



POWERPLANTSIM

Simulation Conference 2018

JANUARY 14-17, 2018

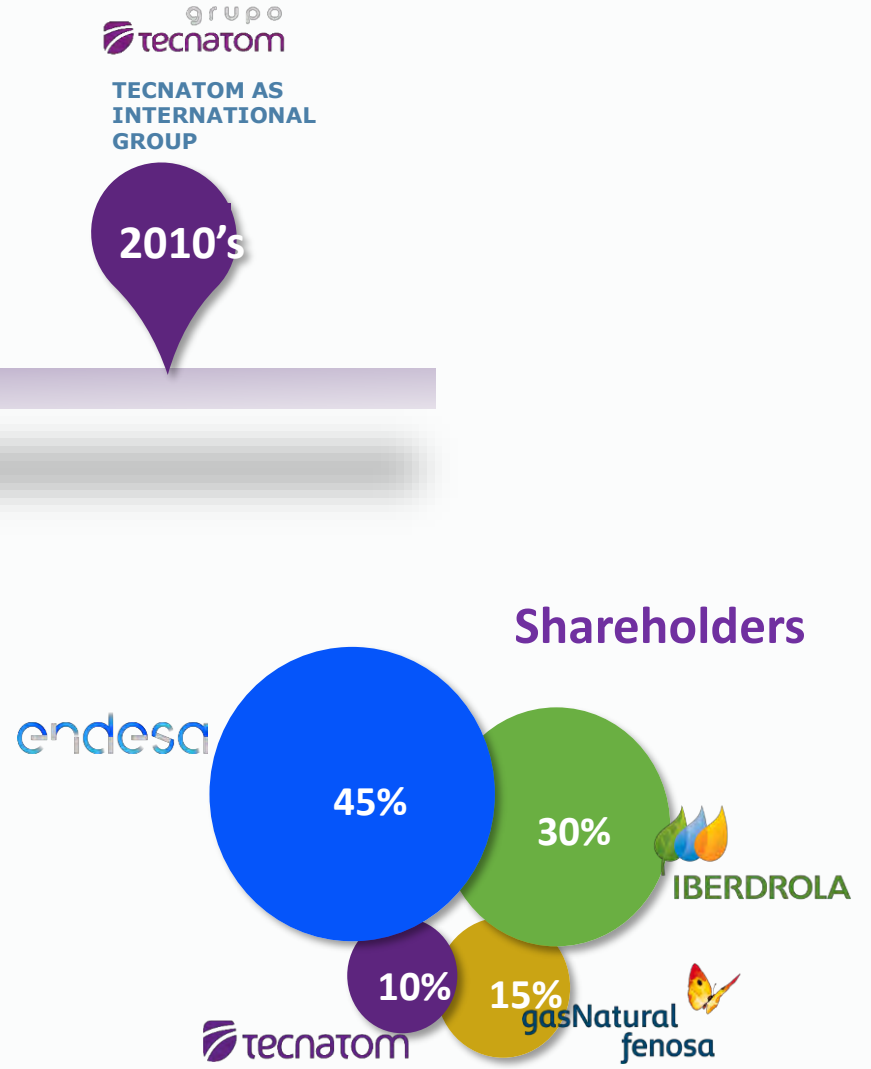
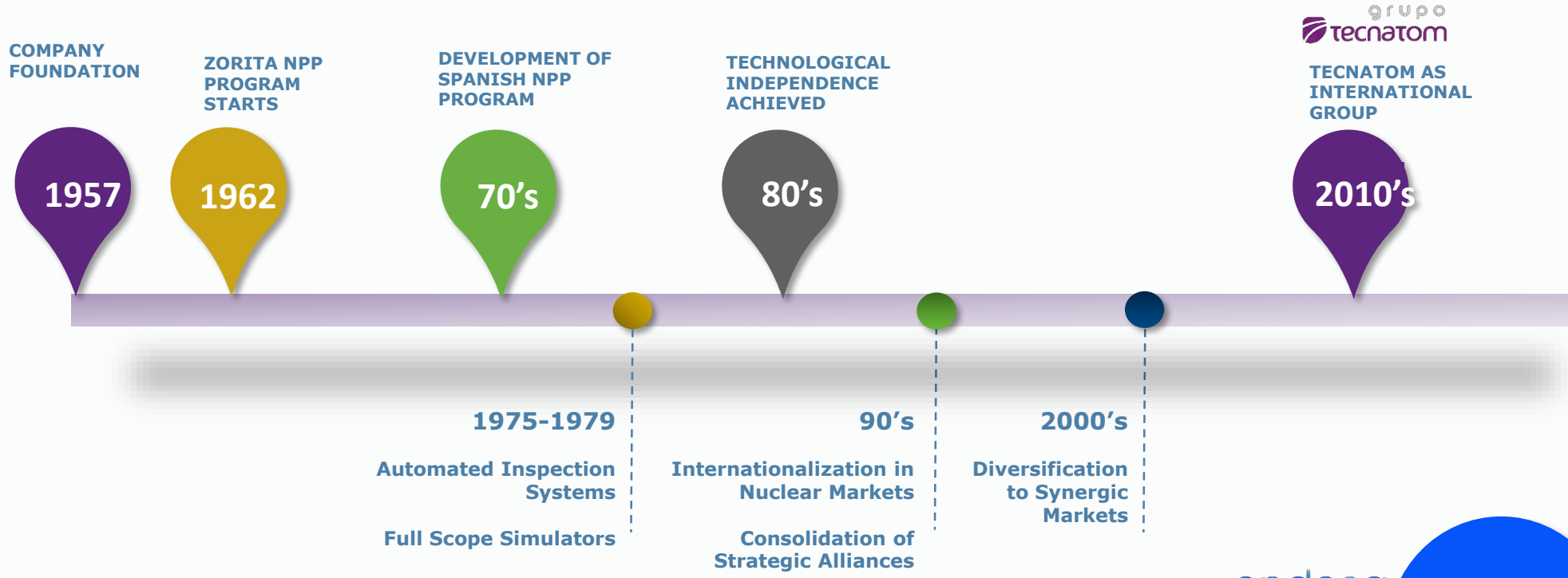
JW Marriott Houston Downtown, Houston, Texas



