

# Experiences Utilizing Apros® Simulator in a renewal with Digital I&C

NUCLEAR SCIENCE AND TECHNOLOGY SYMPOSIUM – SYP 2019

Marina Congress Center, Helsinki, Finland 30.-31.10.2019

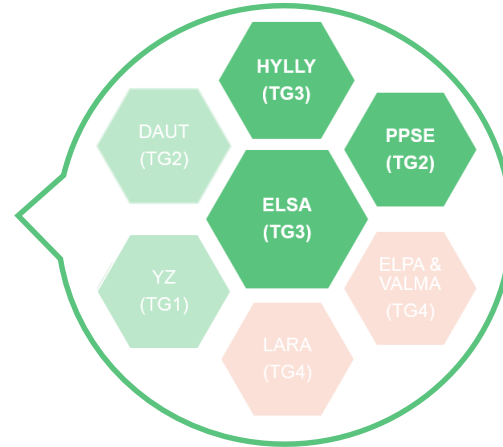
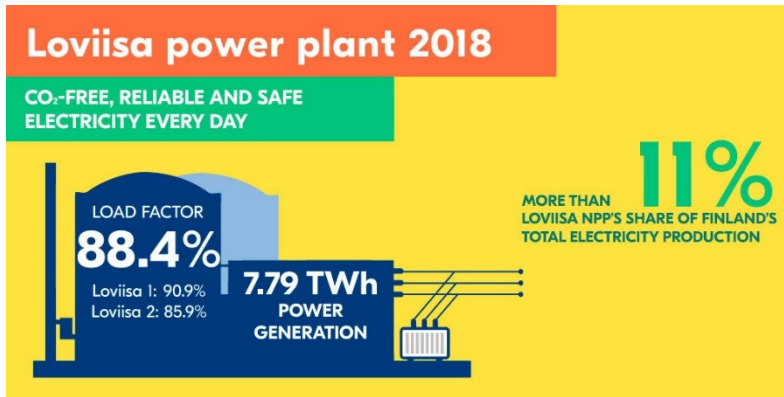
Mika Heikkilä

Fortum Power and Heat Oy, 30.10.2019

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change

fortum

# Loviisa Nuclear Power Plant



## VVER-440 units x2

- Commissioned 1977 & 1980
- Operating licenses valid until 2027 & 2030
  - Lifetime extensions under investigations

## I&C renewal program

- Ensure licensability and improve maintainability of I&C systems until the end of plant lifetime

## Modelling

- Extensive plant model

## Simulators

- Engineering simulator
- Development simulator
- Training simulator x2
- Testing simulator (test field)

# ELSA project (2014-2019)

Largest, single project since the construction of Loviisa NPP

- ✓ **Scope:** Strategically targeted partial renewal - only most important safety or operability improvements
- ✓ **Implementation:** in 3 phases
- ✓ **Main partner:** Rolls-Royce Civil Nuclear SAS (France)

**Rolls-Royce**  
technology,  
design,  
licensing,  
installation and  
commissioning

**Fortum**  
design support,  
licensing with  
ADLAS®, testing  
with APROS®  
and  
commissioning

End result:



The screenshot shows a news article from World Nuclear News. The header includes the 'w n n world nuclear news' logo and navigation links for 'Energy & Environment', 'New Nuclear', 'Regulation & Safety', 'Nuclear Policies', 'Corporate', and 'Uranium & Fuel'. The main headline reads 'Fortum, Rolls-Royce complete automation of Loviisa plant'. Below this is a sub-headline 'I&C upgrade ends in success at Loviisa' and a navigation bar with links for 'Home', 'News', 'Features', 'Opinion', 'Video', 'Events', 'Jobs', 'Buyers' Guide', and 'White Papers'.

