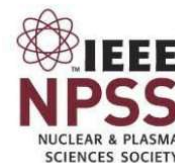




ĐẠI HỌC QUỐC GIA THÀNH PHỐ HỒ CHÍ MINH
TRƯỜNG ĐẠI HỌC KHOA HỌC TỰ NHIÊN
VNUHCM - UNIVERSITY OF SCIENCE



physics
@VNUHCM-US



IEEE NPSS School on Nuclear Power for Sustainable Development



DR. PHAN LE HOANG SANG
UNIVERSITY OF SCIENCE, VNU-HCM



HO CHI MINH CITY | 7-11 SEPTEMBER 2026



Contents

Exercises

- Part 1:** Introduction and guidance
- Part 2:** Exercise 1: Reactor power rise from 0% to 100%
- Part 3:** Exercise 2: Loss of Feedwater Flow
- Part 4:** Exercise 3: Station Blackput
- Part 5:** Summary



Contents

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PART 1

INTRODUCTION AND GUIDANCE

1 Objectives

2 Class Regulations

3 IAEA's Integral Pressurized Water Reactor (iPWR)
Simulator

OBJECTIVES

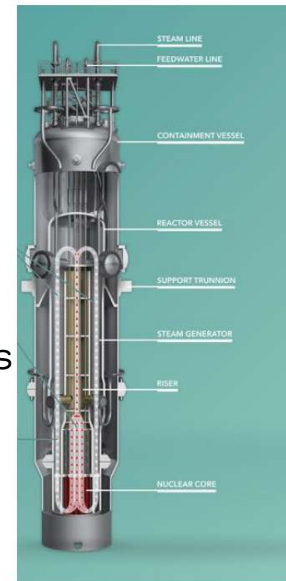
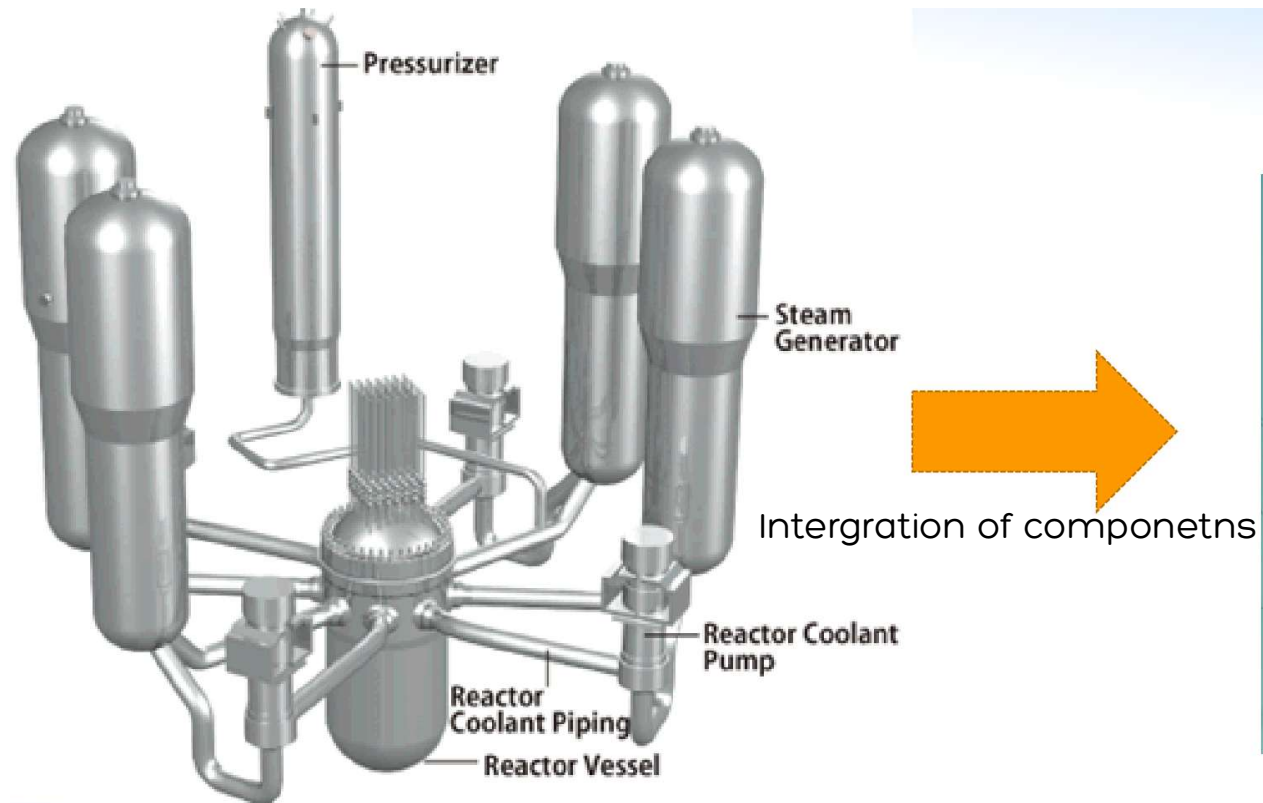
- ❑ Practice simulator startup, initialization, monitoring, and basic HMI navigation.
- ❑ Relate operator actions to reactor kinetics, heat removal, pressure control, inventory response, and safety-system actuation.
- ❑ Record transient data in a consistent format and discuss the physical causes of observed plant behavior.
- ❑ Compare normal operation and abnormal transient behavior within one integrated light-water SMR simulator.

CLASS REGULATIONS

- ❑ Do not save any data on the C: drive!!!
- ❑ Do not install any software on classroom computers without permission.
- ❑ The use of AI tools is not recommended during class exercises, unless explicitly allowed by the instructors.
- ❑ Turn off the computer before leaving the classroom.
- ❑ The communication language during the school is English.
- ❑ Teamwork
- ❑ Do not change system settings or simulator configurations unless instructed.
- ❑ Keep the classroom clean and organized.

IAEA's Integral Pressurized Water Reactor (iPWR) and Simulator

- ❑ Intergration
- ❑ Modularization
- ❑ Natural Circulation
- ❑ Passive Safety



Integral SMRs

Several SMRs adopt “integral design” in which the whole reactor system is integrated in the reactor vessel



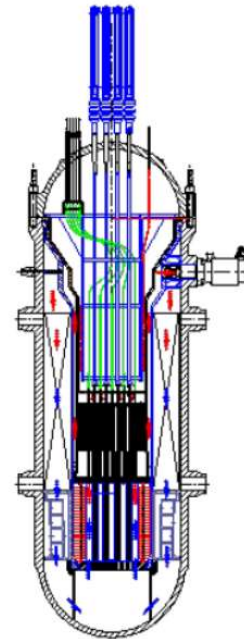
mPower
(B&W)



NuScale
(NuScale Power)
50 MWe



ACP 100
(CNNC)
100 MWe



SMART
(KAERI)
100 MWe



CAREM
(CNEA)
30 MWe

iPWR Simulator Characteristics

Core Cooling

- Natural Circulation
- Forced Circulation

Main Thermahydraulic parameters:

Reactor thermal power ~ 150 MWt

Electrical power ~ 45 MWe

PZR pressure ~ 15.5 Mpa

Feedwater flow ~ 79 kg/s

Passive safety

Automatic Depressurisation system (ADS)

Pressure Injection system (PIS)

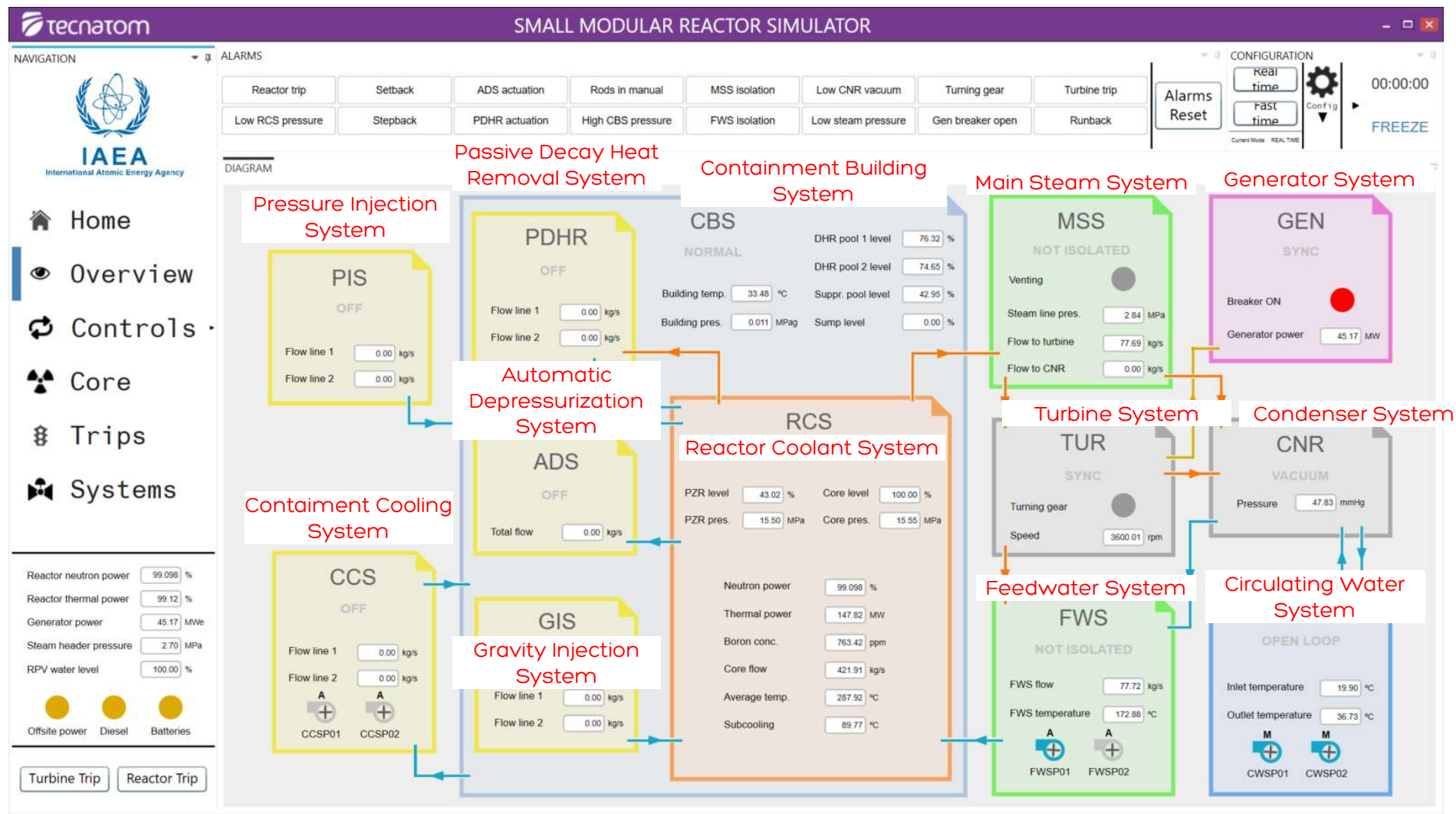
Gravity Injection system (GIS)

Passive heat removal system (PDHR)

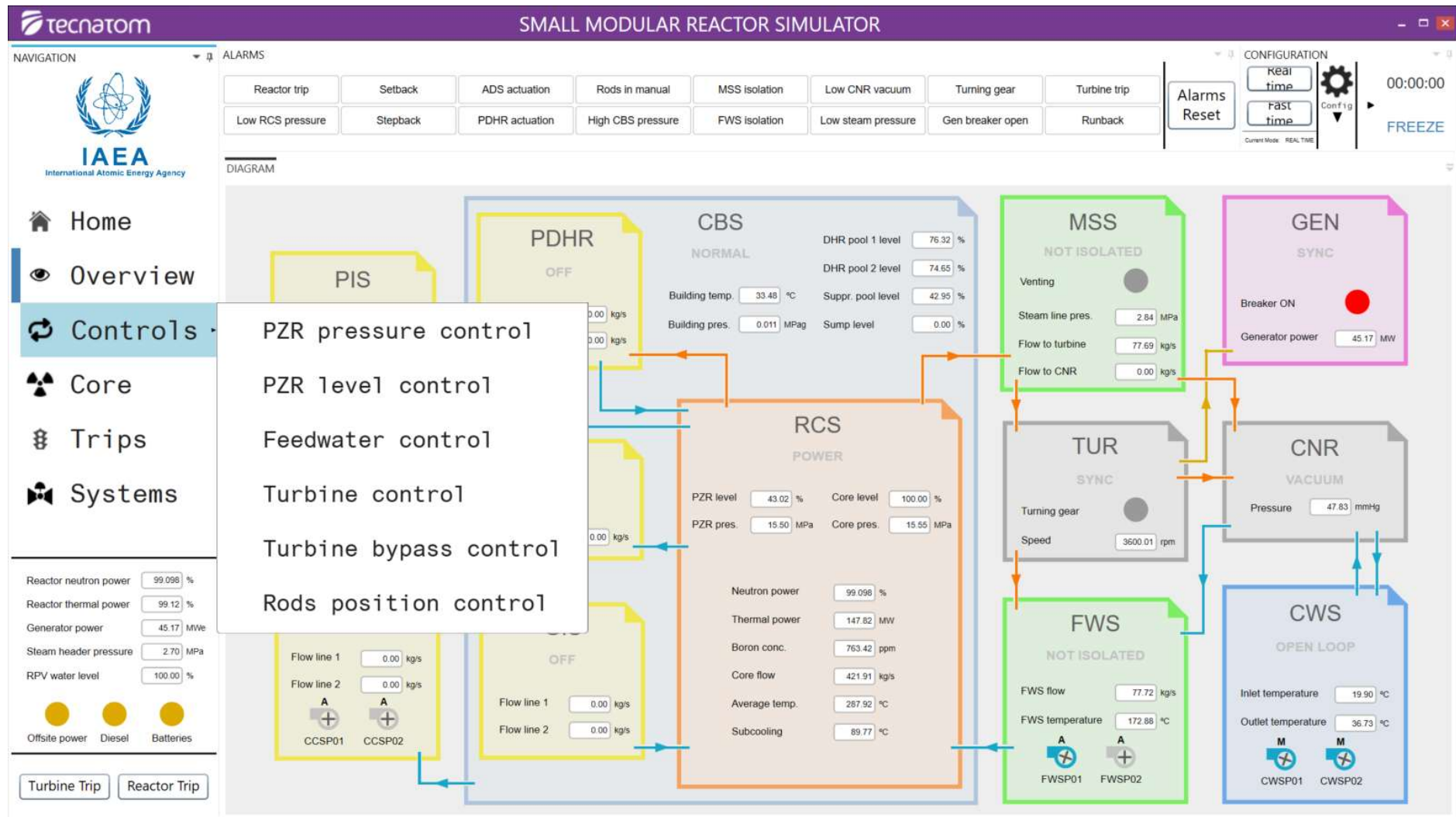
Circulating Water Cooling

- Open Loop (sea, lake, river)
- Closed Loop (Cooling Tower)