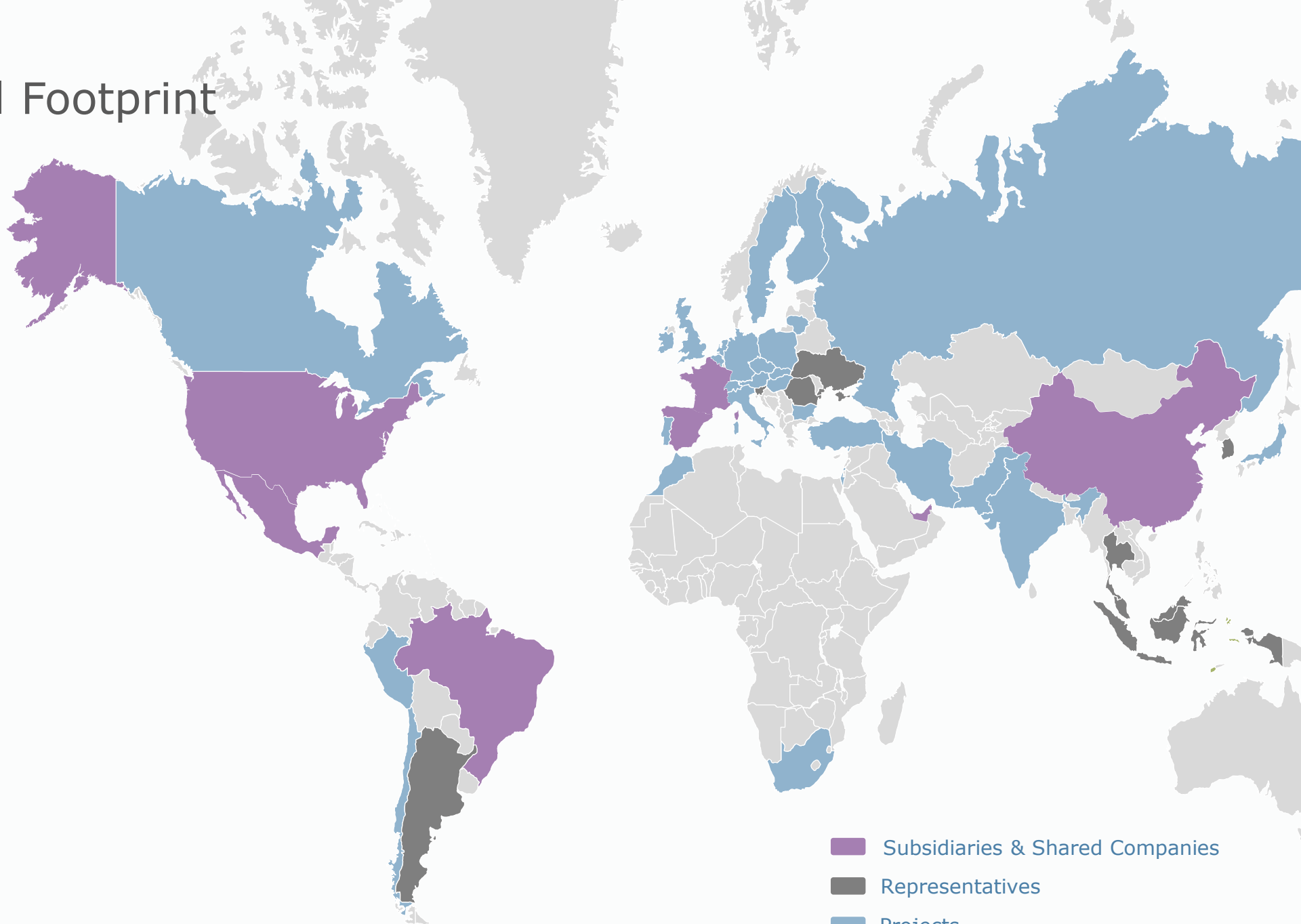
Education on nuclear
fundamentals with iPWR
Basic Principle Simulator

60 Years
providing
Solutions
to our
Clients

Company Milestones



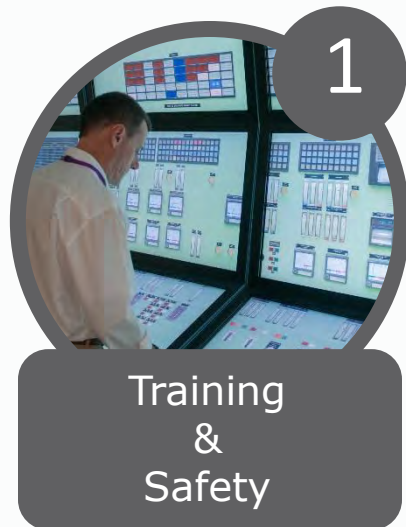
International Footprint



- Subsidiaries & Shared Companies
- Representatives
- Projects

Value proposition

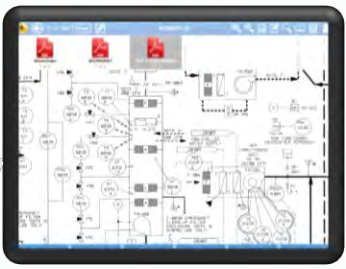
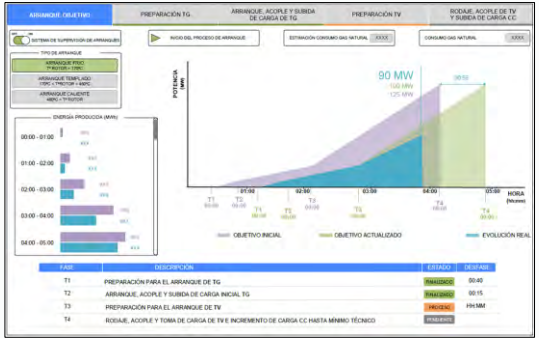
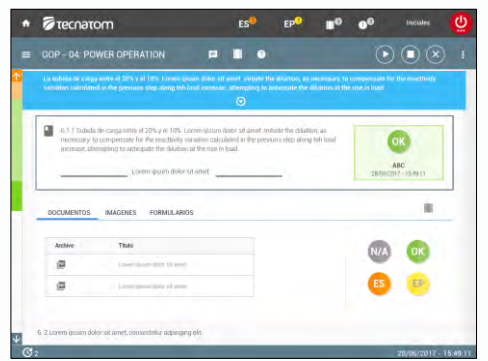
Develop and implement integrated and innovative solutions that promote the safety, efficiency and reliability of your assets, processes and the performance of people



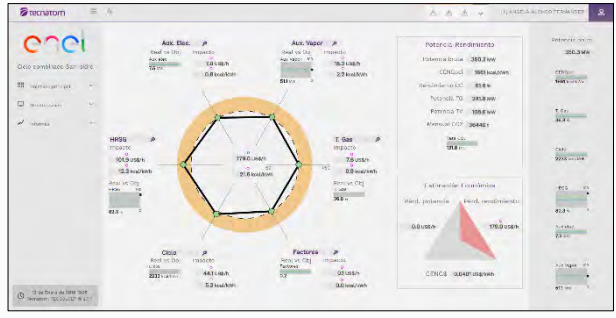
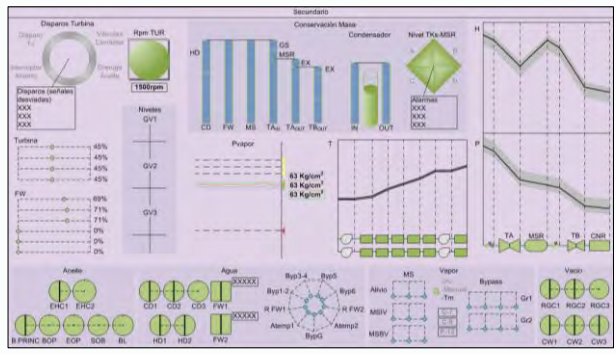
Digital Operation and Asset Management



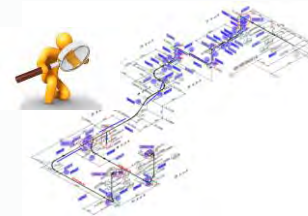
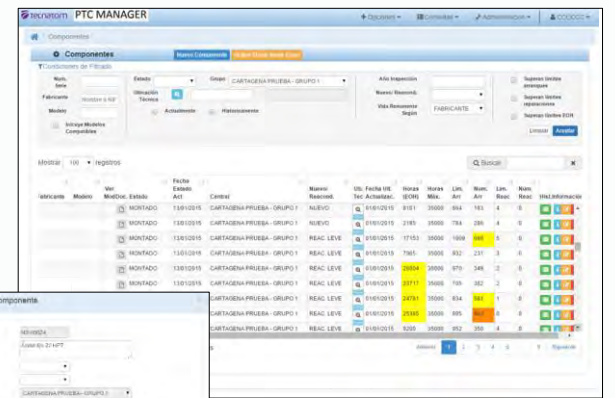
Operation support



