetings with the instructors gave developers better understanding about the real needs in every day use. This way better knowledge about the instructors' needs of using different software tools was received.

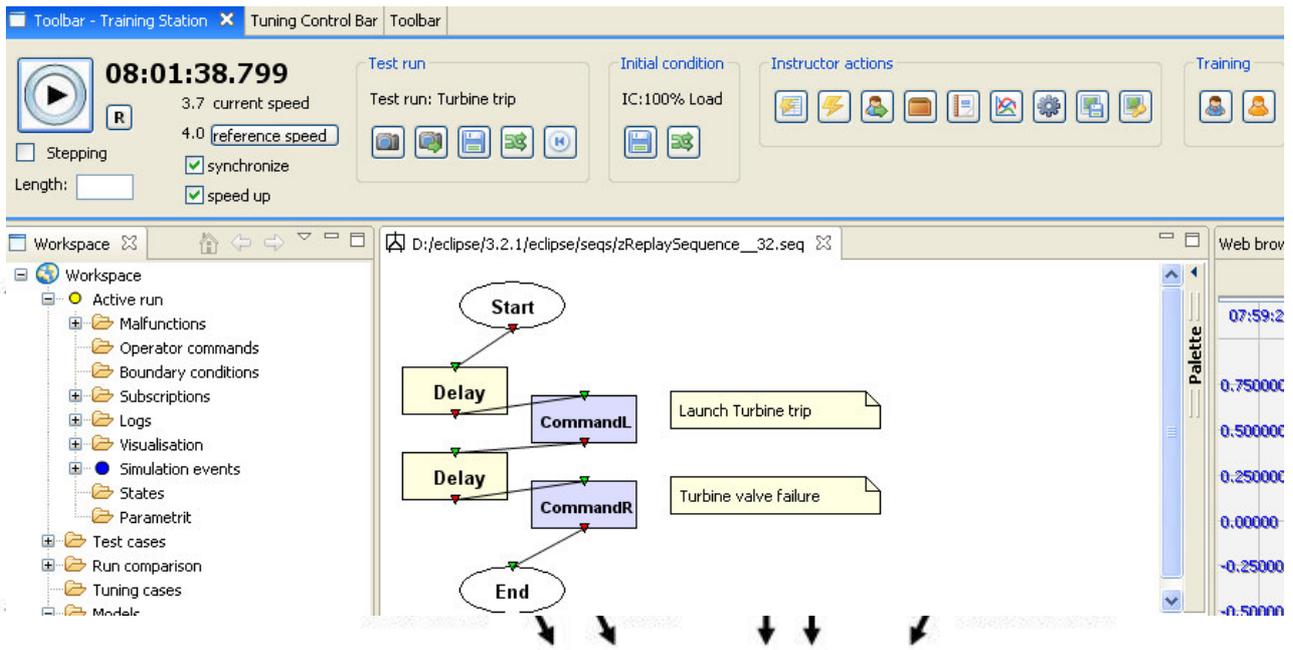


Fig. 3. Training Station toolbar, workspace tree and sequence.



Fig. 2. Main components and interfaces in the Loviisa NPP training simulator.

As a result of the development project Training Station software tool was developed. In the following chapters some features and functionalities developed to instructor station are presented.

### B. Simulation control and data exchange

When a system consists of several components that have to work together, the interfaces between components become critical. Communications between the Instructor Station and other components in training simulator are based on common interfaces or to interfaces dedicated to simulation control and approved by participants. Communication between instructor station and the components involved to simulation is mainly based on web service technology. Data transfer between the components can be made using OPC XML DA [3] data access specification or using proprietary interfaces like Apros communication library (ACL). Simulation commands components involved in simulation can be sent through an interface designed specially for simulation control. The interface is designed in co-operation with the instances taking part of the Loviisa NPP training simulator renewal. This interface provides commands like run, freeze, save and load of initial condition and backtrack, malfunction management and replay.

Training station has facilities for synchronizing and controlling the speed of the simulation run. These features can be used to run all parts of the simulation system with

exactly same time and force the data transfer between components to happen at wanted time instances.

### C. Management of training sessions

Training Station contains tools for planning and managing the training sessions. Fig. 3 Contains some of the views available for the user to manage training session. Typically training session is constructed from pieces. Training session can define which initial condition is used, when malfunctions are activated and cancelled and which variables are stored and how they are visualized in trends. Furthermore sequences of actions can be attached to the session. These actions can e.g. triggering of malfunctions or changing some external boundaries like the temperature of the sea water.

When the session is designed strictly in advance minimum number of actions is needed from instructor during the training. Stored session can be utilized, modified and stored later for instance by adding some new malfunctions or using different initial condition.

Session can also contain results of the simulation that can be analyzed also at later time.

### D. Process and system monitoring

Training Station provides tools for monitoring status of different components and connections in training simulator. Also connections between different components can be established through Training Station.