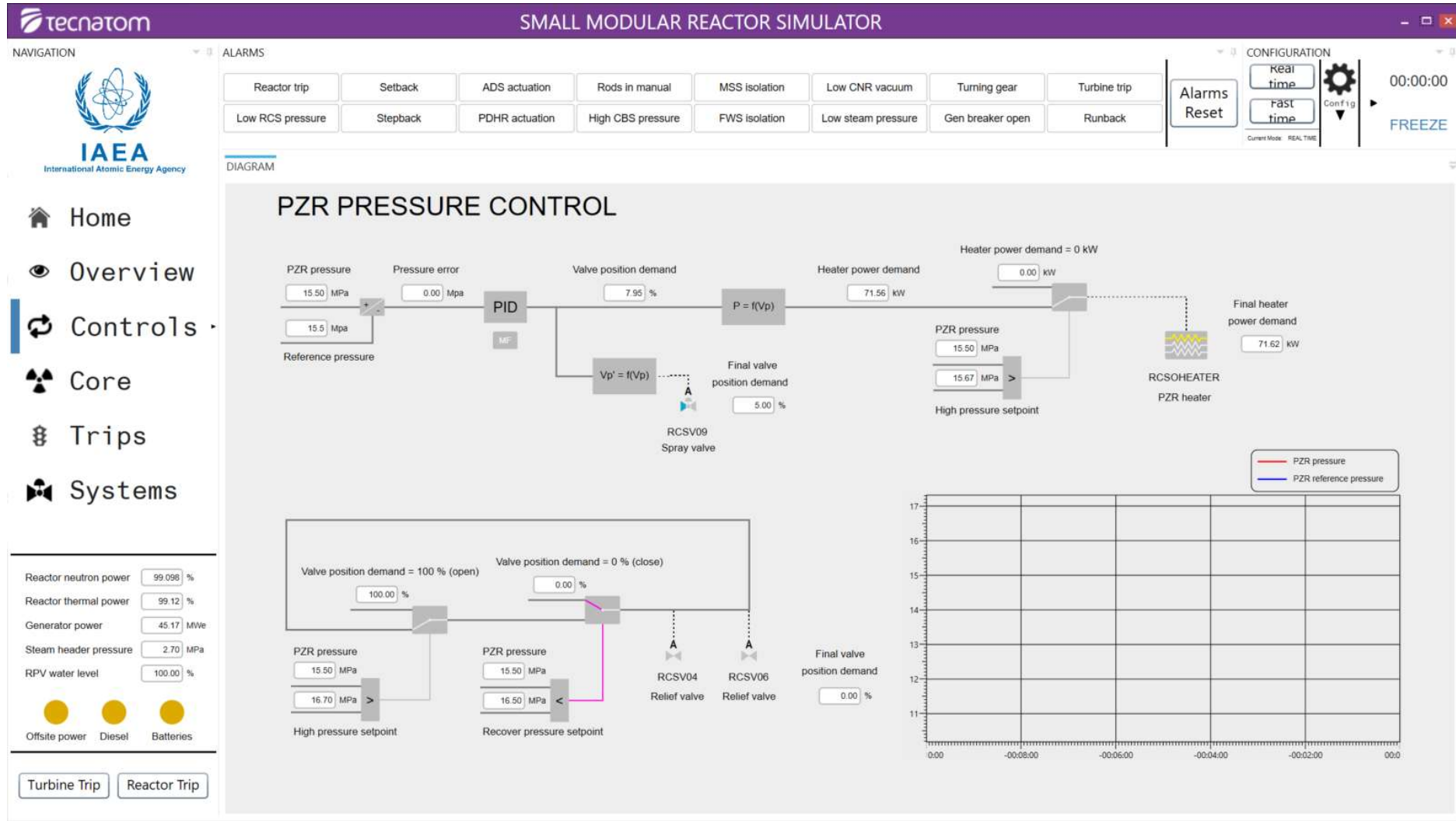
Overview



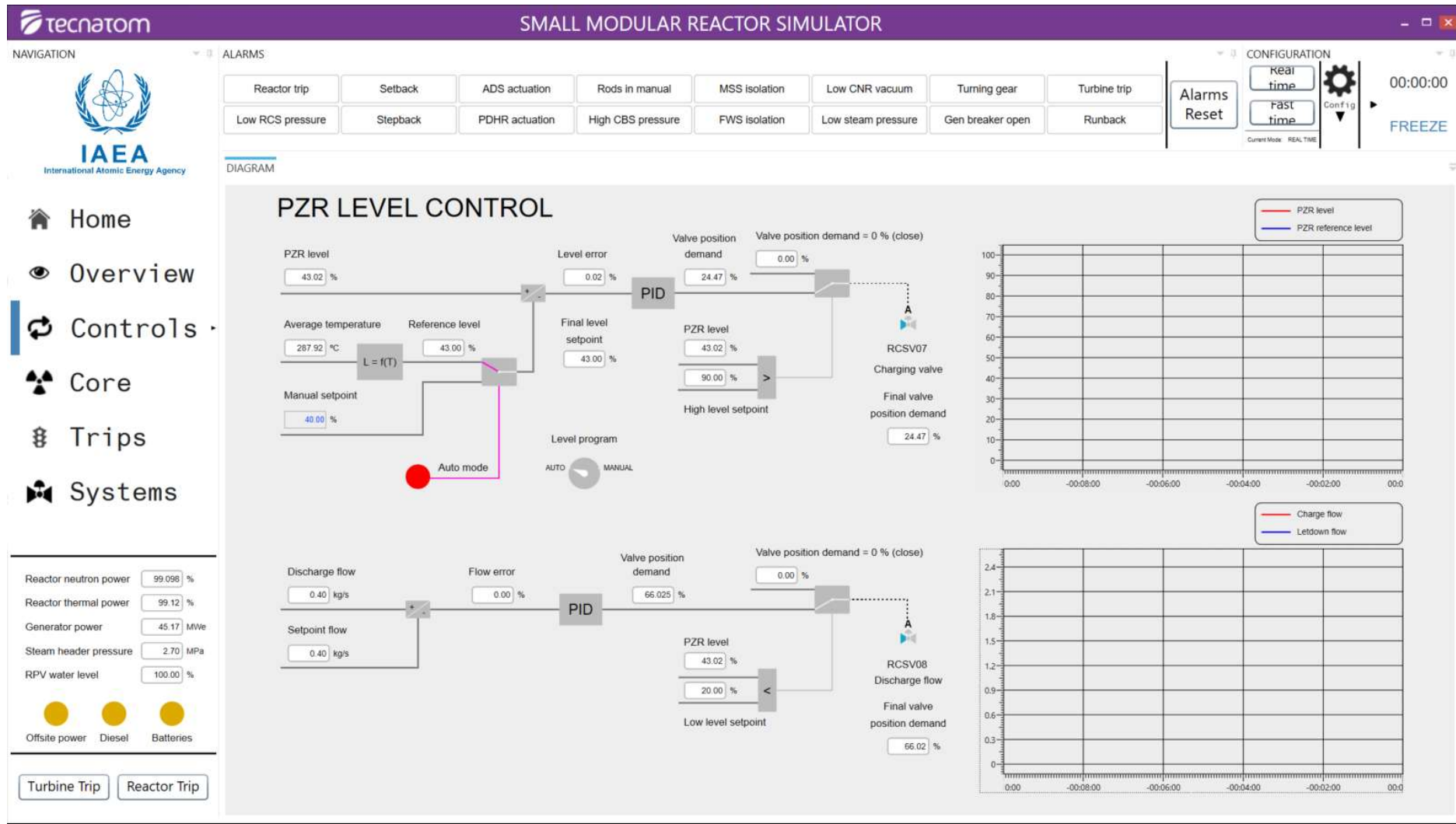
Controls



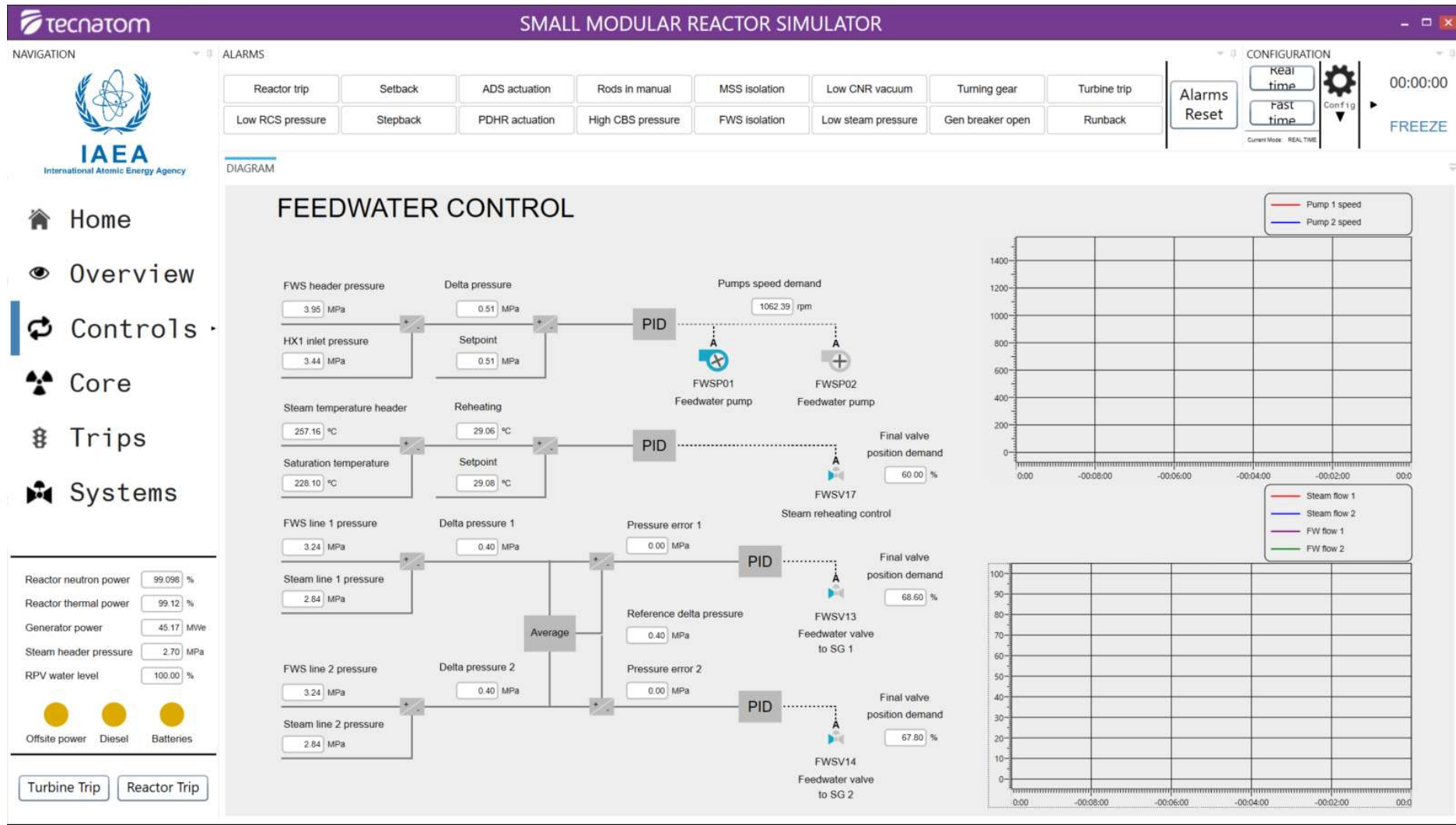
PZR Pressure Control



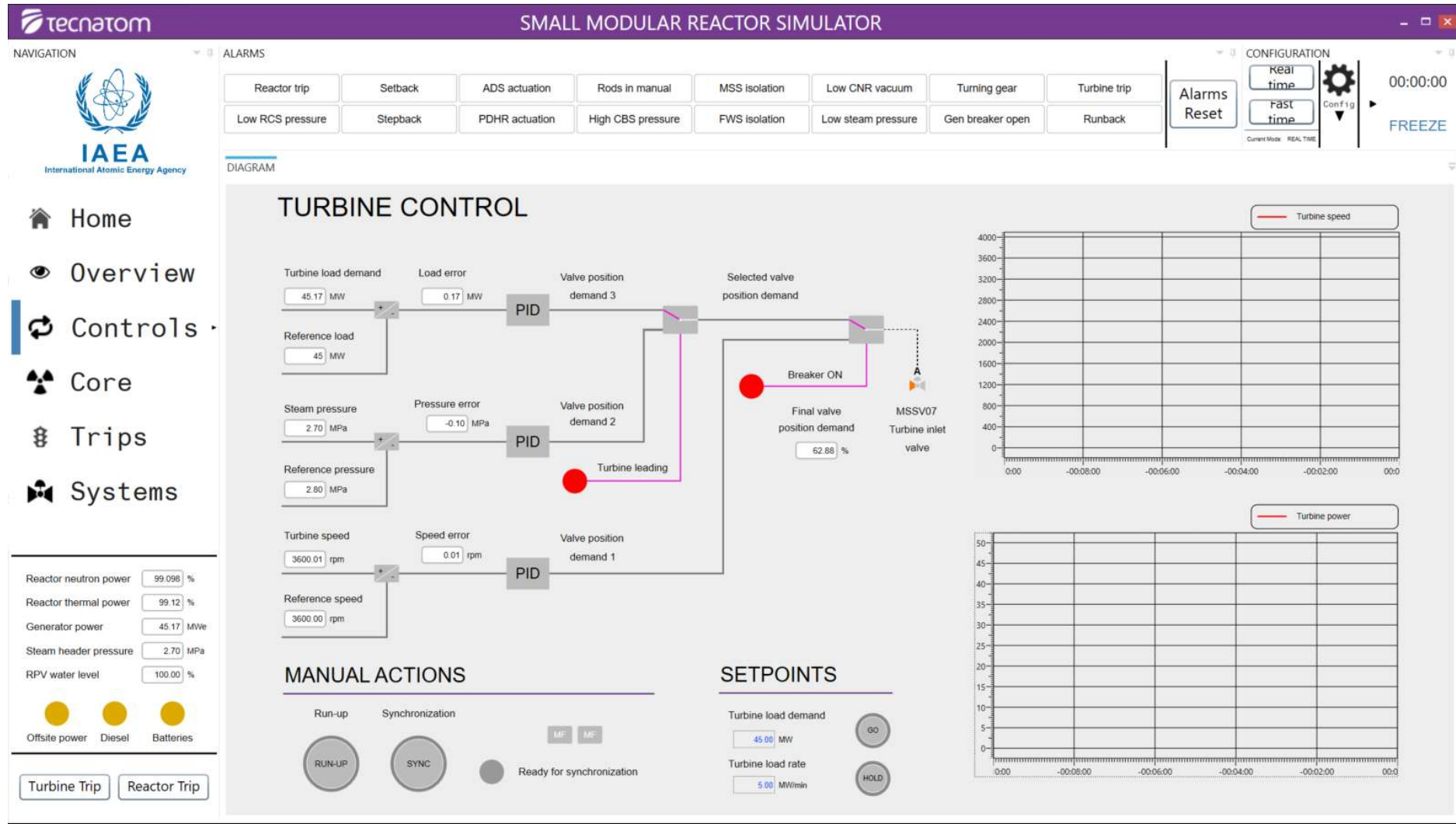
PZR Level Control



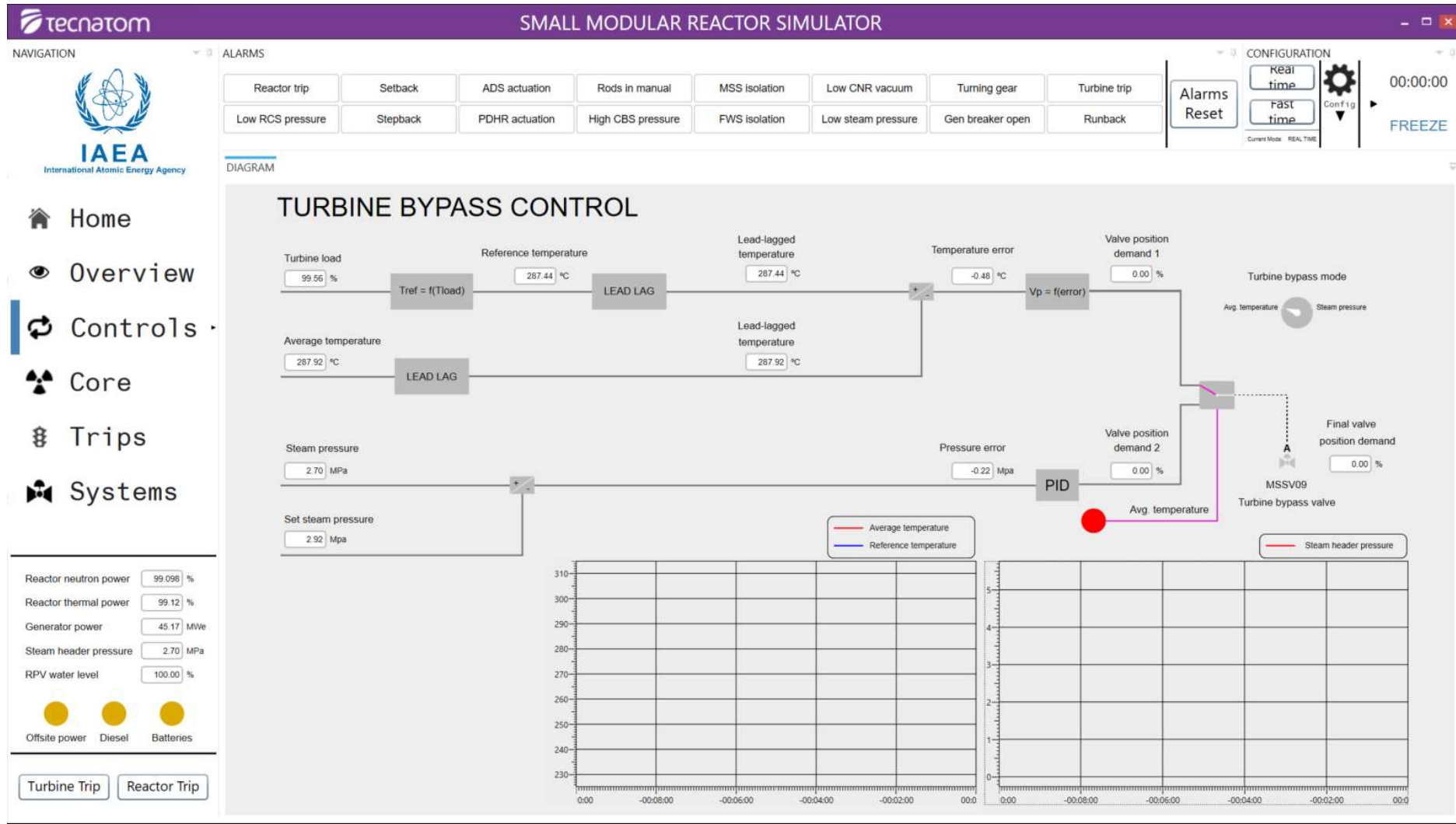
Feedwater Control



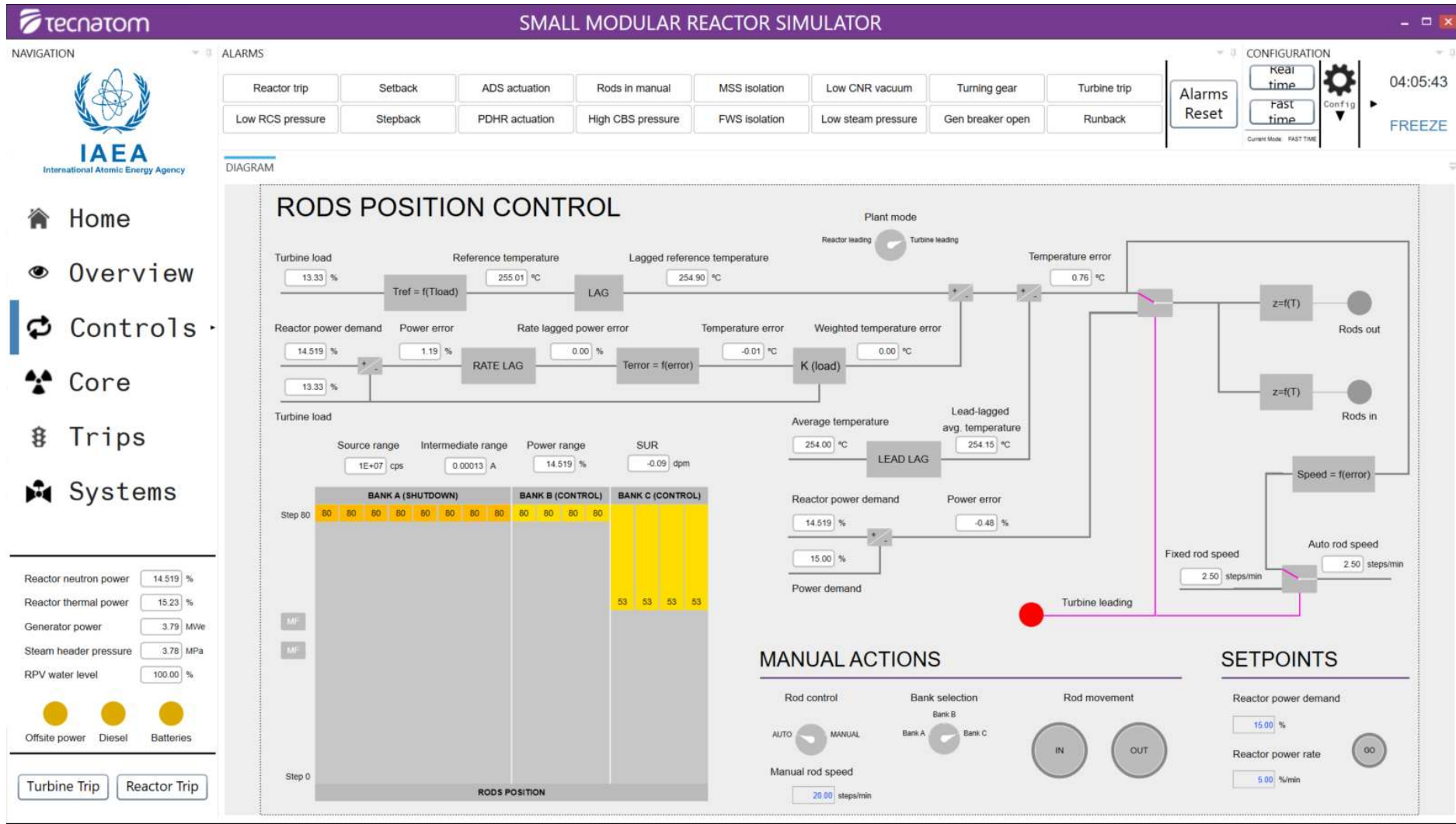
Turbine Control



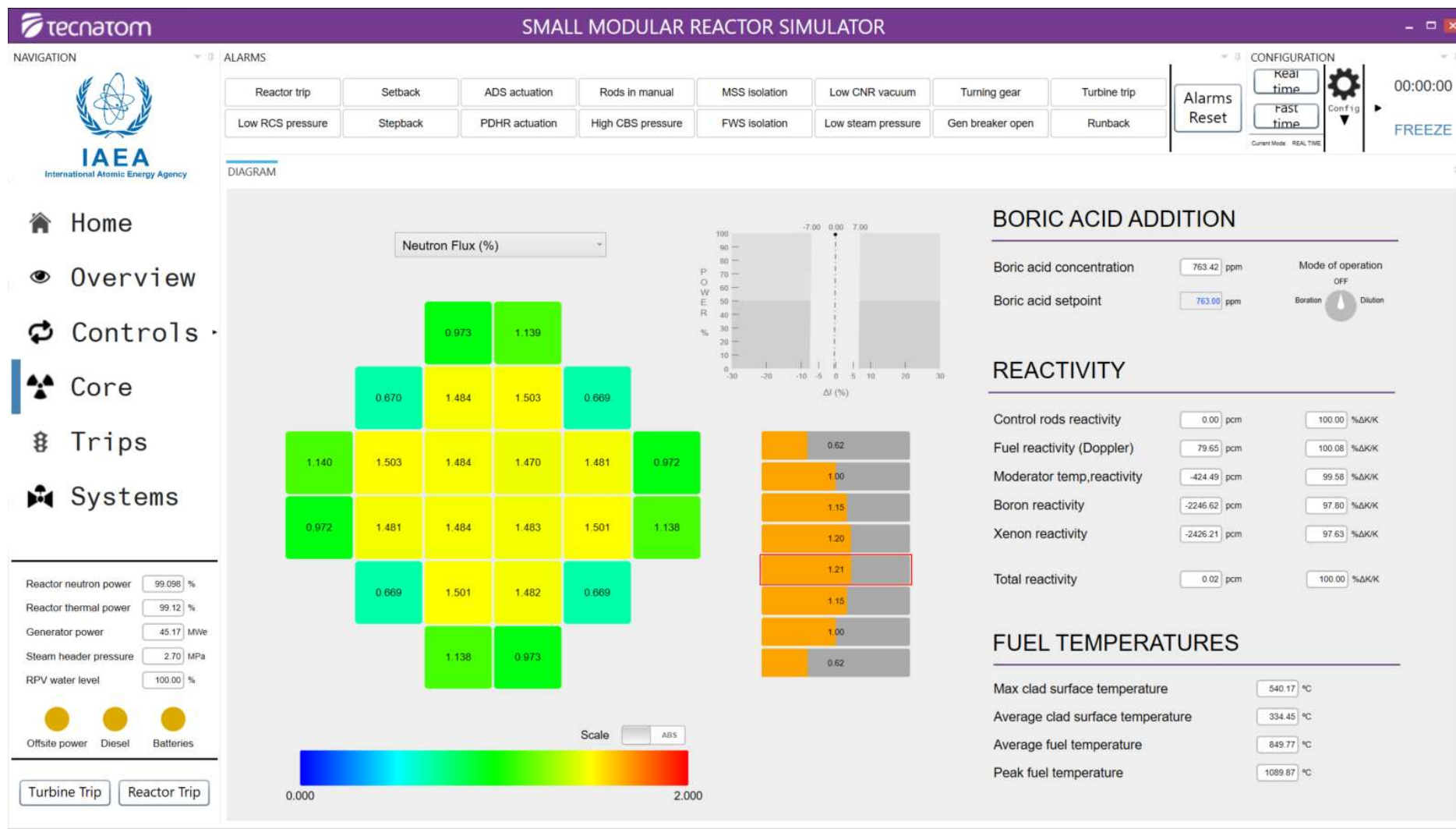
Turbine Bypass Control



Rods Position Control

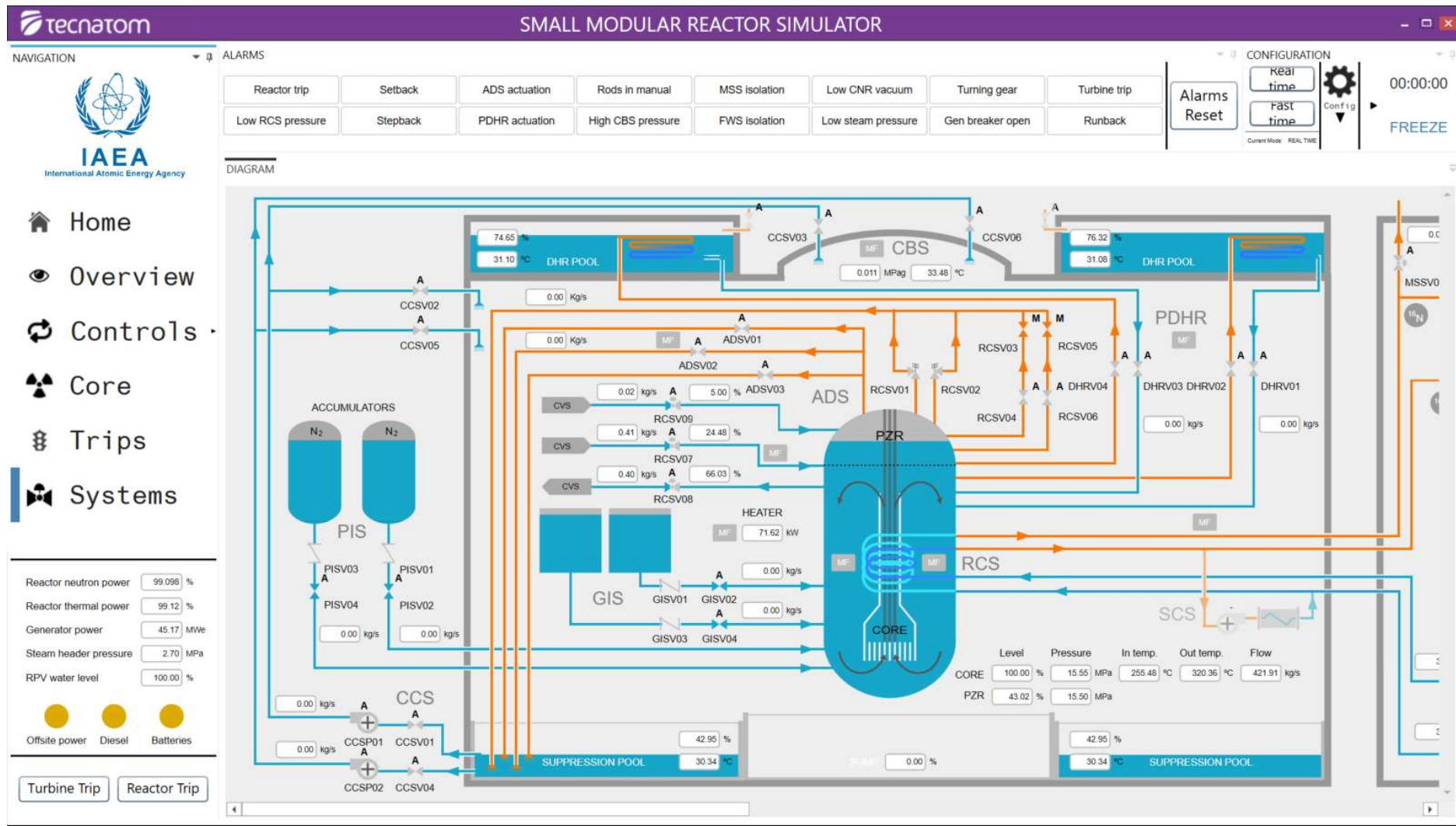


Core

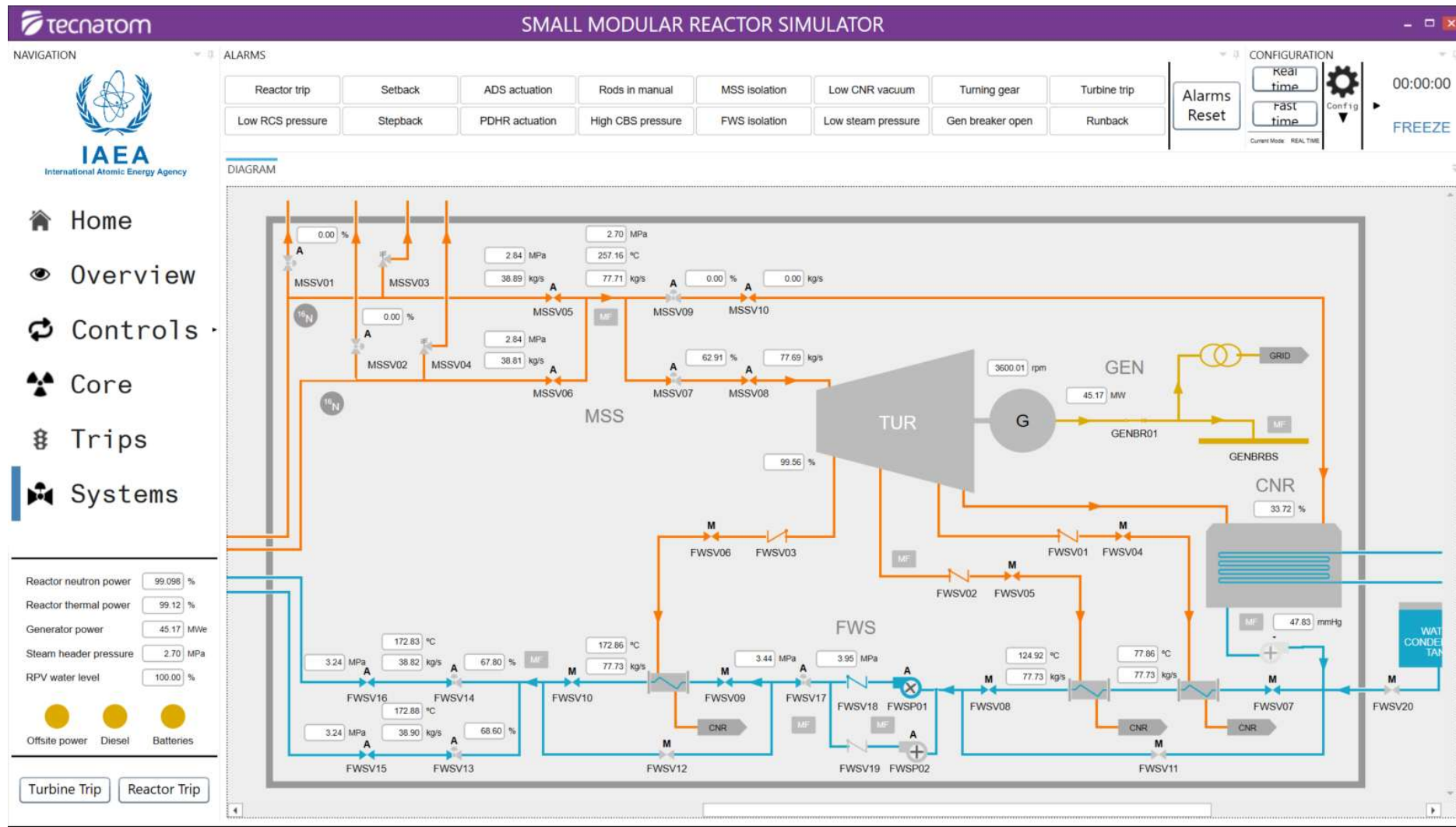




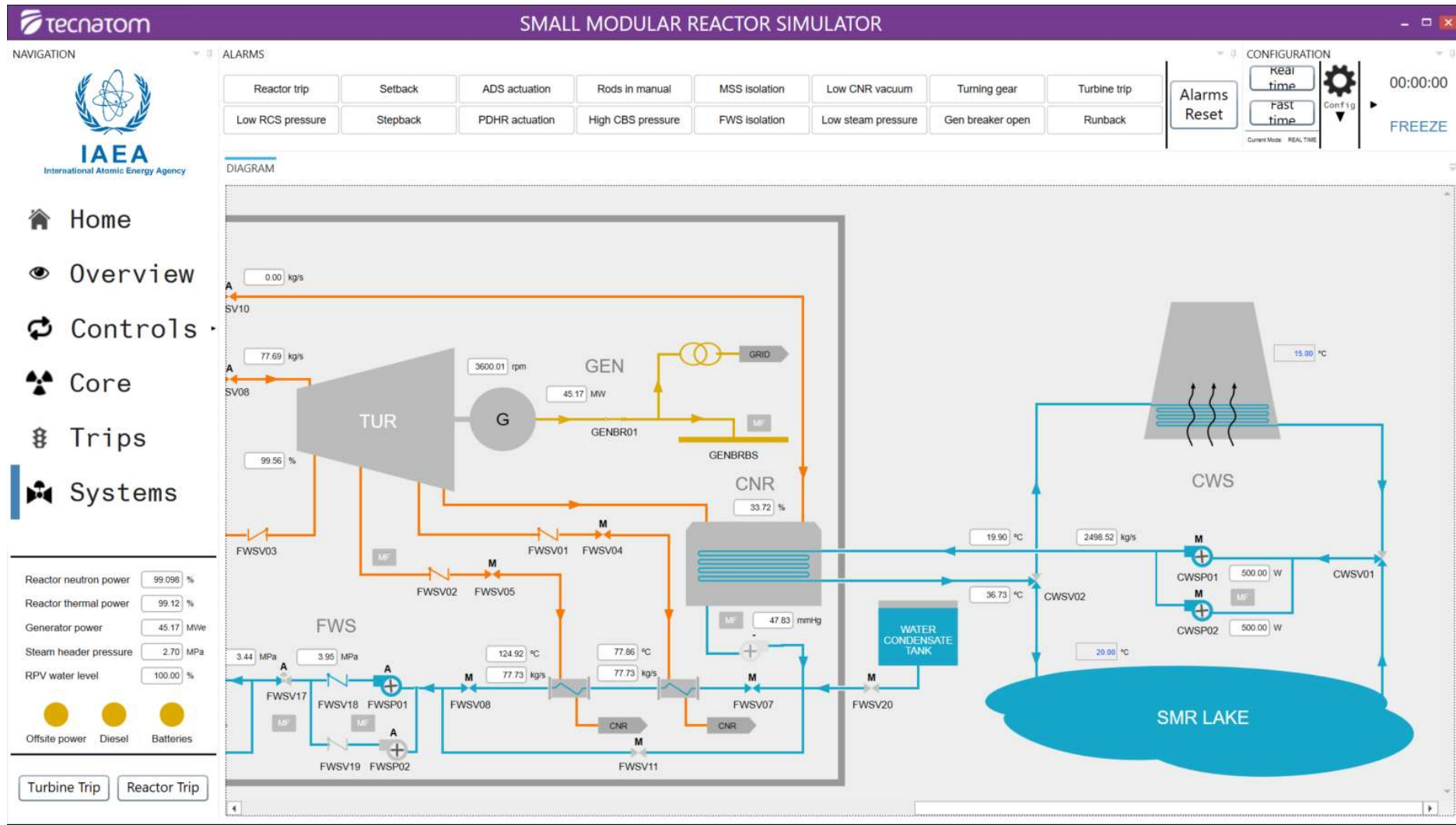
Systems



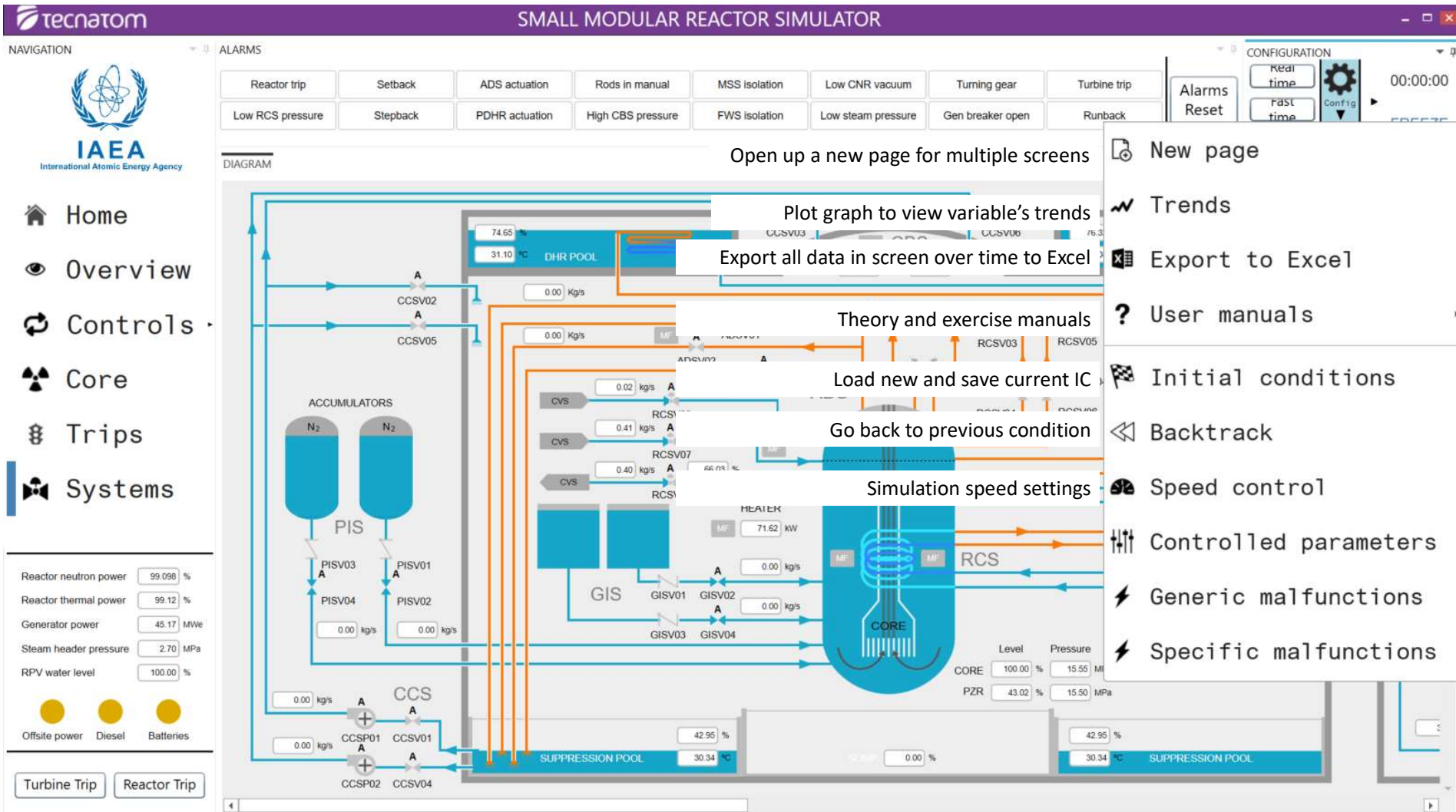
Systems



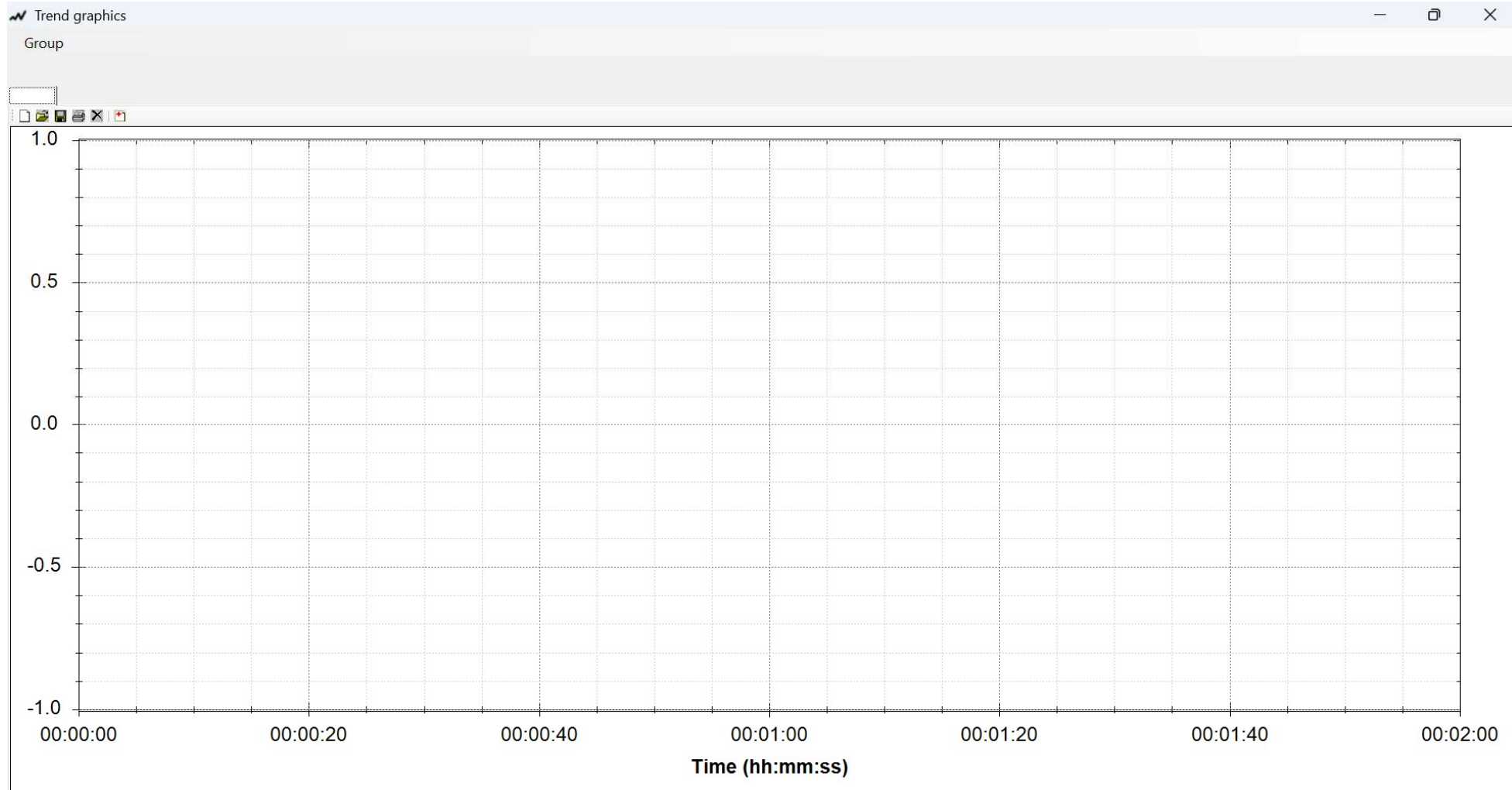
Systems



Config



Trends



Adds a new variable

List of Recorded Variables

SYSTEMS

ALL

ADS
CBS
CCS
CNR
CWS
DHR
FWS
GEN
GIS
MSS
PIS
RCS
TUR

Look for variable

Filters:

Id:

No filter

Description:

No filter

Formula:

No filter

Recorded variables

Formula:	Description:	Id:
ADS_W	ADS Total Flow	ADS Total Flow
ADS_W1	ADS1 valve flow	ADS1 valve flow
ADS_W2	ADS2 valve flow	ADS2 valve flow
ADS_W3	ADS3 valve flow	ADS3 valve flow
CBSLT01_TR	DHR1 Pool level	DHR1 Pool level