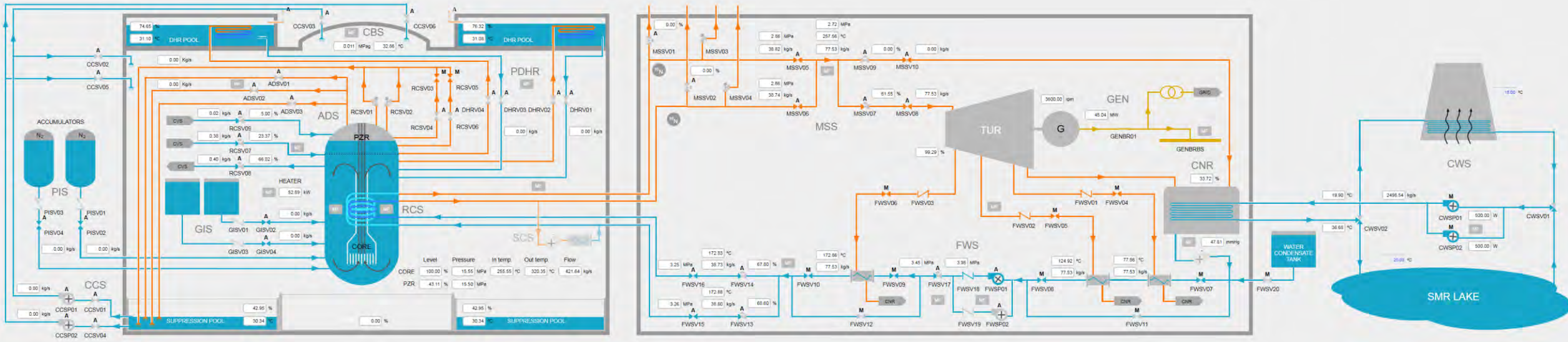
Monitoring



Asset management



Integral Pressurized Water Reactor (iPWR) Simulator



Scope:

Basic Principle Simulator – Generic behavior

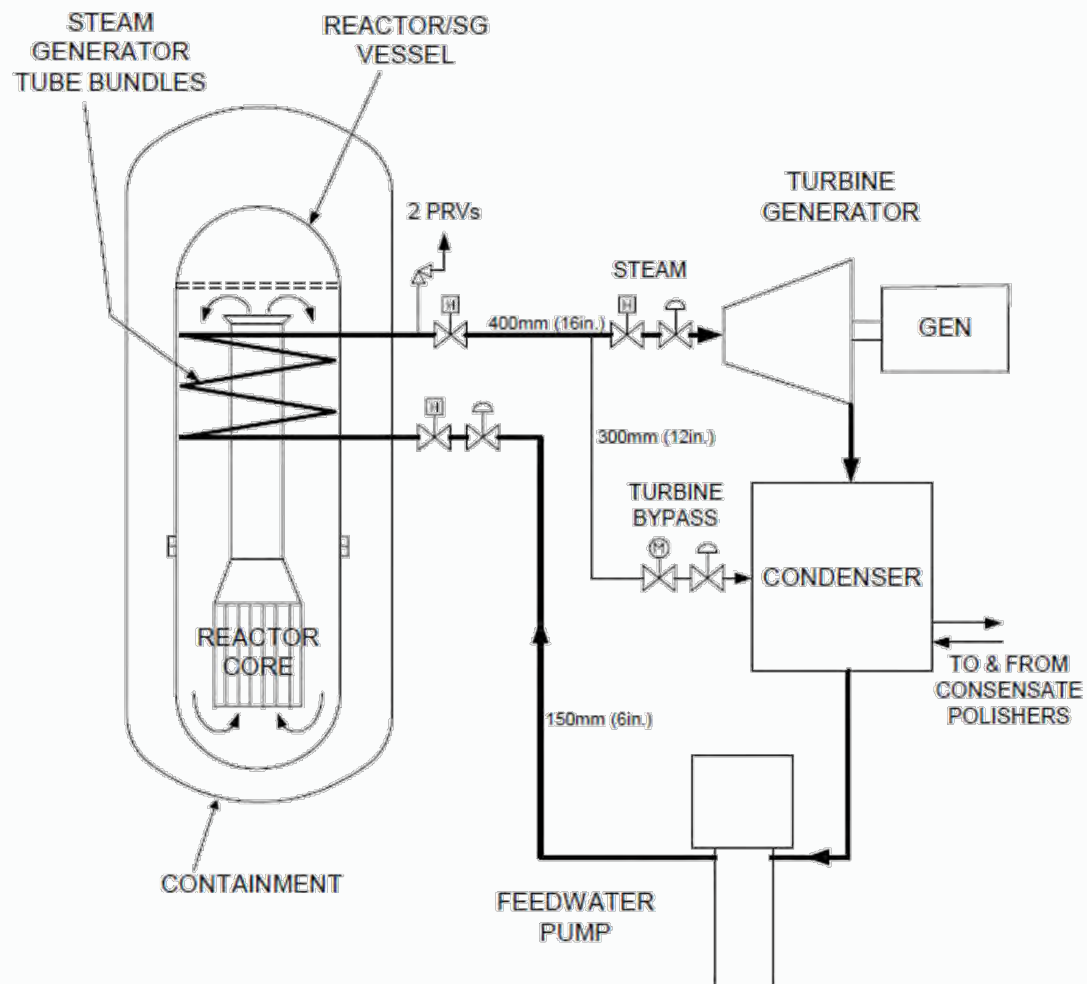
Small Modular Reactor, iPWR type

Part of IAEA's collection of Basic Principle Simulators for Education

Fully developed with Tecnatom's simulation technology

<https://www.iaea.org/NuclearPower/Simulators/>

Integral Pressurized Water Reactor (iPWR) Simulator



Main thermal-hydraulic parameters:

- Reactor thermal power ~ 150 MW
- Electrical power ~ 45 Mwe
- PZR pressure ~ 15.5 Mpa
- Feedwater flow ~ 79 Kg/s

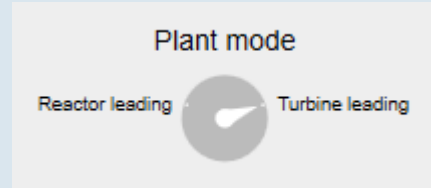
Passive safety:

- Automatic Depressurisation system (ADS)
- Pressure Injection system (PIS)
- Gravity Injection system (GIS)
- Passive decay heat removal (PDHR)