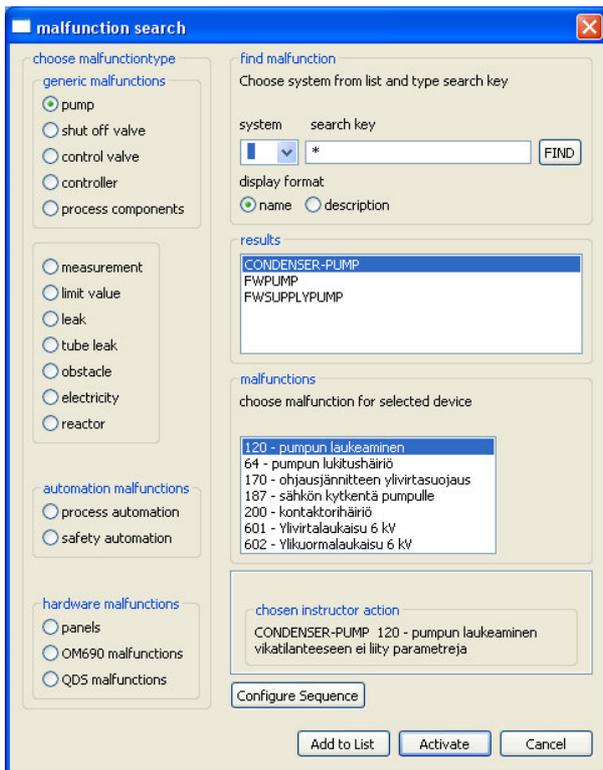


Fig. 4. Instructor action search dialog.

Status of simulation is monitored in terms of simulation speed and number of iterations in calculation. Because of the flexible data access Training Station can be used to monitor any value calculated in APROS. Values can be displayed in trend curves or panel designed for monitoring plant state. Monitored values can also be stored to database for further analysis.

#### E. Instructor Actions

In simulator training, instructor actions play an important role. Instructor Actions can be used to create specific conditions for each training session. Instructor Action Search Dialog IASD (Fig. 4) is a tool created for browsing malfunctions and other instructor actions from the current database, selecting malfunctions for list of predefined malfunctions and also for launching malfunctions. Through Instructor Action Search Dialog malfunctions can be searched and modified straight from APROS database through OPC XML DA interface in a user friendly way. Also malfunctions from other components can be selected through IASD.

With help of IASD malfunctions can be defined to the list of pre-selected malfunctions. Via this list user can launch pre-selected malfunctions just by one mouse click.

#### F. Sequences

Sequence tool can be used for performing number of commands or scripts in defined order or in defined time. Also delays and conditions can be defined so that commands can be always performed after certain period of

time or when certain predefined criteria's are met. Sequences are a useful tool for training purposes. When actions done and command given during the test run are defined in sequence can be repeated every time same way. This way results can be compared reliably. Sequences have been also used for simulator assisted automation testing with good results [See 2]. Fig. 3 contains example sequence, which has Delay and Launch Malfunction steps.

In Training Station two different kinds of sequences can be defined: synchronous and asynchronous. Synchronous sequence controls the simulation session. It can control e.g. when the simulation is stopped or started. Furthermore synchronous sequence takes part in the synchronisation of the training station, i.e. after every time step sequence evaluation code is executed. Training session can contain only one synchronous sequence. On the other hand asynchronous sequences can be started whenever user wants and they are just evaluated until end block of the sequence is reached. Several asynchronous sequences can be executed within the training session. Asynchronous sequences can be started whenever user wants and after execution of sequence is finished simulation will continue normally.

While synchronous sequences are suitable for running predefined run, asynchronous sequence provide a multifunctional tool for creating and executing wide chains of events inside one session.

#### G. Event Logs

Event Log is a tool designed for collecting events coming from different components. All events are transmitted to Event Log where events are categorized e.g., to be either system or simulation events. Events received to Event Log can be visualized to user through Event Log Displays (ELD). Several ELDs can be opened at the same time and for those different filters can be defined. In ELDs events can be filtered e.g. based on event category, component sending events and time when event was received. Also different patterns can be used to filter events coming to different ELDs.

Instructors who have been working for long time Loviisa NPP training simulator think that one of the biggest challenges there will be in training simulator after control room is upgraded to monitor based control room is how instructors are able to figure out which actions operator have made. They are interested also events that haven't cause any traditional operator action like which, operator displays are opened/closed. Event Log should bring new tools to instructor for this challenge.

#### H. Other features

Instructor station contains several other features that are helpful when the training simulator is used.

It provides means to compare results of training sessions. Evaluation can be based on trend pictures or to reference run that instructor has done earlier and

considered how it should be evaluated. These features are based on the work presented in [7].

Instructor station provides tools to create and merge instructor's own process displays. These displays resemble the operator displays, but have features specific to instructors like triggering malfunctions or monitoring measurements that are not available through the normal operator displays.

## V. CONCLUSIONS

Simulators will be utilized extensively in the I&C renewal project of the Loviisa NPP. An engineering simulator will be used in the design and validation of the modifications of the renewal I&C systems. A development simulator is aimed for the design testing, and acceptance of the new Man Machine Interface. A testing simulator will be used for the testing of the new I&C systems and returning the of the controllers mainly during the Factory Acceptance Tests. Process simulator will be in all these cases Apros and in many phases Instructor station or its predecessor Testing station has been utilized. This gives definite synergy advantages.

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