CBSLT02_TR	DHR2 Pool level	DHR2 Pool level
CBSLT03_TR	Subpression pool level	Subpression pool le...
CBSLT04_TR	Sump level	Sump level
CBSPT01_TR	Containment pressure.	Containment pressu...
CBSTE01_TR	DHR1 Pool temperature	DHR1 Pool temperat...
CBSTE02_TR	DHR2 Pool temperature	DHR2 Pool temperat...
CBSTE03_TR	Subpression pool temperature	Subpression pool te...
CBSTE04_TR	Containment temperature	Containment tempe...
CCSFT01_TR	Containment coolant spray flow 1	Containment coolan...
CCSFT02_TR	Containment coolant spray flow 2	Containment coolan...
CNRLT01_TR	Condenser level	Condenser level

Initial Conditions

Initial Conditions

Control

Load IC

Save IC

LOADED IC

IC#	Time	Date	Description	N. Malf.	OvR.	RCSNP01_TR
1	7:57:39	17/10/2016	100%BOL, Natural Circulation	0	0	99.1

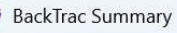
IC SUMMARY

Official ICs ICs Free 1 ICs Free 2 ICs Free 3 ICs Free 4

IC#	Time	Date	Description	N. Malf.	OvR.	RCSNP01_TR
1	7:57:39	17/10/2016	100%BOL, Natural Circulation	0	0	99.1
2	7:59:58	17/10/2016	100%MOL, Natural Circulation	0	0	98.7
3	8:00:21	17/10/2016	100%EOL, Natural circulation	0	0	98.8
4	9:02:04	17/10/2016	100%BOL, Forced Circulation	0	0	99.3