Configuration capabilities

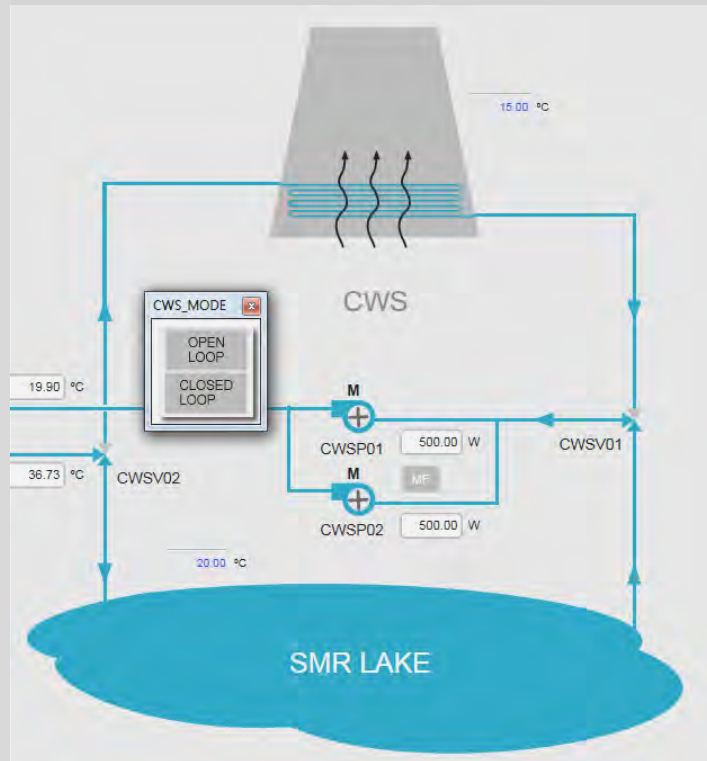
Operating modes

- ✓ Reactor Leading Mode
- ✓ Turbine Leading Mode



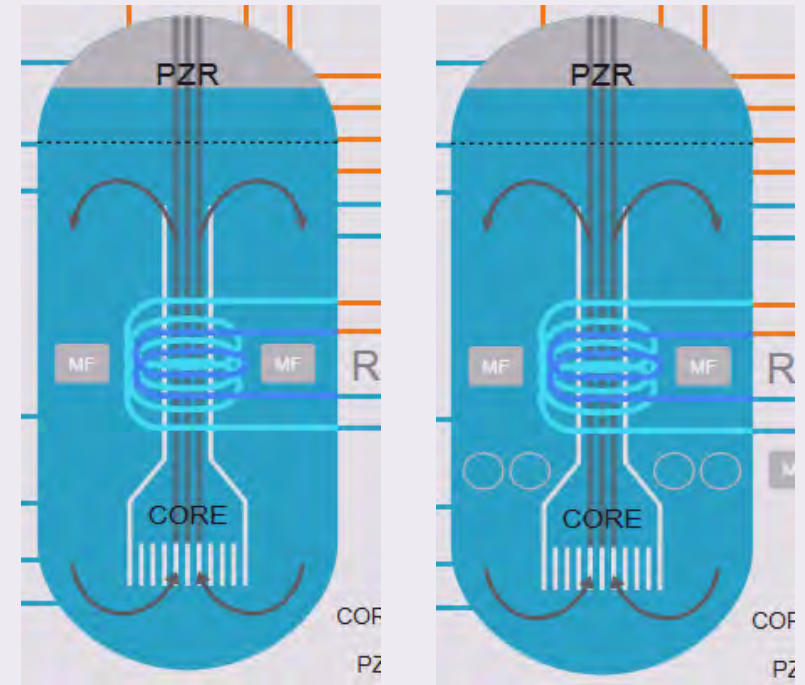
Circulating water cooling

- ✓ Open loop
- ✓ Closed loop



Core cooling

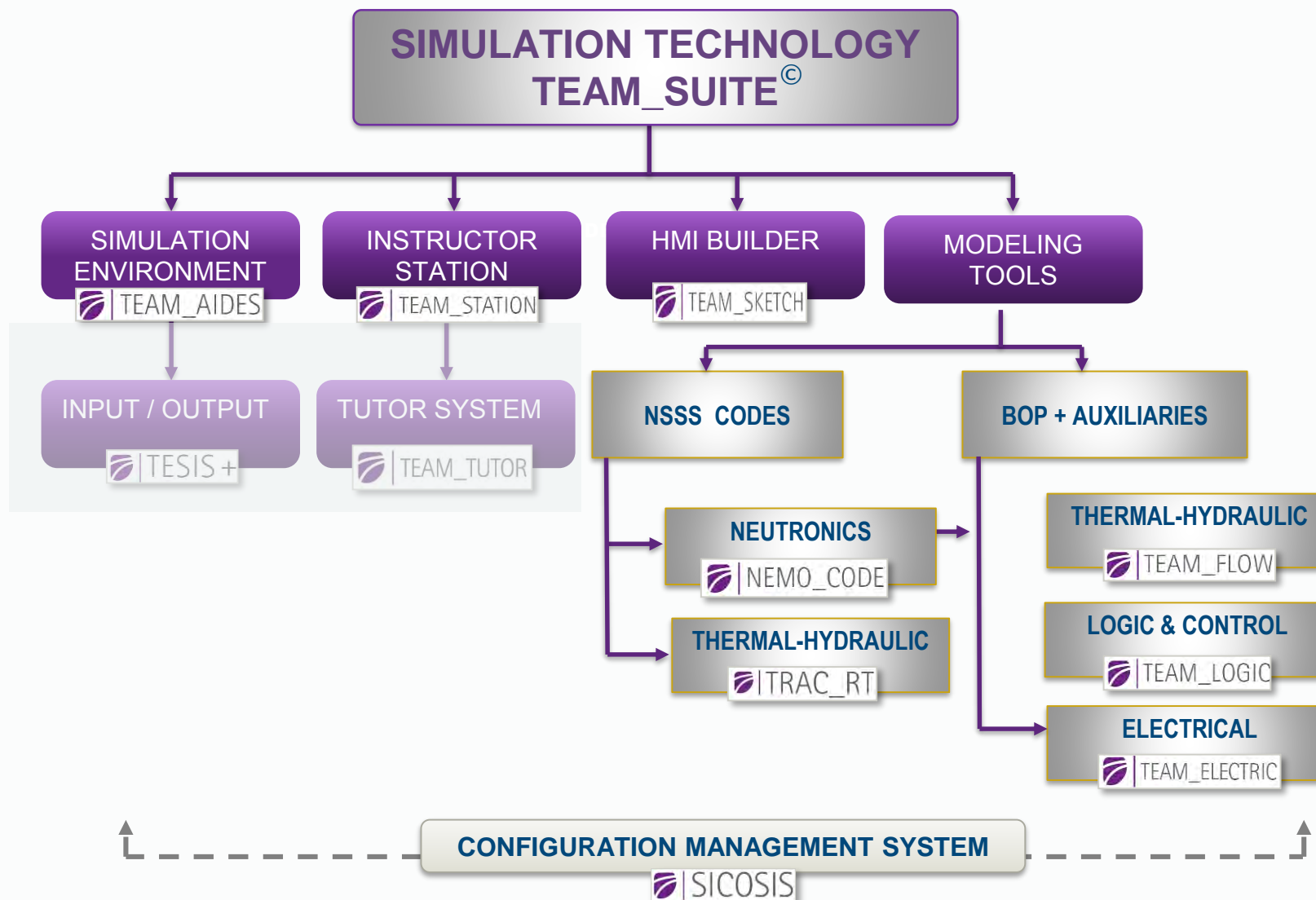
- ✓ Natural circulation
- ✓ Forced circulation