**w n n**  
world nuclear news

Energy & Environment | New Nuclear | Regulation & Safety | Nuclear Policies | **Corporate** | Uranium & Fuel |

**Fortum, Rolls-Royce complete automation of Loviisa plant**

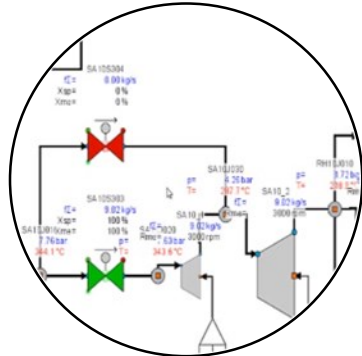
**Successful implementation of  
Rolls-Royce digital I&C  
technologies at Fortum's Loviisa  
nuclear power plant**

# ELSA Key Success Factors



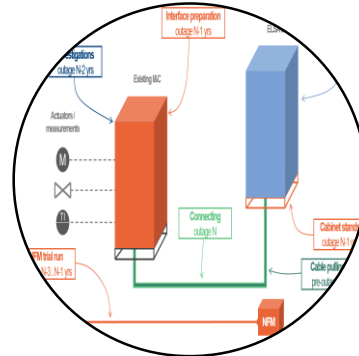
## ADLAS® – Advanced licensing and safety engineering

- Clear formulation of requirements on plant & functional level
- V&V of the architecture
- Renewal of all safety analyses



## APROS® testing

- Errors in design discovered earlier
- Decreasing test field length through using system emulations
- Validation against simulated plant model
- Tuning of reactor power controller



## Preparatory works

- Pre-approval of scope and modifications sought from STUK
- Interface analysis & testing in previous outage
- Preliminary installations in previous outage or during operation



## Progress assurance

- Active schedule management on several areas, both on Fortum and Supplier side
- Risk mitigation based on schedule delays or margins
- Involvement of STUK with licensing schedule
- Active monitoring of works during the outages

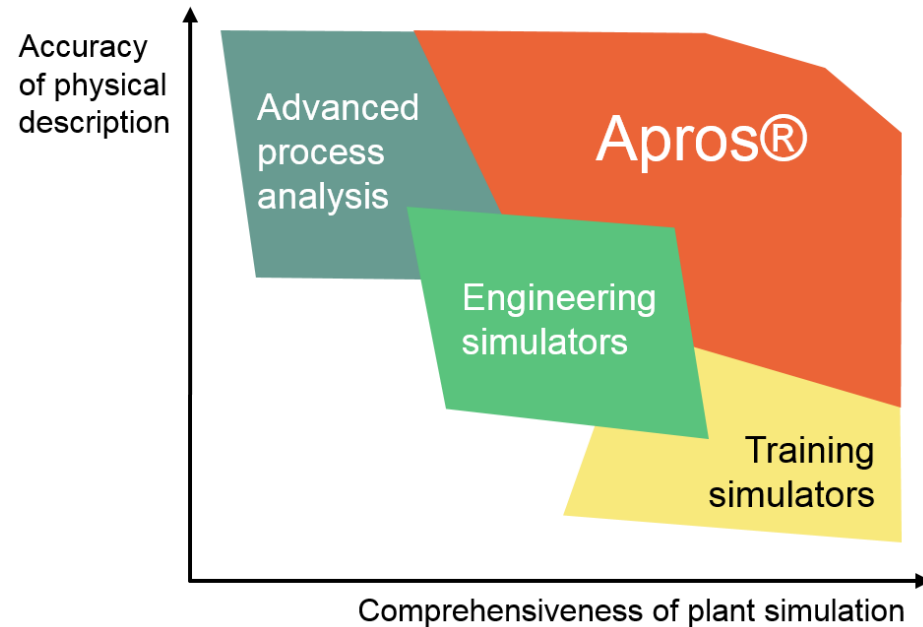


## Operational excellence

- Shared mindset with Fortum and Supplier - can-do attitude
- Responsibilities shared based on knowledge and availability
- Lessons learnt from each outage and even from consecutive plant units

**Continuous improvement!**

# Apros® - Process Simulation Software



- comprehensive plant model covering reactor island, turbine island, balance of plant, electrical and automation systems
- light water reactor types covered: BWR, PWR, VVER
- solvers included: 1D- and 3D neutronics, incl. two-group nodal kinetic model, thermal hydraulic, and six-equation flow models
- complete process component libraries including containment, cooling towers, passive systems, and severe accident management systems
- complete automation model incl. PID controls, interlockings, sequence controls
- plant electrical systems and grid model
- connectivity to third party software & I&C systems: Areva TXS, Siemens SPPA-T2000, ABB PCS, Rolls-Royce Spline