5	9:02:47	17/10/2016	100%MOL, Forced Circulation	0	0	99.0
6	9:03:29	17/10/2016	100%EOL, Forced Circulation	0	0	98.9
7	9:04:11	17/10/2016	0% BOL, NC, Before withdrawing rods	0	0	0.0
8	9:04:49	17/10/2016	NC, Hot Reactor critical condition Keff=1	0	0	0.0
9	9:05:10	17/10/2016	NC, Hot zero power at the point of adding heat, POAH	0	0	0.0
10	9:05:47	17/10/2016	0%BOL, FC, Before withdrawing rods	0	0	0.0
11	9:06:22	17/10/2016	FC, Hot Reactor critical condition Keff=1	0	0	0.0
12	9:06:43	17/10/2016	FC, Hot zero power at the point of adding heat, POAH	0	0	0.0
13	—	—	Available Initial Condition	0	0	NaN
14	—	—	Available Initial Condition	0	0	NaN
15	—	—	Available Initial Condition	0	0	NaN
16	—	—	Available Initial Condition	0	0	NaN
17	—	—	Available Initial Condition	0	0	NaN
18	—	—	Available Initial Condition	0	0	NaN
19	—	—	Available Initial Condition	0	0	NaN
20	—	—	Available Initial Condition	0	0	NaN
21	—	—	Available Initial Condition	0	0	NaN
22	—	—	Available Initial Condition	0	0	NaN
23	—	—	Available Initial Condition	0	0	NaN
24	—	—	Available Initial Condition	0	0	NaN
25	—	—	Available Initial Condition	0	0	NaN