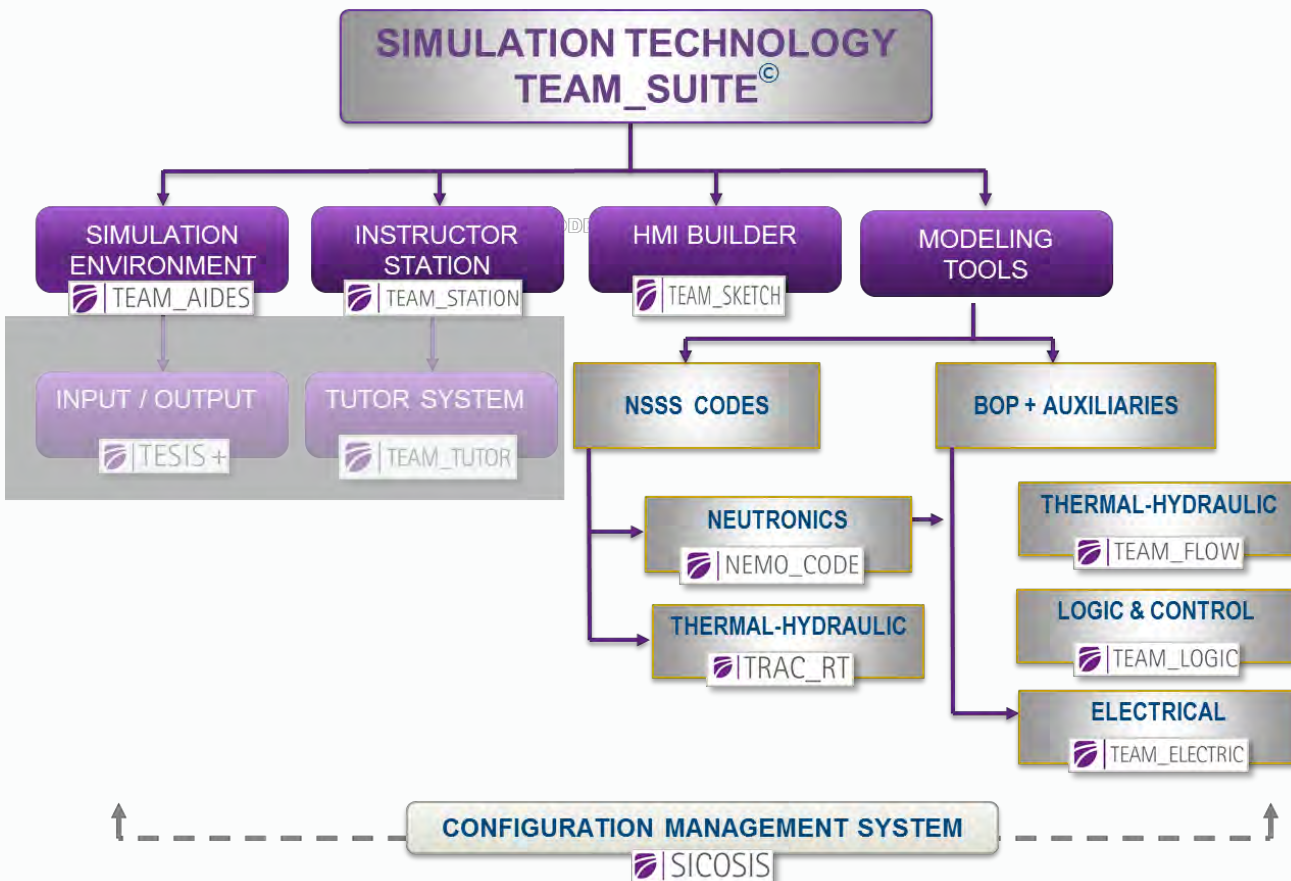
Setpoints

● Low-low level vessel % < %

Technological approach

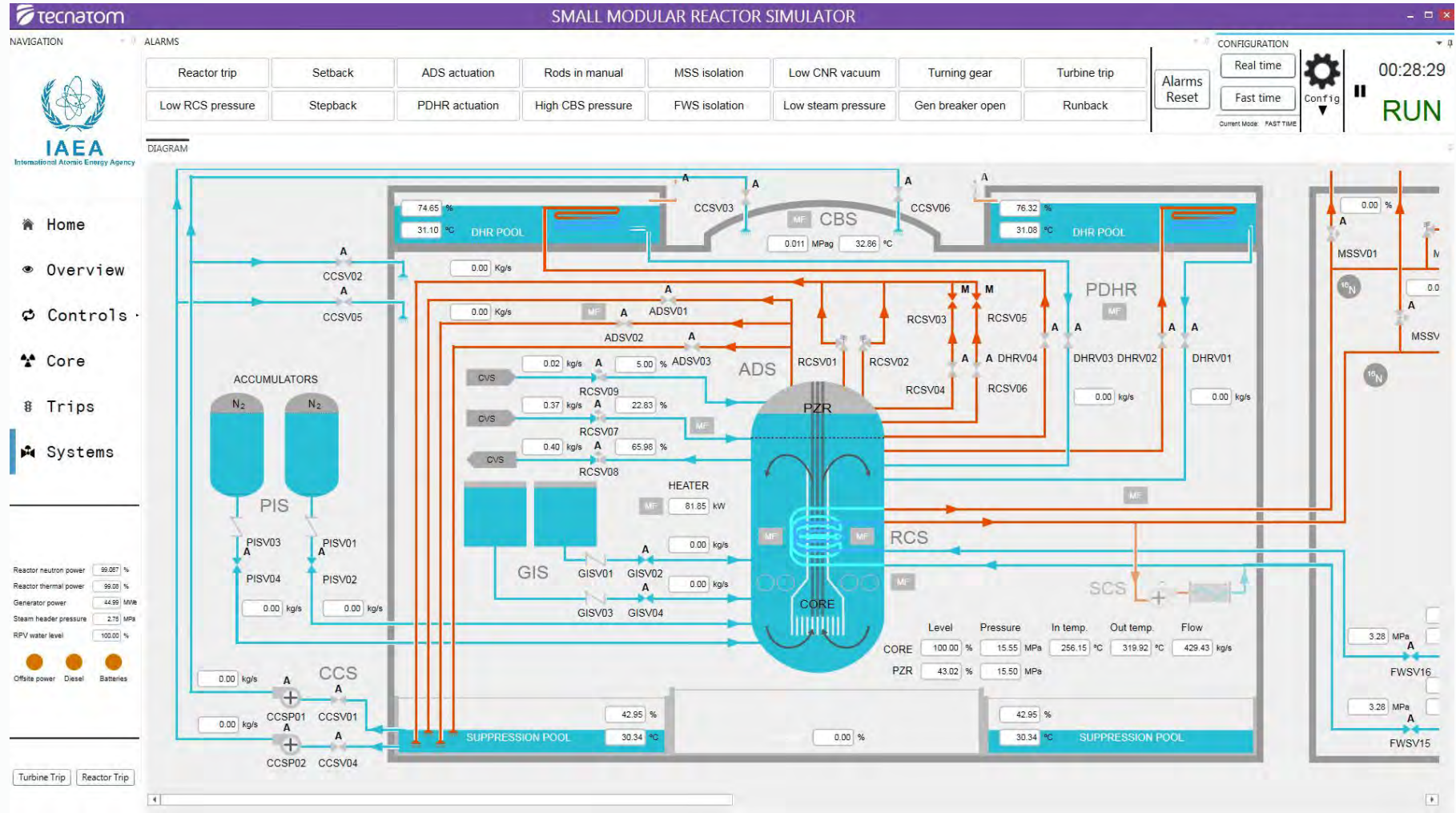


Technological approach



NEUTRONICS NEMO_CODE	Neutronic model
THERMAL-HYDRAULIC ITRAC_RT	Reactor Coolant System Main Steam Feedwater Turbine Containment building & pools
THERMAL-HYDRAULIC TEAM_FLOW	Condenser cooling Emergency core cooling Containment cooling
LOGIC & CONTROL TEAM_LOGIC	Reactor and Protection System Valves / pumps logics
ELECTRICAL TEAM_ELECTRIC	Generator system