**Apros® is a comprehensive, accurate and user friendly software product for modelling and dynamic simulation of power plants, energy systems and industrial processes.**

Developed by Fortum and VTT Technical Research Centre of Finland since 1986 - [www.apros.fi](http://www.apros.fi)

# Apros® - Process Simulation Software

Fields of industry:



Nuclear power and thermal power production



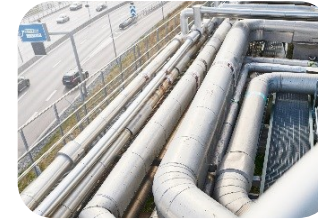
Pulp and paper



Desalination models



Solid Oxide Fuel Cells



District heating

Users:

Power plants

Engineering offices

Safety authorities

Research organizations

Universities

Key uses:

Safety analysis

Engineering support

I&C testing

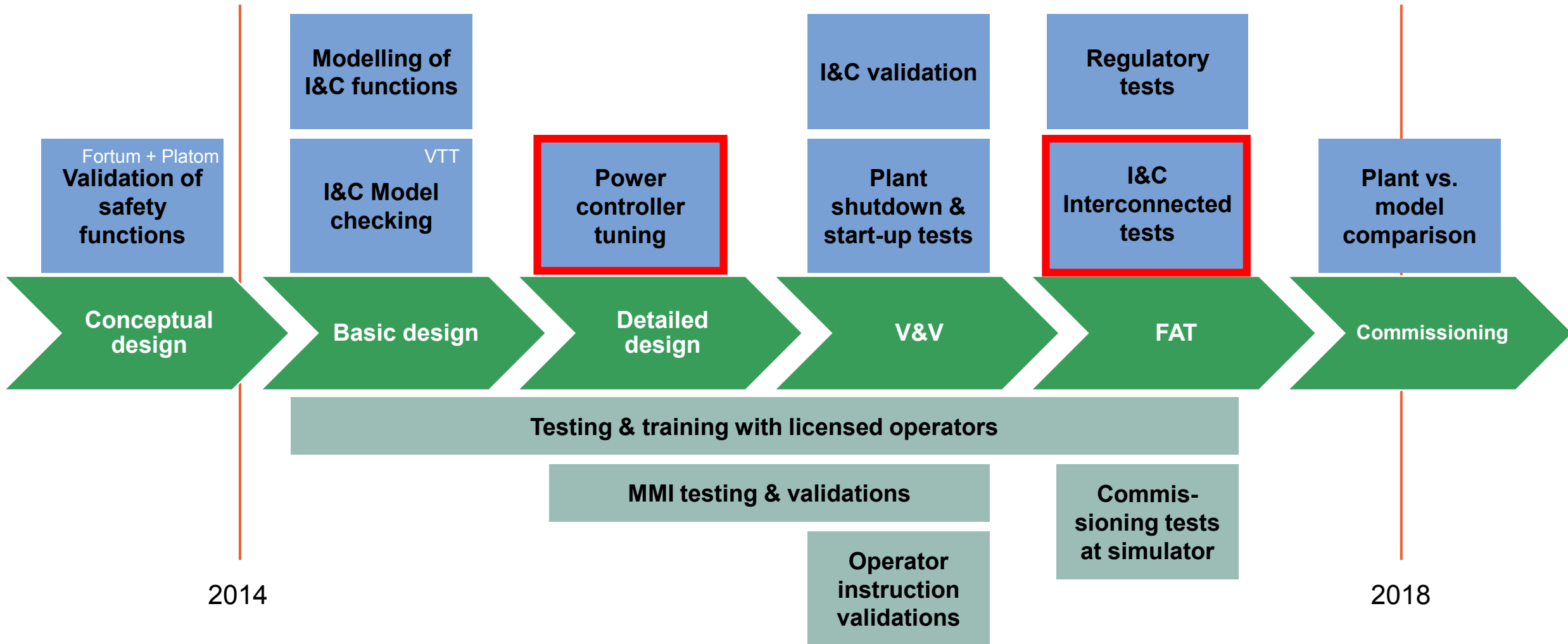
Operator training

Research and development

Apros® has users in 33 countries

*Nuclear references e.g. in Japan, Slovenia, Sweden, China, Russia, Finland.*