26	—	—	Available Initial Condition	0	0	NaN
27	—	—	Available Initial Condition	0	0	NaN
28	—	—	Available Initial Condition	0	0	NaN
29	—	—	Available Initial Condition	0	0	NaN
30	—	—	Available Initial Condition	0	0	NaN

VARIABLES

Description	Loaded IC	Current value	Selected IC
RCSNP01_TR Power	99.1	99.1	



—  

CI#1 07/09/2026 3:27:34 AM	CI#7 07/09/2026 3:26:32 AM	CI#1 9/7/2026 3:26:10 AM
----------------------------	----------------------------	--------------------------

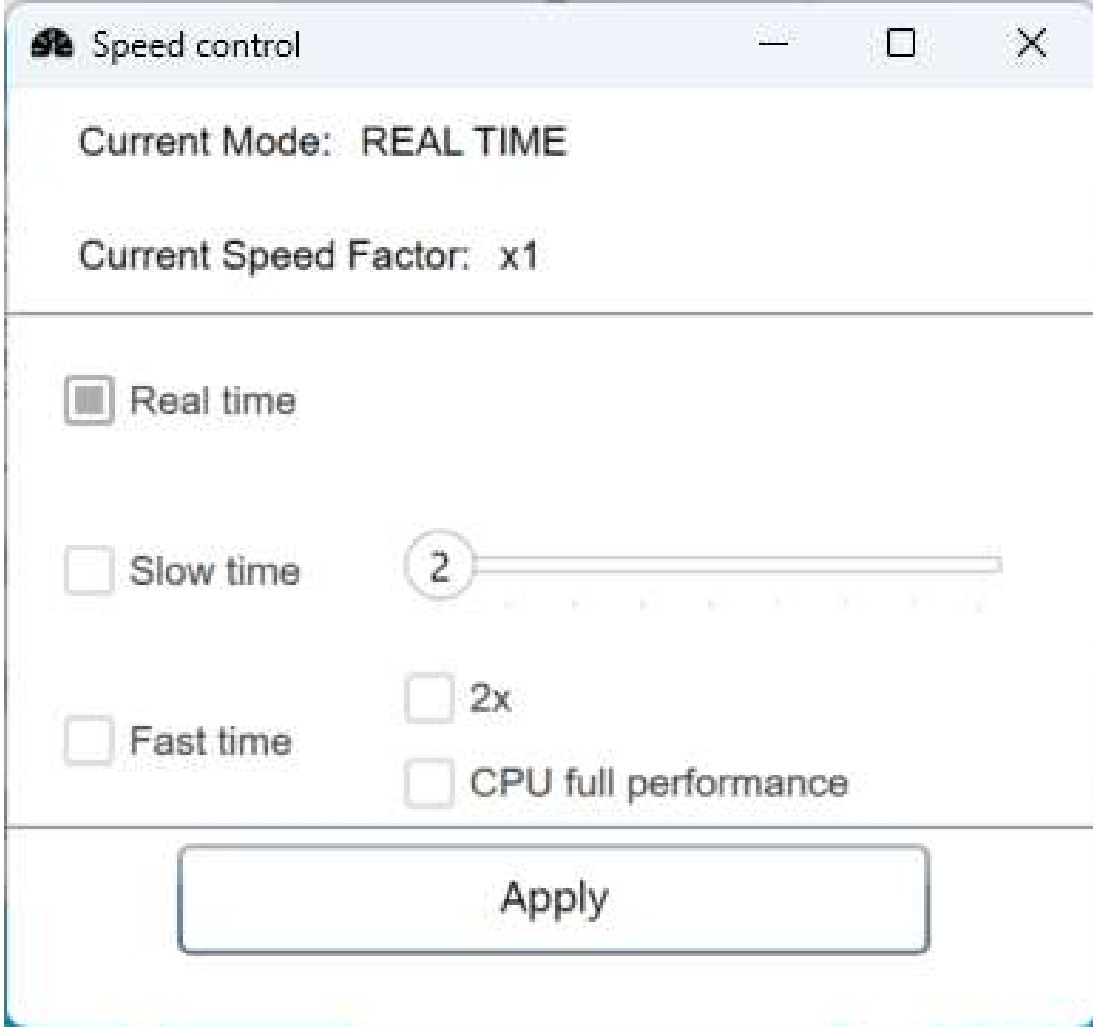
[illegible]

Current va 60 seconds

New value: seconds **Change**

Min: 60, Max: 1200

Speed Control



A screenshot of a 'Speed control' dialog box. The window has a title bar with a gear icon, the text 'Speed control', and standard minimize, maximize, and close buttons. The main area is divided into sections. The top section shows 'Current Mode: REAL TIME' and 'Current Speed Factor: x1'. Below this is a section with four options: 'Real time' (checked), 'Slow time' (unchecked), 'Fast time' (unchecked), and 'CPU full performance' (unchecked). The 'Slow time' option is accompanied by a slider control set to '2'. At the bottom is an 'Apply' button.