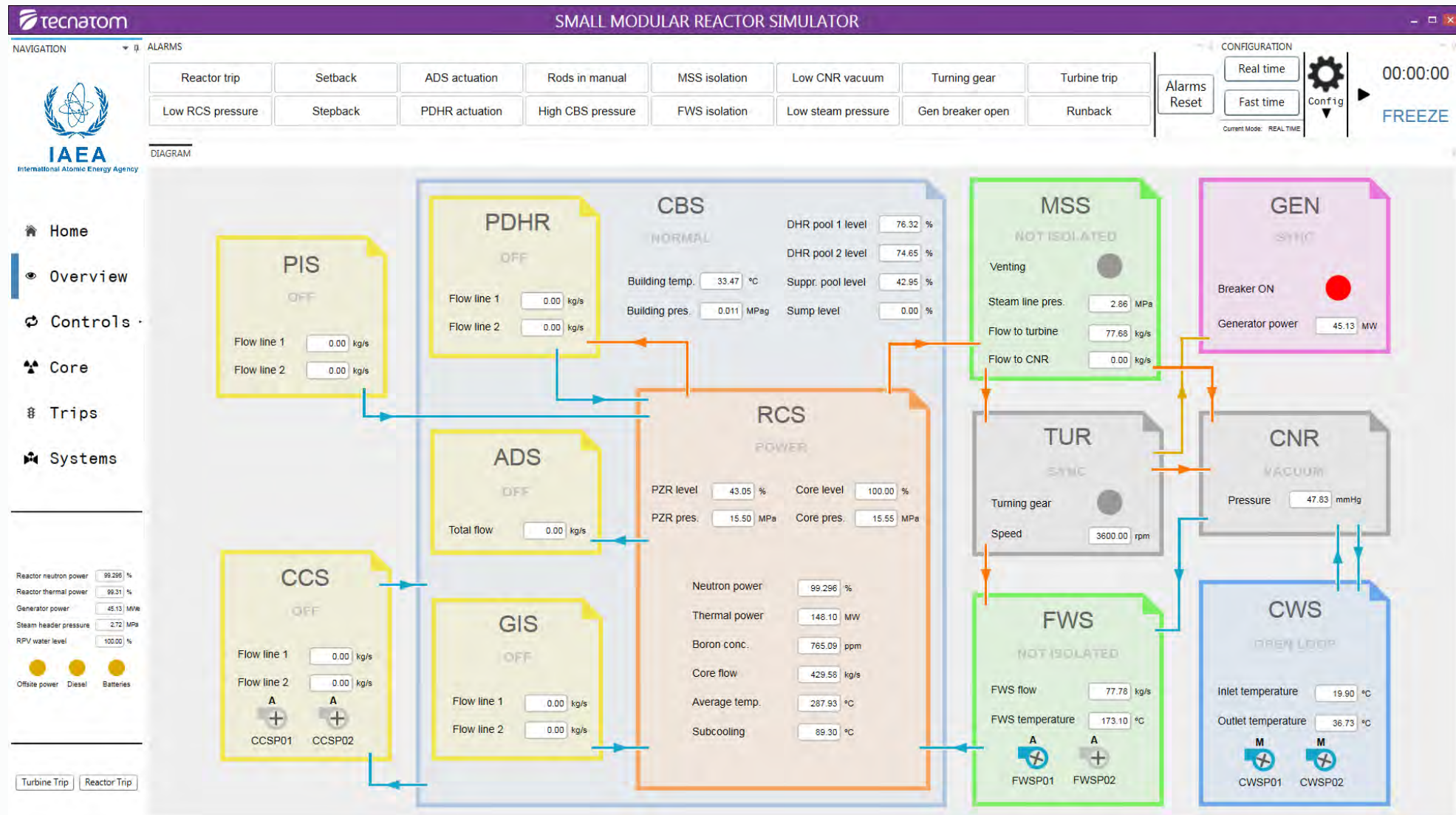
Graphical User Interface

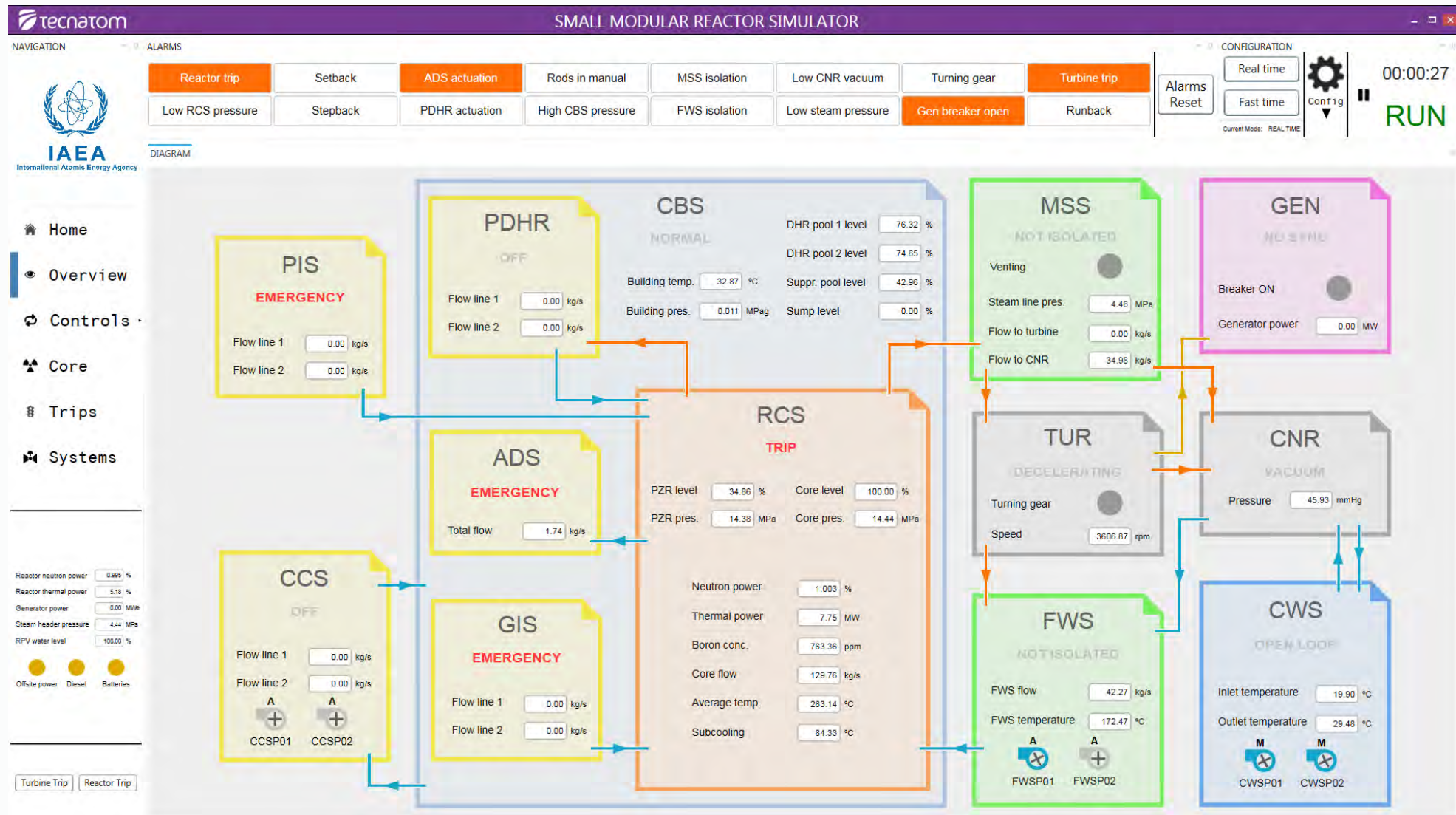


Human Factors Engineering principles & methods

NUREG-0700

The image shows the cover of the NUREG-0700 report, titled 'Human-System Interface Design Review Guidelines'. The cover features a vertical strip of icons on the left side, including a person, a radiation symbol, a nuclear symbol, and a gear. The title is prominently displayed in the center. At the bottom, it identifies the publisher as the U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Washington, DC 20555-0001.





Control loops



tecnaTom
SMALL MODULAR REACTOR SIMULATOR

NAVIGATION

- Home
- Overview
- Controls
- Core
- Trips
- Systems

ALARMS

Reactor trip	Setback	ADS actuation	Rods in manual	MSS isolation	Low CNR vacuum	Turning gear	Turbine trip
Low RCS pressure	Stepback	PDHR actuation	High CBS pressure	FWS isolation	Low steam pressure	Gen breaker open	Runback

CONFIGURATION

Real time

Fast time

Alarms Reset

Config

00:12:04

FREEZE

IAEA

International Atomic Energy Agency

TURBINE BYPASS CONTROL

The diagram illustrates the control logic for the turbine bypass valve. It starts with a Turbine load of 0.50%. This load is processed through a transfer function $T_{ref} = f(Iload)$ to produce a Reference temperature of 250.19 °C. This reference temperature passes through a LEAD LAG block to become a Lead-lagged temperature of 250.43 °C. Simultaneously, the Average temperature of 233.31 °C also passes through a LEAD LAG block to become a Lead-lagged temperature of 239.08 °C. The difference between these two temperatures is the Temperature error of 11.35 °C. This error is fed into a transfer function $V_p = f(error)$ to produce a Valve position demand 1 of 0.00%. The Steam pressure is 3.89 MPa, and the Set steam pressure is 4.00 MPa. The difference between these is the Pressure error of -0.10 MPa. This error is fed into a PID controller to produce a Valve position demand 2 of 6.47%. The final valve position demand is the sum of demand 1 and demand 2, resulting in a Final valve position demand of 6.50%. This demand controls the MSSV09 Turbine bypass valve. The valve's position is monitored via Avg. temperature and Steam pressure feedback loops.