# Utilization of Apros® simulators in ELSA project





# Reactor Power Controller renewal

## Original Reactor Power Control System (ARM)

- Analogue Russian technology
- Cascaded MSHP and NF controllers
  - Simple increase/decrease controller



## New Reactor Power Control System (RPCS)

- Digital Rolls-Royce Spline technology
- Cascaded MSHP and NF controllers
  - Industrial standard controller

### Design basis for new system:

- Functionalities are based on the original ARM system
- ARM systems' behavior during the process transients to be used as a reference

**Challenge:** Transient based testing limited with real power plant processes



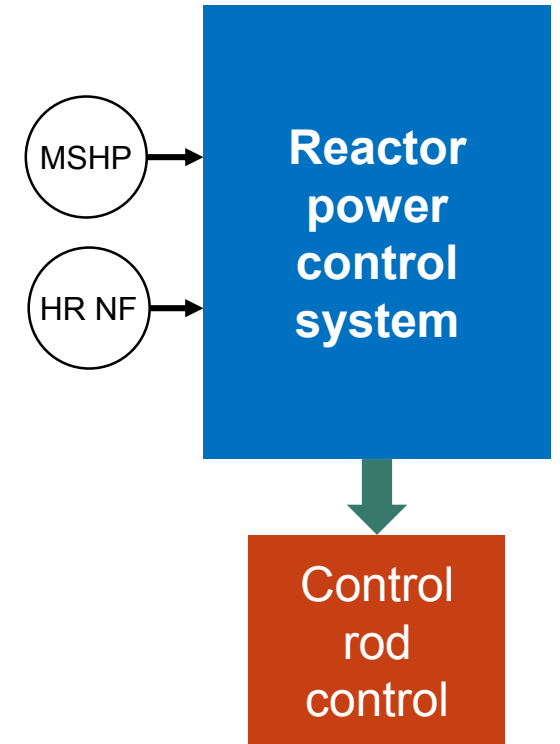
# Reactor Power Controller renewal - Tuning

## Controller parameters

- 13 test cases defined by Loviisa operators and I&C experts
- Apros® plant model and Rolls-Royce I&C emulation
- Test results compared to the modelled ARM controller