Speed control

Current Mode: REAL TIME

Current Speed Factor: x1

☒ Real time

☐ Slow time 2

☐ Fast time

☐ 2x

☐ CPU full performance

Apply

Controlled Parameters

Interaction with Simulation			
Generic Malfs. Specific Malfs. Controlled Parameters			
Generic Malfs. Specific Malfs. Controlled Parameters			
ALL	Num.	Description	Current Value
	CWS PC14	?#Sink temperature (open loop) (0 . 100 °c)	20
	CWS PC15	?#Wet-bulb temperature of cooling air (close loop) (0 . 100 °c)	15
	FWS CN10	?#FWSV13 (FW control valve) AI_MANUAL MODE (0 . 100 %)	68.596
	FWS CN11	?#FWSV14 (FW control valve) AI_MANUAL MODE (0 . 100 %)	67.798
	MSS CN21	?#MSSV01 (Relief valve) AI_MANUAL MODE (0 . 100 %)	0
	MSS CN22	?#MSSV02 (Relief valve) AI_MANUAL MODE (0 . 100 %)	0
	MSS CN8	?#MSSV07 (Turbine control valve) AI_MANUAL MODE (0 . 100 %)	62.899
	MSS CN9	?#MSSV09 (MSB control valve) AI_MANUAL MODE (0 . 100 %)	0
	PCS PC24	?#Reactor Scram: 1. Low pressure upper plenum (11 MPa) (0 . 100 Mpa)	11
	PCS PC25	?#Reactor Scram: 2. Low level upper plenum (5%) (0 . 100 %)	5
	PCS PC26	?#Reactor Scram: 5. Low flow Downcomer (345 Kg/s) (0 . 100 Kg/s)	0
	PCS PC27	?#Reactor Scram: 6. High core outlet T (340 °C) (0 . 100 °C)	340
	PCS PC28	?#Reactor Scram: 7. High reactor neutron flux (120%) (0 . 100 %)	120
	PCS PC29	?#Reactor Scram: 8. High log rate = 7dpm (0 . 100 %/segundo)	2
	PCS PC30	?#Reactor Scram: 9. High reactor coolant pressure (16.4MPa) (0 . 100 Mpa)	16.4
	PCS PC31	?#Reactor setback4:If zone flux > 115% (0 . 100 %)	115
	PCS PC32	?#Reactor setback1: High steam header pressure (4.9 MPa) (0 . 100 Mpa)	4.9
	PCS PC33	?#Reactor setback2: High pressurizer level (67%) (0 . 100 %)	67
	PCS PC34	?#Actuation ADS 2.High upper plenum pressure (17.2 MPa) (0 . 100 Mpa)	17.2
	PCS PC35	?#Actuation ADS 3.Low upper plenum pressure (9 MPa) (0 . 100 Mpa)	9
	PCS PC36	?#Actua ADS 1.High containment pressure (0.19 bar) (0 . 100 Mpa)	0.019
	PCS PC37	?#Feedwater pumps trip 2. Low steam header pressure (1Mpa) (0 . 100 Mpa)	0
	PCS PC40	?#Low Low Level RPV (ADS Actuation) (90%) (0 . 100 %)	90
	RCS CN16	?#RCSV04 (Relief valve) AI_MANUAL MODE (0 . 100 %)	0
	RCS CN17	?#RCSV06 (Relief valve) AI_MANUAL MODE (0 . 100 %)	0
	RCS CN18	?#RCSV07 (Charge valve) AI_MANUAL MODE (0 . 100 %)	24.475
	RCS CN19	?#RCSV08 (Discharge valve) AI_MANUAL MODE (0 . 100 %)	66.025
	RCS CN20	?#RCSV09 (Spray valve) AI_MANUAL MODE (0 . 100 %)	5
	RCS CN23	?#Heater Power (0 . 12 KW)	7.9508
	RCS CN38	?#Boron Concentration (ppm) (0 . 100 ppm)	763
	RCS CN42	?#Setpoint letdown charge (0 . 100 ?)	0.4
	RCS CN6	?#Setpoint pressure (0 . 100 Mpa)	15.5
	RCS CN7	?#Setpoint Level PZR (0 . 100 %)	40
	RCS PC1	?#Control rod length in core (0 . 100 %)	0
	RCS PC2	?#Control rod insertion/withdrawal rate (0 . 100 %/min)	20
	RCS PC3	?#Power demand (0 . 100 %)	99.098
	RCS PC4	?#Power demand rate (0 . 100 %/min)	1
	TUR PC12	?#Turbine power demand setpoint (0 . 100 MW)	45
	TUR PC13	?#Turbine demand ramp rate (0 . 100 MW/min)	5

[illegible]

[illegible]



Contents

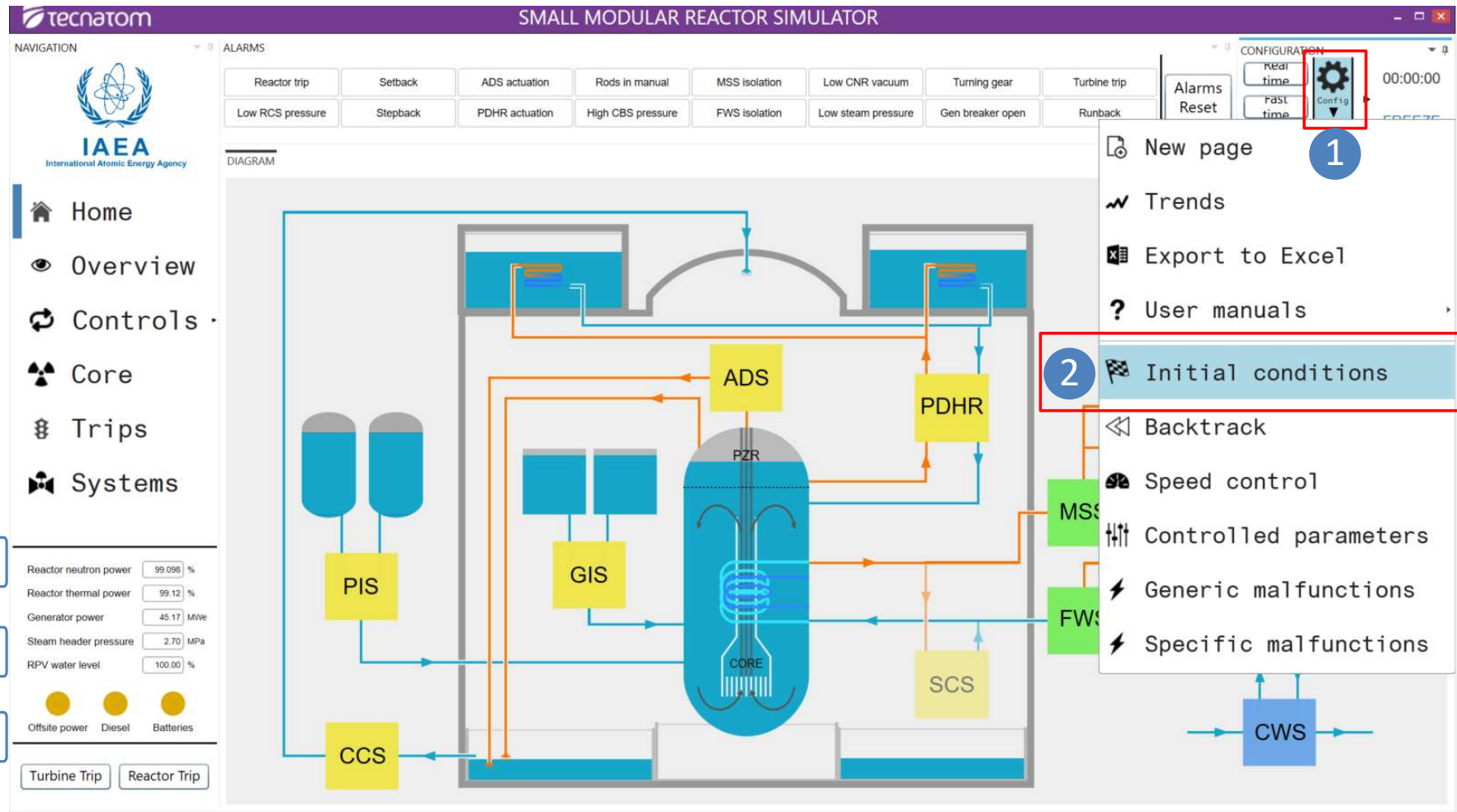
Exercises

- Part 1: Introduction
- Part 2: Exercise 1: Reactor power rise from 0% to 100%
- Part 3: Exercise 2: Loss of Feedwater Flow
- Part 4: Exercise 3: Station Blackout
- Part 5: Summary

SETUP - Reset the Simulator

Reset the Simulator to
IC #7 '0% BOL, NC,
Before Rod withdrawal'
or
IC #10 '0% BOL, FC,
Before Rod withdrawal'.

- 1 Config
- 2 Initial conditions
- 3 Choose IC#7
- 4 Load IC#7



BOL: Beginning of Life, NC: Natural Circulation, FC: Forced Circulation

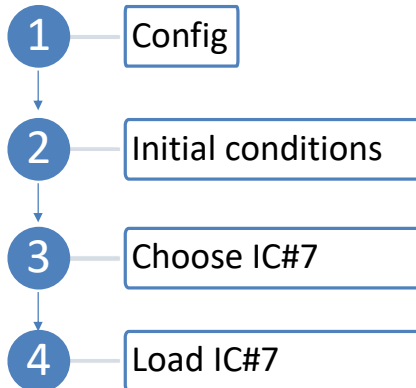
SETUP - Reset the Simulator

Reset the Simulator to

IC #7 '0% BOL, NC, Before Rod withdrawal'

or

IC #10 '0% BOL, FC, Before Rod withdrawal'.



4

Initial Conditions

Control

Load IC Save IC

LOADED IC

IC#	Time	Date	Description	N. Malf.	OvR.	RCSNP01_TR
1	7:57:39	17/10/2016	100%BOL, Natural Circulation	0	0	99.1
2	7:59:58	17/10/2016	100%MOL, Natural Circulation	0	0	98.7
3	8:00:21	17/10/2016	100%EOL, Natural circulation	0	0	98.8
4	9:02:04	17/10/2016	100%BOL, Forced Circulation	0	0	99.3
5	9:02:47	17/10/2016	100%MOL, Forced Circulation	0	0	99.0
6	9:03:29	17/10/2016	100%EOL, Forced Circulation	0	0	98.9
7	9:04:11	17/10/2016	0% BOL, NC, Before withdrawing rods	0	0	0.0
8	9:04:49	17/10/2016	NC, Hot Reactor critical condition Keff=1	0	0	0.0
9	9:05:10	17/10/2016	NC, Hot zero power at the point of adding heat, POAH	0	0	0.0
10	9:05:47	17/10/2016	0%BOL, FC, Before withdrawing rods	0	0	0.0
11	9:06:22	17/10/2016	FC, Hot Reactor critical condition Keff=1	0	0	0.0

3

IC SUMMARY

Official ICs ICs Free 1 ICs Free 2 ICs Free 3 ICs Free 4

IC#	Time	Date	Description	N. Malf.	OvR.	RCSNP01_TR
1	7:57:39	17/10/2016	100%BOL, Natural Circulation	0	0	99.1
2	7:59:58	17/10/2016	100%MOL, Natural Circulation	0	0	98.7
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4	9:02:04	17/10/2016	100%BOL, Forced Circulation	0	0	99.3
5	9:02:47	17/10/2016	100%MOL, Forced Circulation	0	0	99.0
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7	9:04:11	17/10/2016	0% BOL, NC, Before withdrawing rods	0	0	0.0
8	9:04:49	17/10/2016	NC, Hot Reactor critical condition Keff=1	0	0	0.0
9	9:05:10	17/10/2016	NC, Hot zero power at the point of adding heat, POAH	0	0	0.0
10	9:05:47	17/10/2016	0%BOL, FC, Before withdrawing rods	0	0	0.0
11	9:06:22	17/10/2016	FC, Hot Reactor critical condition Keff=1	0	0	0.0

VARIABLES

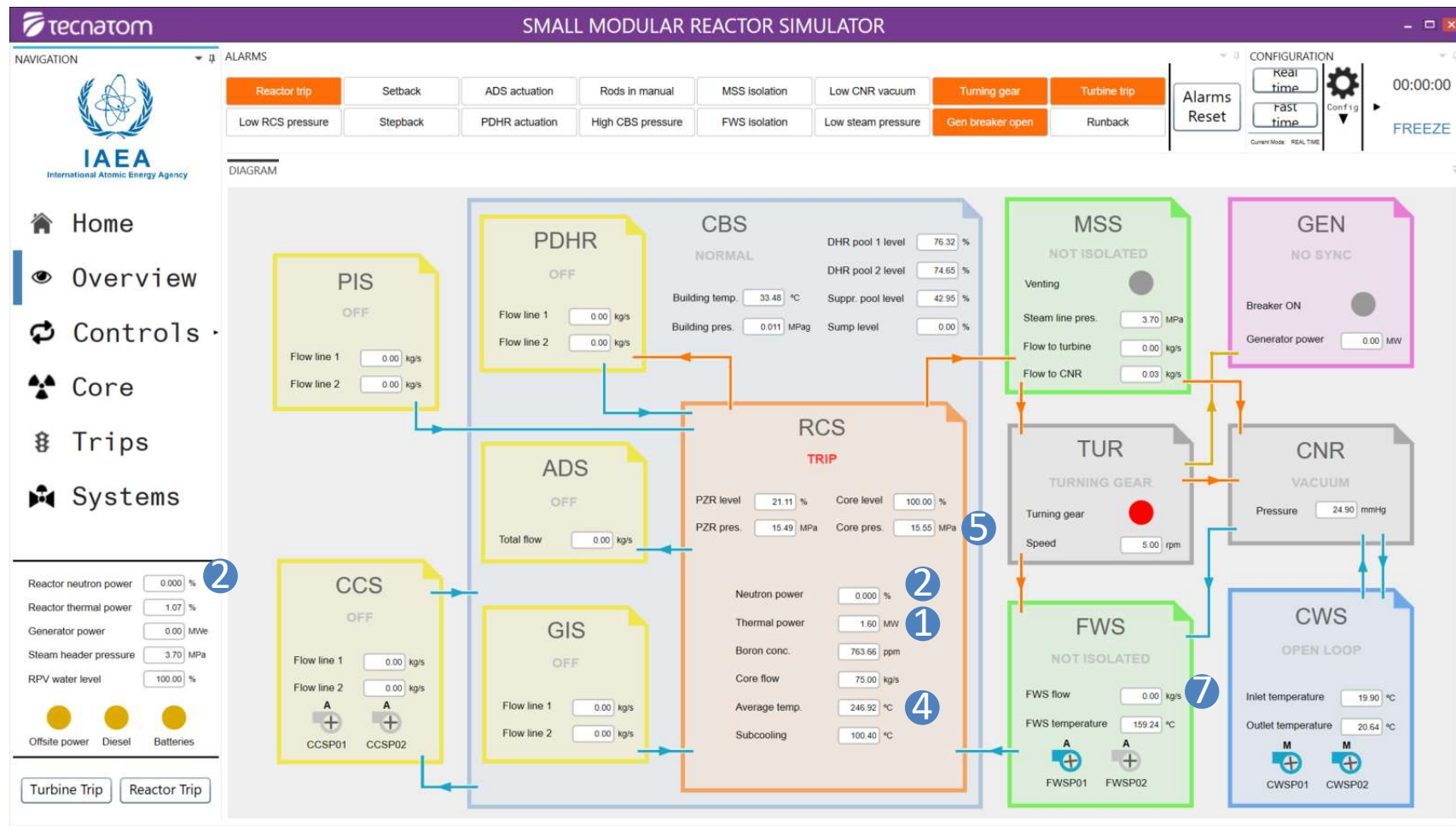
Description	Loaded IC	Current value	Selected IC
RCSNP01_TR Power		99.1	0.0