Reactor neutron power: 0.048 %

Reactor thermal power: 2.96 %

Generator power: 0.00 MWe

Steam header pressure: 3.89 MPa

RPV water level: 99.88 %

Offsite power Diesel Batteries

Turbine Trip

Reactor Trip

This graph shows the temperature response. The Reference temperature (blue line) is constant at 250.19 °C until approximately 00:09:30, where it drops to 250.43 °C. The Average temperature (red line) follows this step change with a lag, starting to decrease around 00:09:30 and reaching a new steady state of approximately 239.08 °C by 00:10:30.

This graph shows the steam header pressure response. The pressure is constant at 3.89 MPa until approximately 00:09:30, where it drops to 4.00 MPa. The pressure then exhibits a transient spike, peaking at approximately 4.5 MPa around 00:10:00, before settling back to a steady state of approximately 3.89 MPa by 00:10:30.

Simulator control and supervision



tecnatom
SMALL MODULAR REACTOR SIMULATOR

NAVIGATION ALARMS

CONFIGURATION 00:03:25

Reactor trip

Low RCS pressure

Setback

Stepback

ADS actuation

PDHR actuation

Rods in manual

High CBS pressure

MSS isolation

FWS isolation

Low CNR vacuum

Low steam pressure

Turning gear

Gen breaker open

Turbine trip

Runback

IAEA
International Atomic Energy Agency

DIAGRAM

Alarms Reset

Real time

Fast time

Config

00:03:25

RUN

Home

Overview

Controls

Core

Trips

Systems

- New page
- Trends
- Export to Excel
- User manuals
- Initial conditions
- Backtrack
- Speed control
- Controlled parameters
- Generic malfunctions
- Specific malfunctions

Reactor neutron power: 0.03%
Reactor thermal power: 2.85%
Generator power: 0.00 MW
Steam header pressure: 3.00 MPa
RPV water level: 99.99%

Offsite power: ● Diesel: ● Batteries: ●

	Level	Pressure	In temp.	Out temp.	Flow
CORE	98.98 %	5.26 MPa	247.44 °C	264.65 °C	66.37 kg/s
PZR	16.96 %	5.20 MPa			

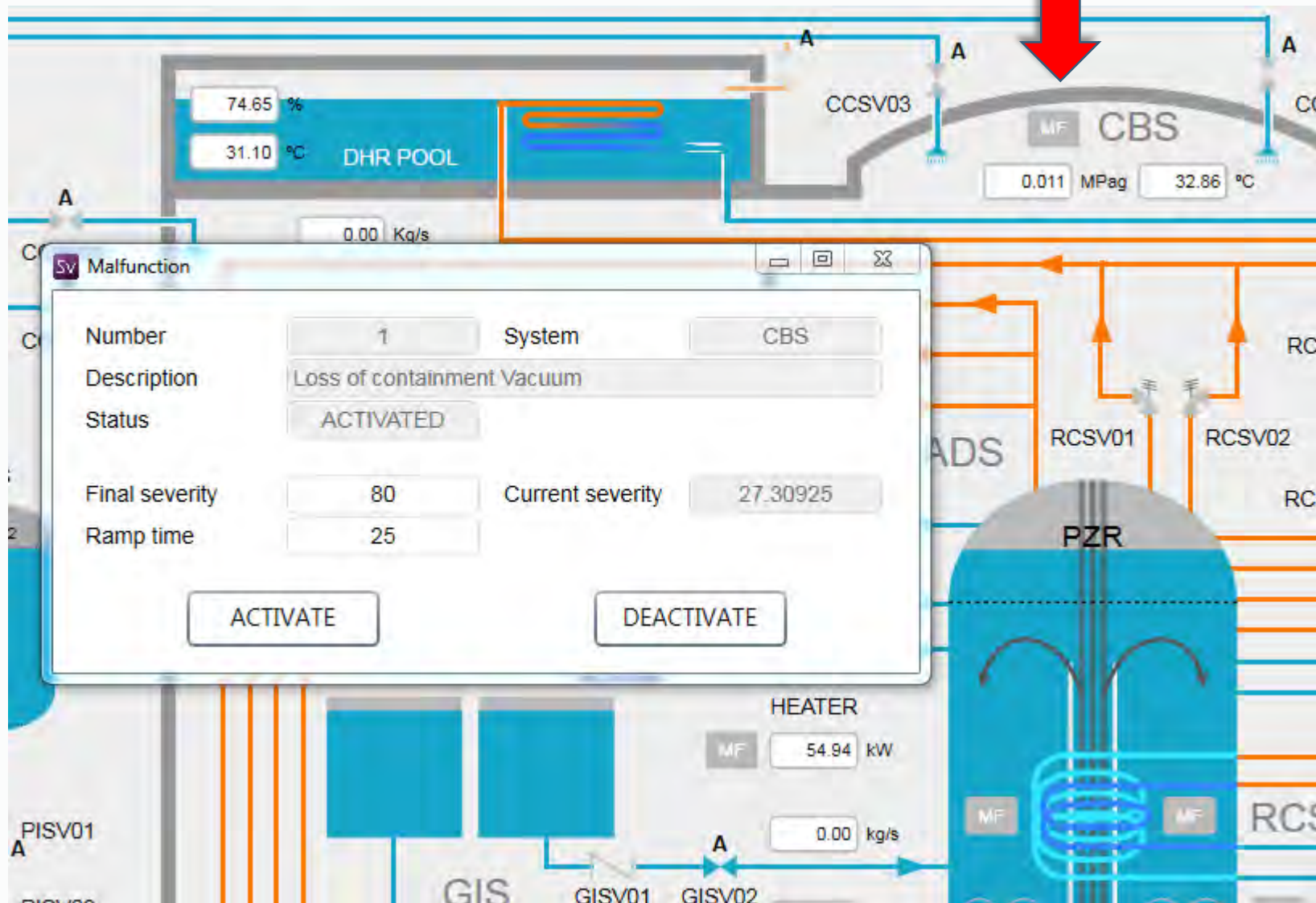
Turbine Trip

Reactor Trip

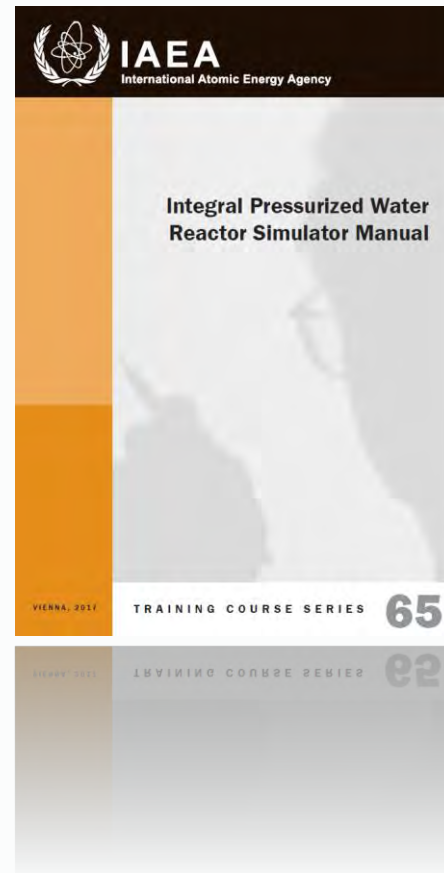
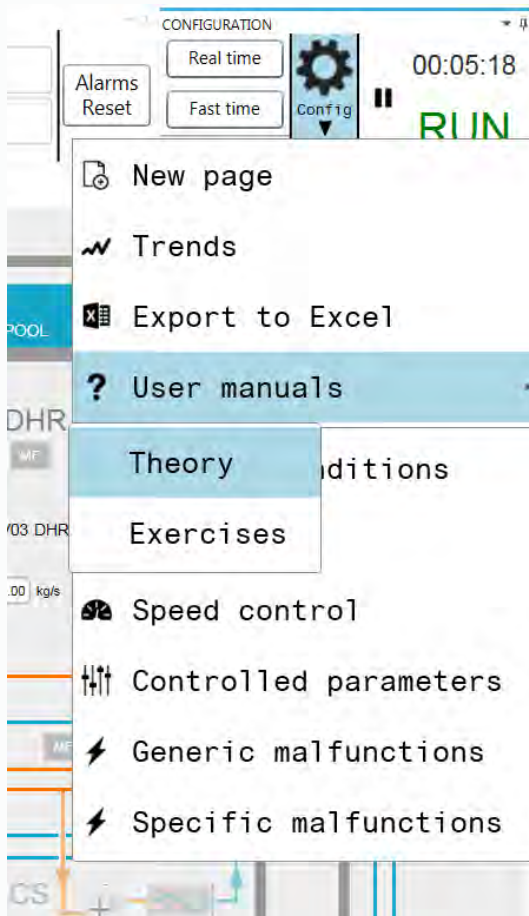
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Malfunctions activation