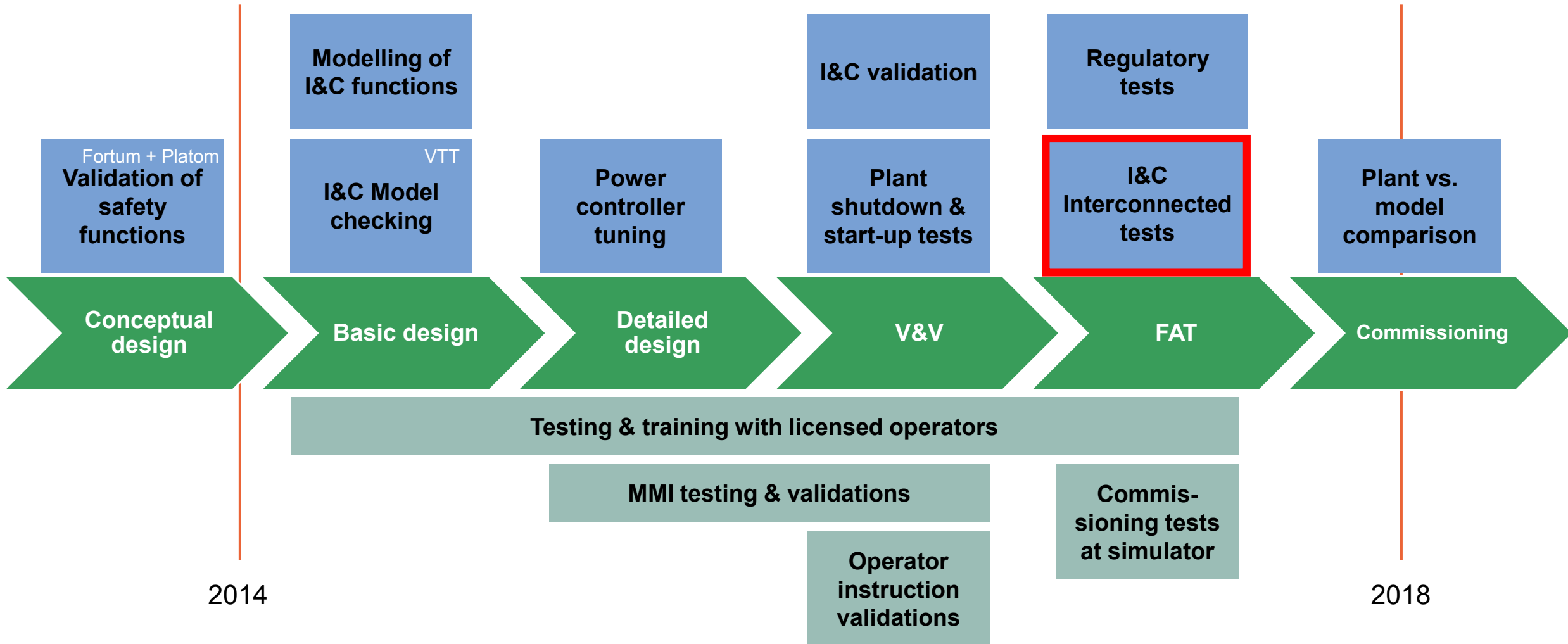
## Final controller verification

- at test field with real I&C cabinets
- during plant start-up using restricted scope of transients