BOL: Beginning of Life, NC: Natural Circulation, FC: Forced Circulation

STEP 1 - Check the stability of variables

Check the following variables are stable:

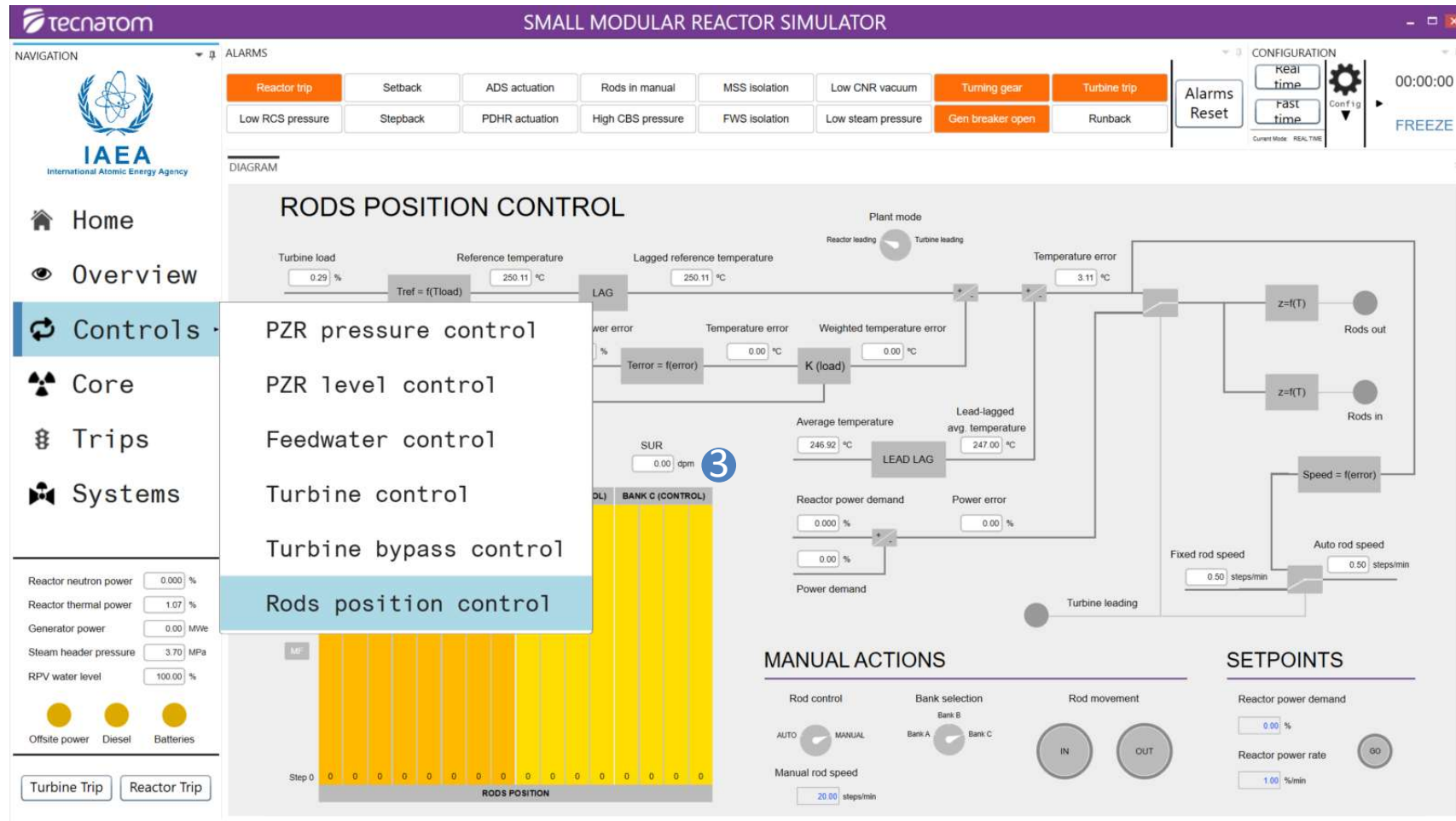
- 1 Thermal power
1.59 MW_t
- 2 Neutron power
0 %
- 3 SUR
0 dpm
- 4 Primary temperature
248 °C (tending to 250 °C)
- 5 Primary pressure
15.5 MPa
- 6 Primary level
~ 23%
- 7 FW flow
~ 0.02 kg/s



STEP 1 - Check the stability of variables

Check the following variables are stable:

- 1 Thermal power
1.59 MW_t
- 2 Neutron power
0 %
- 3 SUR
0 dpm
- 4 Primary temperature
248 °C (tending to 250 °C)
- 5 Primary pressure
15.5 MPa
- 6 Primary level
~ 23%
- 7 FW flow
~ 0.02 kg/s

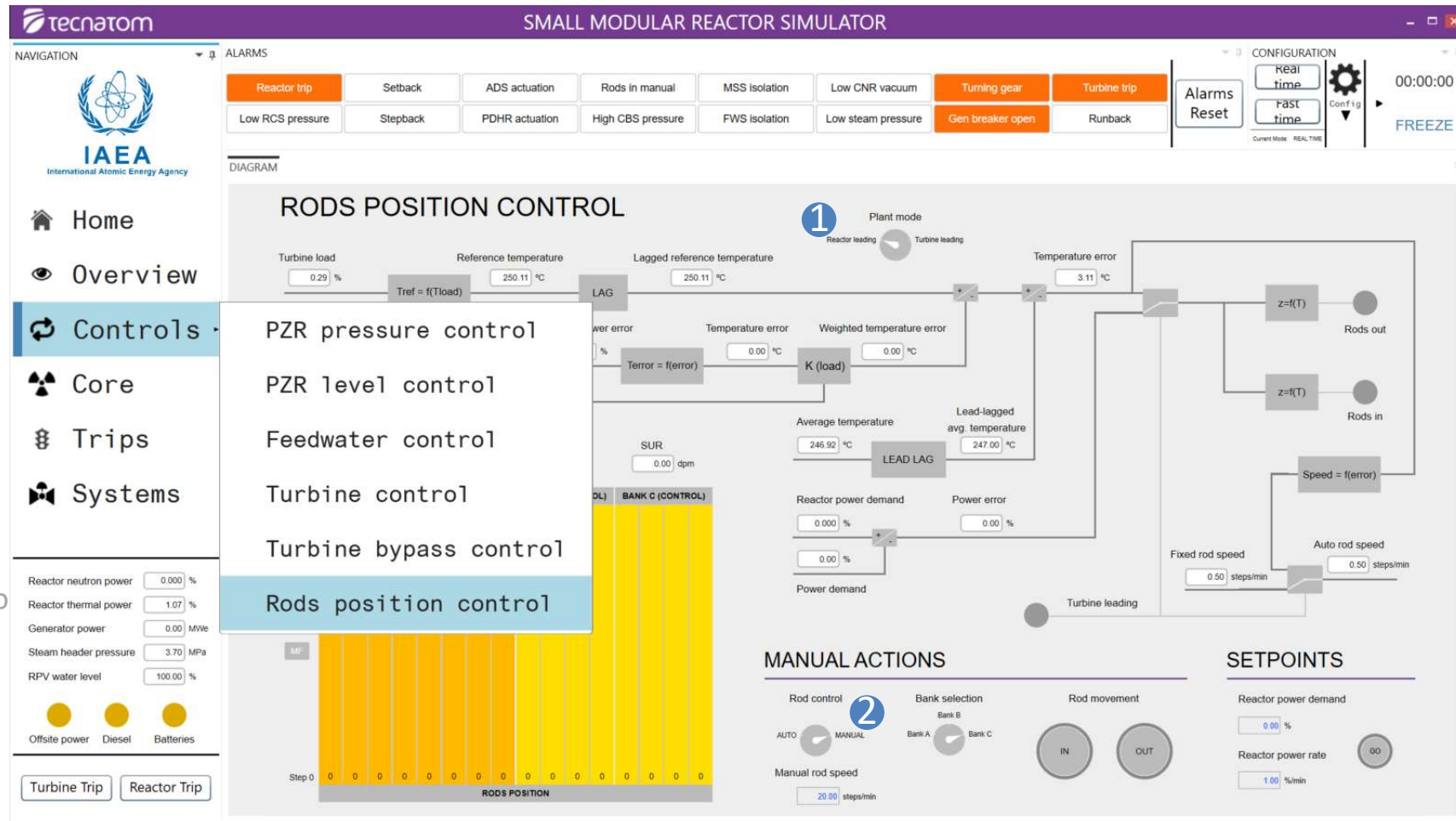


Controls → Rods position control

STEP 2 - Check the status of the main plant control

Ensure proper status of the main plant controls:

- 1 **Plant mode**
Reactor leading mode
- 2 **Rod Control**
Manual mode
- 3 **MSB**
Steam pressure mode
- 4 **FW system in Auto**
FW control valves
(FWSV13/FWSV14) in Auto
- 5 **CW and CNR systems in service**
CW system in service
(opened or closed loop)
- 6 **FW control adjusting FW flow**

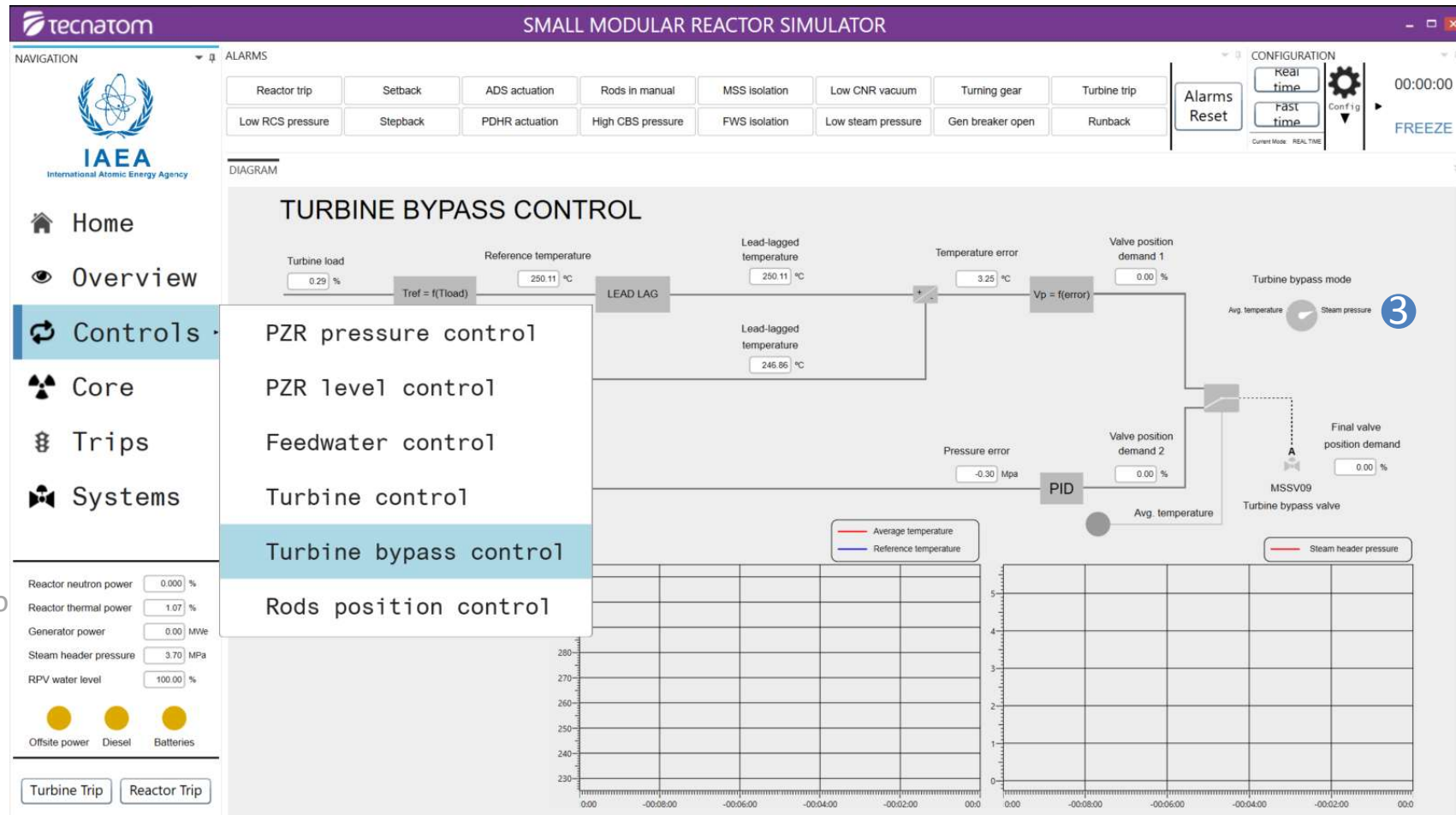


Controls → Rods position control

STEP 2 - Check the status of the main plant control

Ensure proper status of the main plant controls:

- 1 **Plant mode**
Reactor leading mode
- 2 **Rod Control**
Manual mode
- 3 **MSB**
Steam pressure mode
- 4 **FW system in Auto**
FW control valves
(FWSV13/FWSV14) in Auto
- 5 **CW and CNR systems in service**
CW system in service
(opened or closed loop)
- 6 **FW control adjusting FW flow**