Training material



Exercises for standard operations:

- Load maneuvering in turbine leading mode
- Reactor power decrease from 100% to 0%
- Reactor trip and restart
- ...

Exercises for malfunction transient Events

- Loss of feedwater Flow
- Turbine runback
- Large steam generator tube rupture
- ...

TABLE 11. STATION BLACKOUT (cont.)

MALFUNCTION:	SM-GEN-1	DESCRIPTION:	Station blackout (total loss of AC power)		
STEP ID.	PROCEDURE STEPS		GUI SHEET	EXPECTED RESPONSE	STATE
5	Verify turbine trip: (1) Verify there is no steam flow going to the turbine.		Systems	<ul style="list-style-type: none"> — MSS to TUR flow (MSSFT04_TR) goes to zero (MSSV08 is a 'fail close' valve); — MSS to CNR flow (MSSFT05_TR) is zero (MSSV09 is a 'fail close' valve); — Turbine trip and generator breaker open alarms. 	
6	Verify power supply: (1) Offsite power light is off; (2) Emergency diesel light is off; (3) Battery light is on.				
7	Verify main steam safety valves are dumping steam to atmosphere.		Systems	<ul style="list-style-type: none"> — MSSV03/4 open; — Safety valve relief setpoint is 5.70 MPa. 	
NOTE	ADS valves are fail close valves. On a station blackout event, ADS valves close to avoid an unnecessary breach on the reactor coolant pressure boundary. These valves should be powered from its associated batteries before they are fully discharged.				

Different operating systems and platforms

The screenshot displays the 'SMALL MODULAR REACTOR SIMULATOR' interface. At the top, there's a navigation menu with 'Home', 'Overview', 'Controls', 'Core', and 'Trips'. Below this is the IAEA logo. The main area features a schematic diagram of the reactor system, including a central CORE, ADS (Automatic Dependent System), PDHR (Pressure Dependent Hydrogen Recombination), PIS (Pressure Independent System), GIS (Gas Inlet System), CCS (Cooling System), MSS (Main Steam System), TUR (Turbine), GEN (Generator), FWS (Feed Water System), CNR (Circulating Nuclear Reactor), and CWS (Cooling Water System). The interface also includes an 'ALARMS' section with various status indicators, a 'CONFIGURATION' panel with 'Real time' and 'Fast time' options, and a 'RUN' button. The background shows a Windows 7 desktop with a taskbar and a sidebar menu in Arabic.

Windows 7 or higher

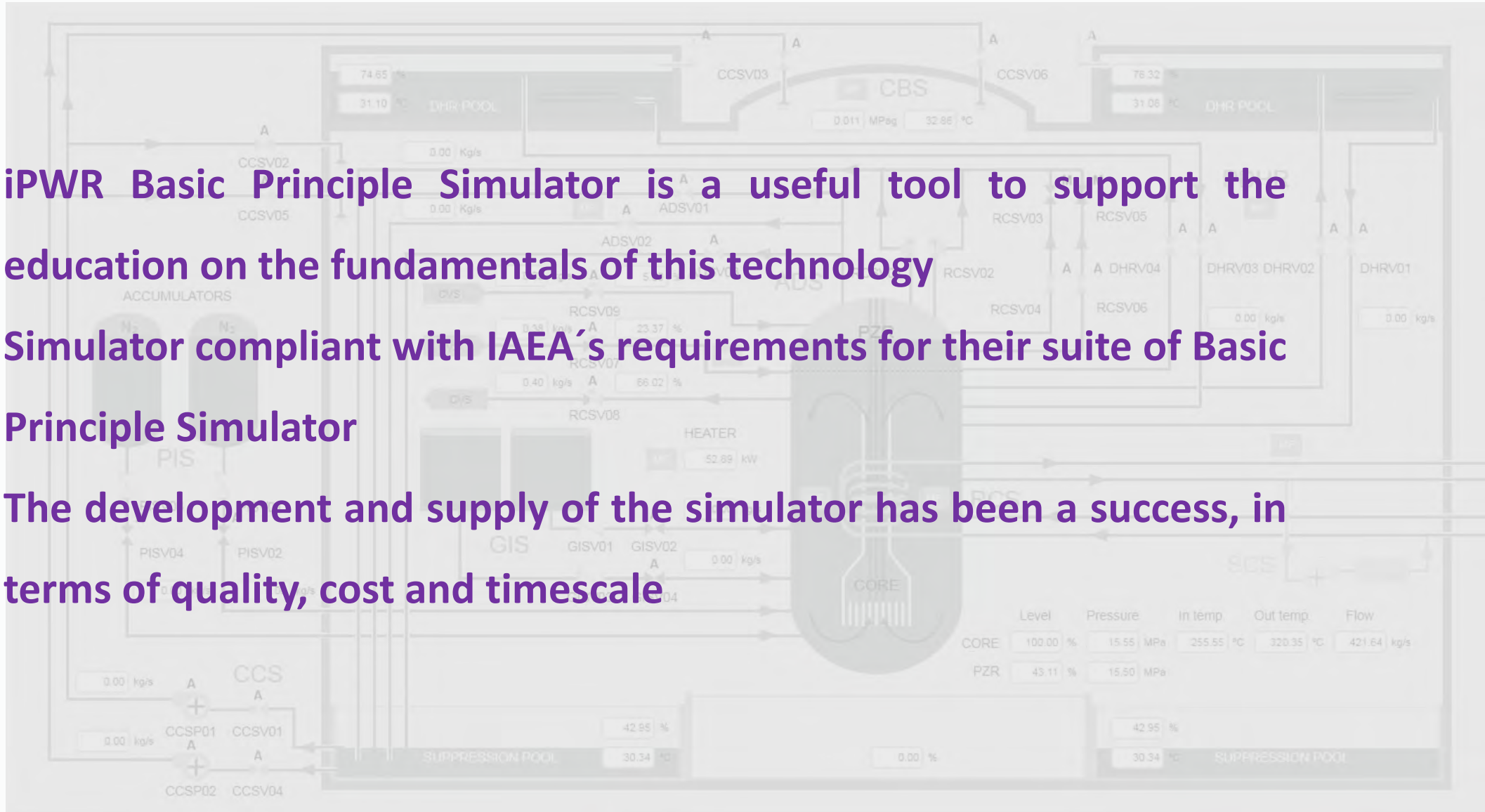
32-bit / 64-bit

Chinese, Japanese, Korean, Arabic,...



Conclusions

- ✓ iPWR Basic Principle Simulator is a useful tool to support the education on the fundamentals of this technology
- ✓ Simulator compliant with IAEA's requirements for their suite of Basic Principle Simulator
- ✓ The development and supply of the simulator has been a success, in terms of quality, cost and timescale





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