No need for controller tuning has been found after the commissioning

# Utilization of Apros® simulators in ELSA project

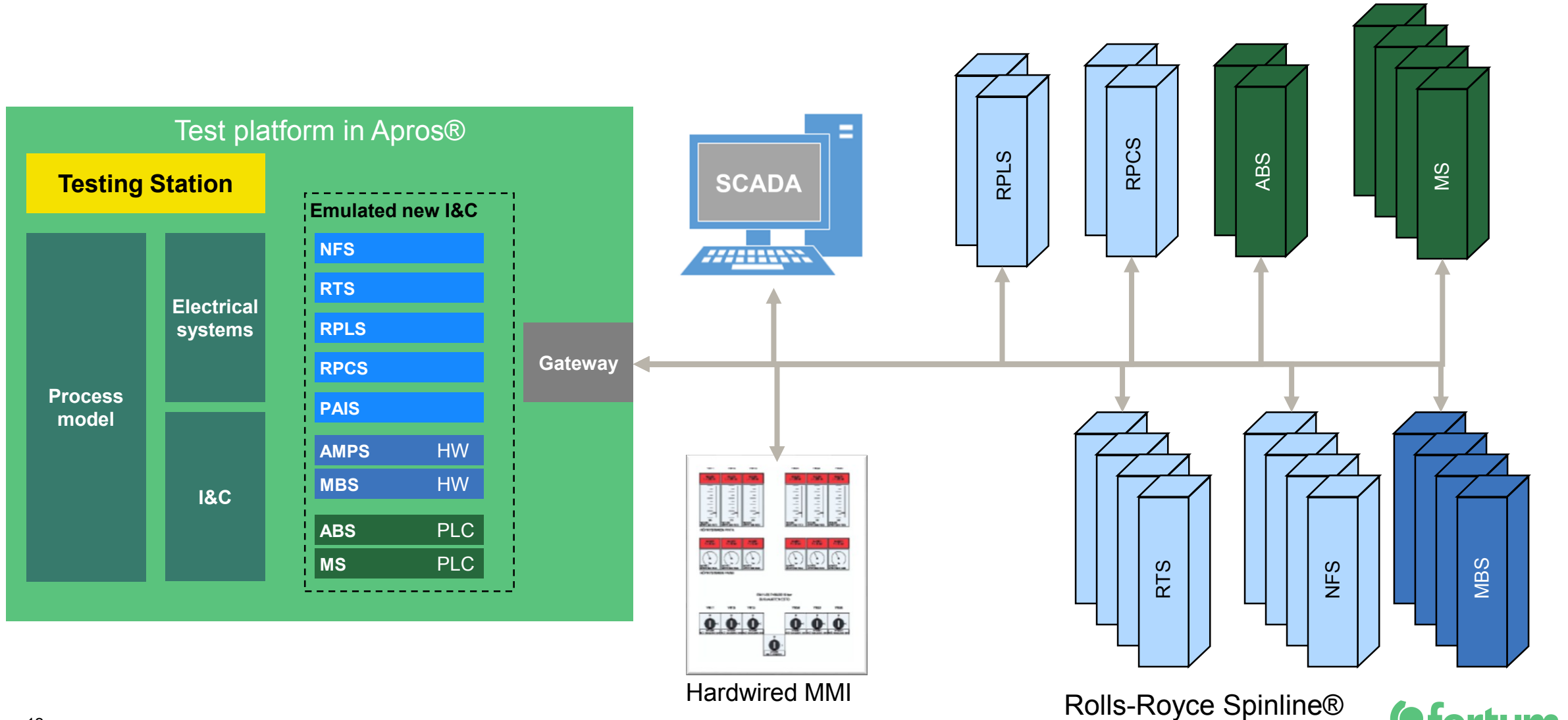


# ELSA Interconnected tests (ICT)

- **Conventional I/O testing by Rolls-Royce**
- **Simulator based I&C testing with Fortum & STUK**
  - Tests with realistic process response to ensure that I&C systems work with power plant processes as expected
  - Apros® model connected to Rolls-Royce I&C cabinets
    - Progressive testing by replacing emulated I&C systems one by one with real I&C cabinets
    - Interactions between the systems
    - Comparison of the results to the tests with emulated I&C
  - Additional tests requested by STUK



# ELSA ICT architecture – emulations vs. real I&C



# Overall test strategy

## ICT Tests

Test cases defined by I&C supplier

- System performance
- Functional validations
- Degraded modes
- Periodic tests



## Additional simulator based ICT Tests

- Test cases based on the expertise of NPP operators' and simulation experts
  - Special transient test cases for the power controller
- Testing of the new I&C functions with the other plant I&C systems and processes



## Regulatory tests

Beyond design bases test cases that challenged the plant as a whole



# Benefits – Increased Quality

## Extensive test coverage

- Dynamic transients with realistic plant process response
- I&C system behavior in different plant states
- I&C systems' interconnections and interaction

## Earlier error findings

- Testing of I&C functions before manufacturing of the cabinets
- Software and hardware modifications possible based on simulator findings

## Test repeatability

- Basic design vs. detailed design
- Emulated I&C vs. real I&C cabinets
- Validation of the design modifications

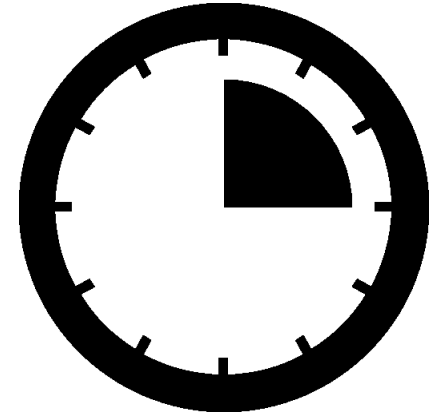


**No significant deficiencies were found during or after the commissioning**

# Benefits – Time savings

## Reduced test field and commissioning time

- Flexibility of testing schedule through the switching between emulated and real I&C
  - Testing can be performed using available cabinets – only one, several, all
- Extensive process transients and controller tuning was done at test-field
  - Gives confidence in the tuning of the controllers with the emulated I&C
    - Minimizes the outage duration



Estimated time saving at ELSA test field was approx. 7 months

Commissioning of new I&C systems was performed during normal refueling outages



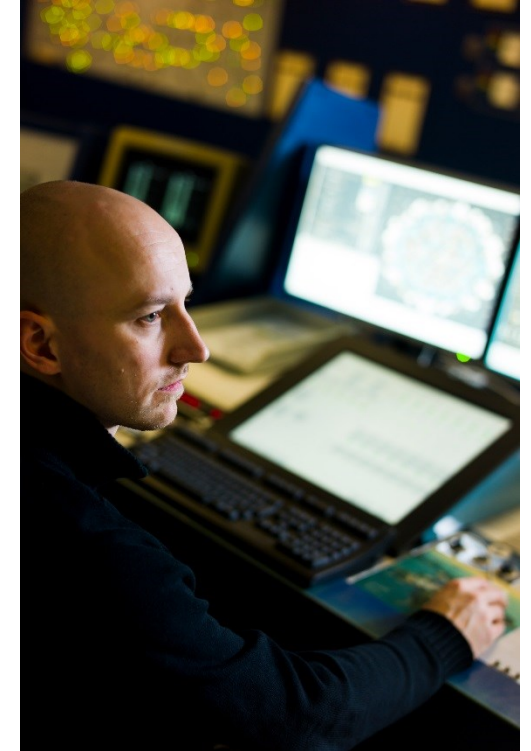
# Benefits - Operator engagement

## Win-win in the co-operation with operating personnel

- Simulators enable operating personnel's efficient involvement
  - ✓ Allows I&C project to benefit from operators' knowledge and experience
  - ✓ Increases the confidence on the project and reduce the change resistance
  - ✓ Increases operators' knowledge, helps them to learn and adopt to new systems

## Guarantee of consistency between training simulator and real I&C systems

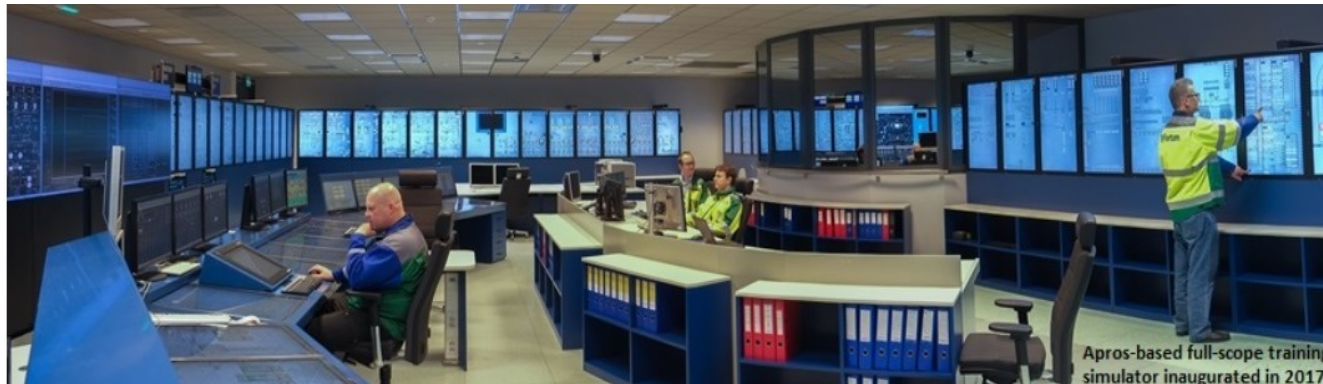
- ✓ Testing and training of future I&C modifications is possible at simulators



Only positive feedback received about the new I&C systems from the operating personnel

# Summary

- Modelled plant systems and processes can be utilized effectively in I&C renewal
- Extensive utilization of simulators saved time and increased quality
  - Transients required for power controller tuning and testing
- Future modifications can be simulator tested without extensive test field
- **Lessons learned:** Simulator models, MMI and operating personnel to be involved in design and testing even earlier in upcoming projects



IAEA OSART  
2018  
“Good practice”

More about ELSA project:

<https://www.neimagazine.com/features/featureic-upgrade-ends-in-success-at-loviisa-7048883/>

**Thank you for your attention!**  
**Questions?**