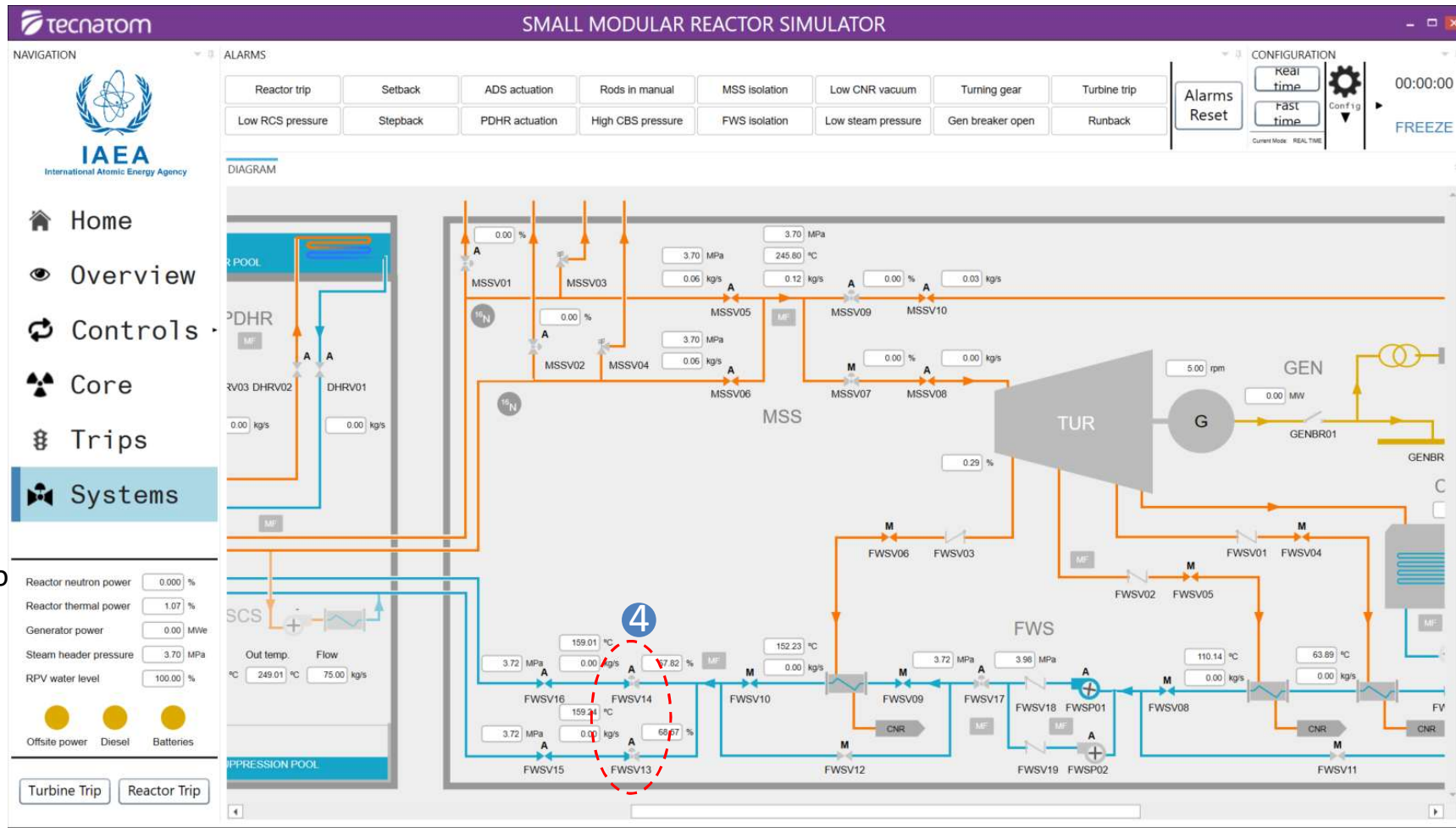


Controls → Turbine bypass control

STEP 2 - Check the status of the main plant controls

Ensure proper status of the main plant controls:

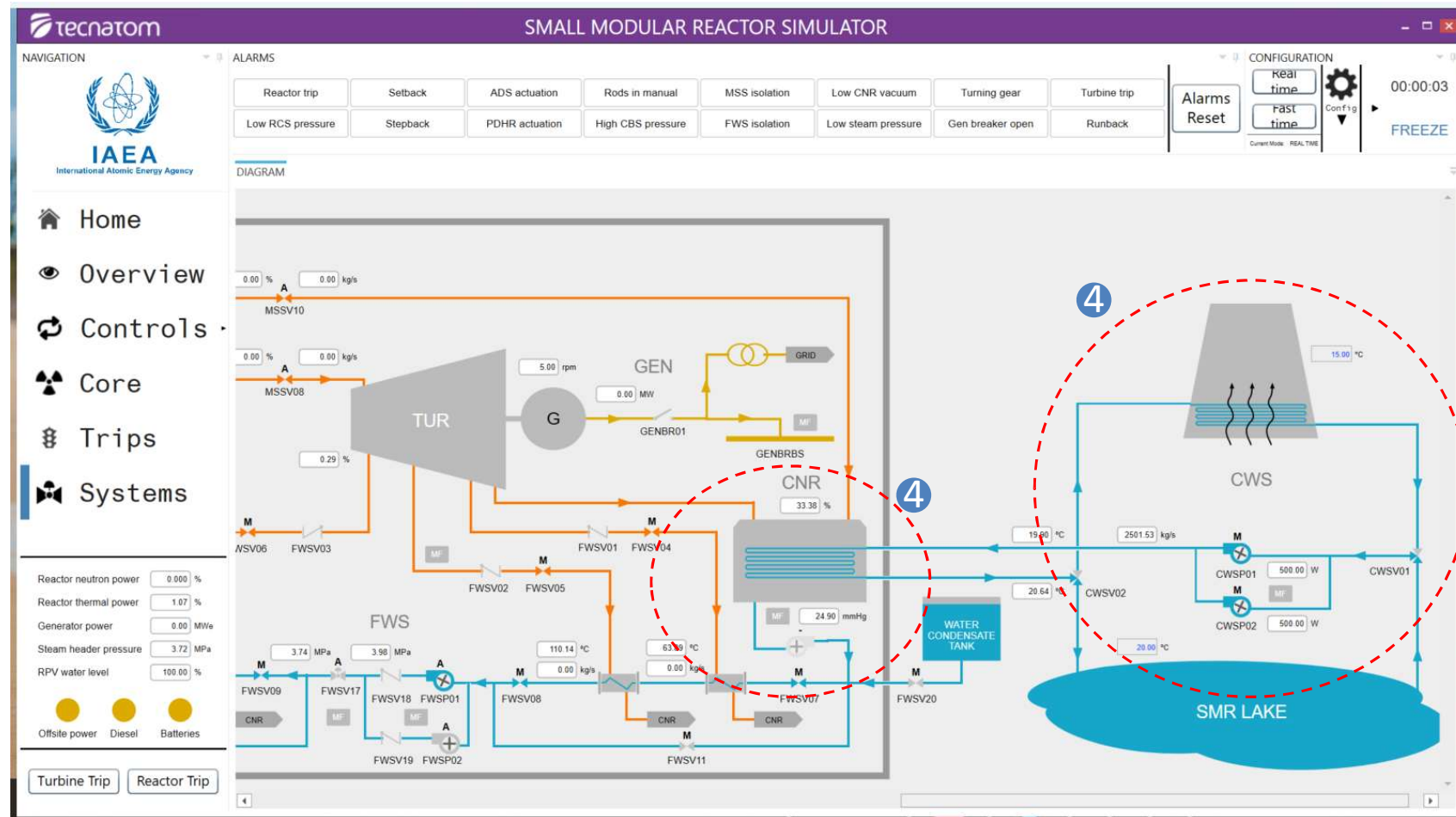
- 1 **Plant mode**
Reactor leading mode
- 2 **Rod Control**
Manual mode
- 3 **MSB**
Steam pressure mode
- 4 **FW system in Auto**
FW control valves
(FWSV13/FWSV14) in Auto
- 5 **CW and CNR systems in service**
CW system in service
(opened or closed loop)
- 6 **FW control adjusting FW flow**



STEP 2 - Check the status of the main plant controls

Ensure proper status of the main plant controls:

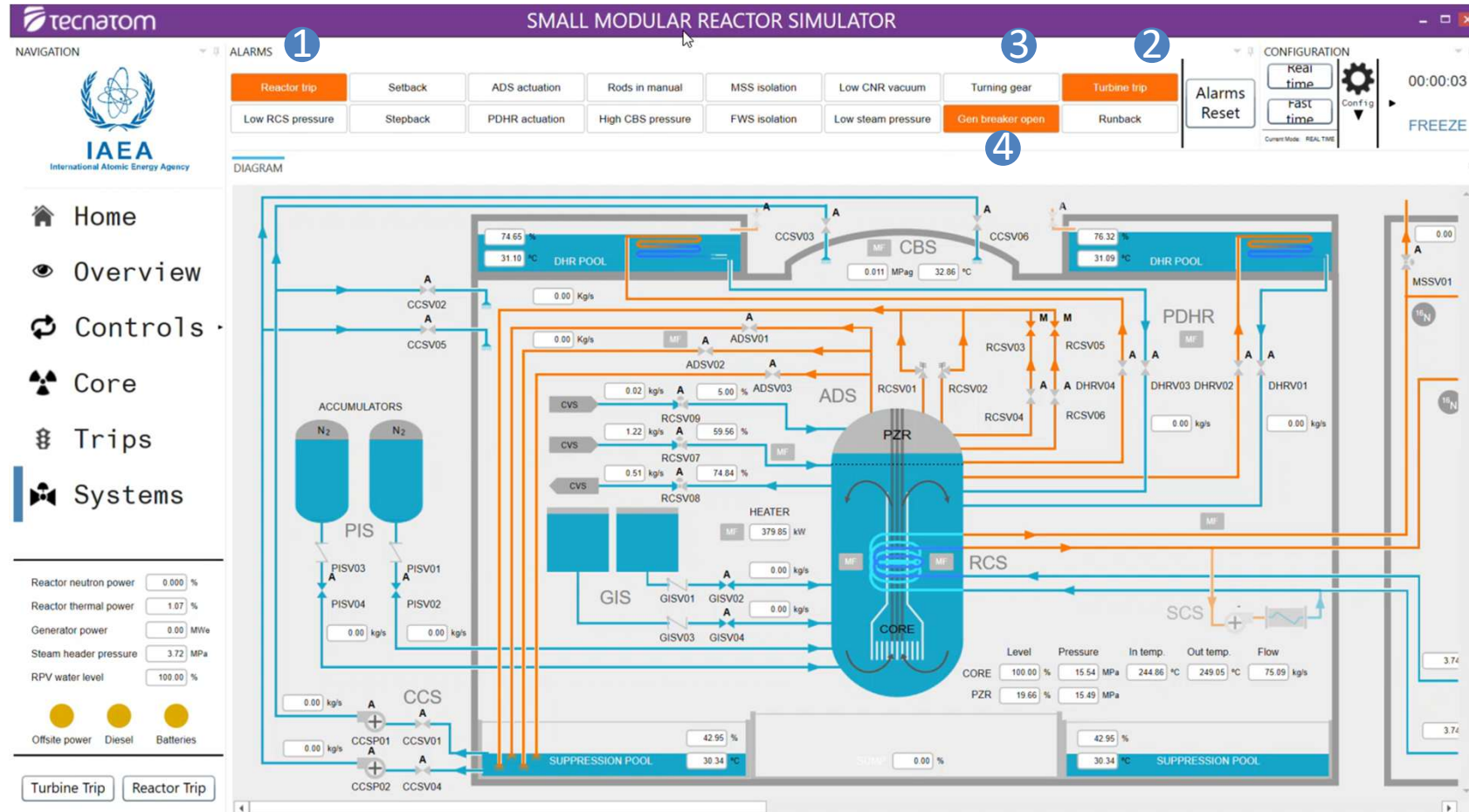
- 1 **Plant mode**
Reactor leading mode
- 2 **Rod Control**
Manual mode
- 3 **MSB**
Steam pressure mode
- 4 **FW system in Auto**
FW control valves
(FWSV13/FWSV14) in Auto
- 5 **CW and CNR systems in service**
CW system in service
(opened or closed loop)
- 6 **FW control adjusting FW flow**



STEP 3 - Check the alarm conditions

Check the following alarm conditions exist:

- 1 **Reactor trip**
Exist or not
- 2 **Turbine trip**
Exist or not
- 3 **Turning gear**
Exist or not
- 4 **Generator breaker open**
Exist or not



STEP 4 - Reset Reactor Trip Signal

Reactor alarm trip deactivates.

- 1 Open Trips display screen
- 2 Press RUN button
- 3 Press Alarm Reset button
- 4 Press RESET button in REACTOR TRIPS area
- 5 Reactor trip signal cleared

The screenshot displays the SMALL MODULAR REACTOR SIMULATOR interface. The top navigation bar includes the IAEA logo and the text "IAEA International Atomic Energy Agency". The main interface is divided into several sections:

- NAVIGATION:** Home, Overview, Controls, Core, Trips (highlighted with a blue bar and a "1" in a circle), Systems.
- ALARMS:** A row of buttons for various alarms: Reactor trip (highlighted with a blue bar and a "5" in a circle), 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.
- DIAGRAM:** A section for reactor diagrams.
- REACTOR TRIPS:** A list of trip conditions with their current values and setpoints. A "RESET" button is highlighted with a blue bar and a "4" in a circle.
- REACTOR SETBACKS:** A list of setback conditions with their current values and setpoints. A "RESET" button is highlighted with a blue bar and a "4" in a circle.
- REACTOR STEPBACKS:** A list of stepback conditions with their current values and setpoints. A "RESET" button is highlighted with a blue bar and a "4" in a circle.
- TURBINE TRIPS:** A list of turbine trip conditions with their current values and setpoints. A "RESET" button is highlighted with a blue bar and a "5" in a circle.
- TURBINE RUNBACK:** A list of turbine runback conditions with their current values and setpoints. A "RUNBACK" button is highlighted with a blue bar and a "4" in a circle.
- ADS ACTUATION:** A list of ADS actuation conditions with their current values and setpoints. A "RESET" button is highlighted with a blue bar and a "4" in a circle.
- PDHR ACTUATION:** A list of PDHR actuation conditions with their current values and setpoints. A "RESET" button is highlighted with a blue bar and a "4" in a circle.

The bottom status bar shows the following information:

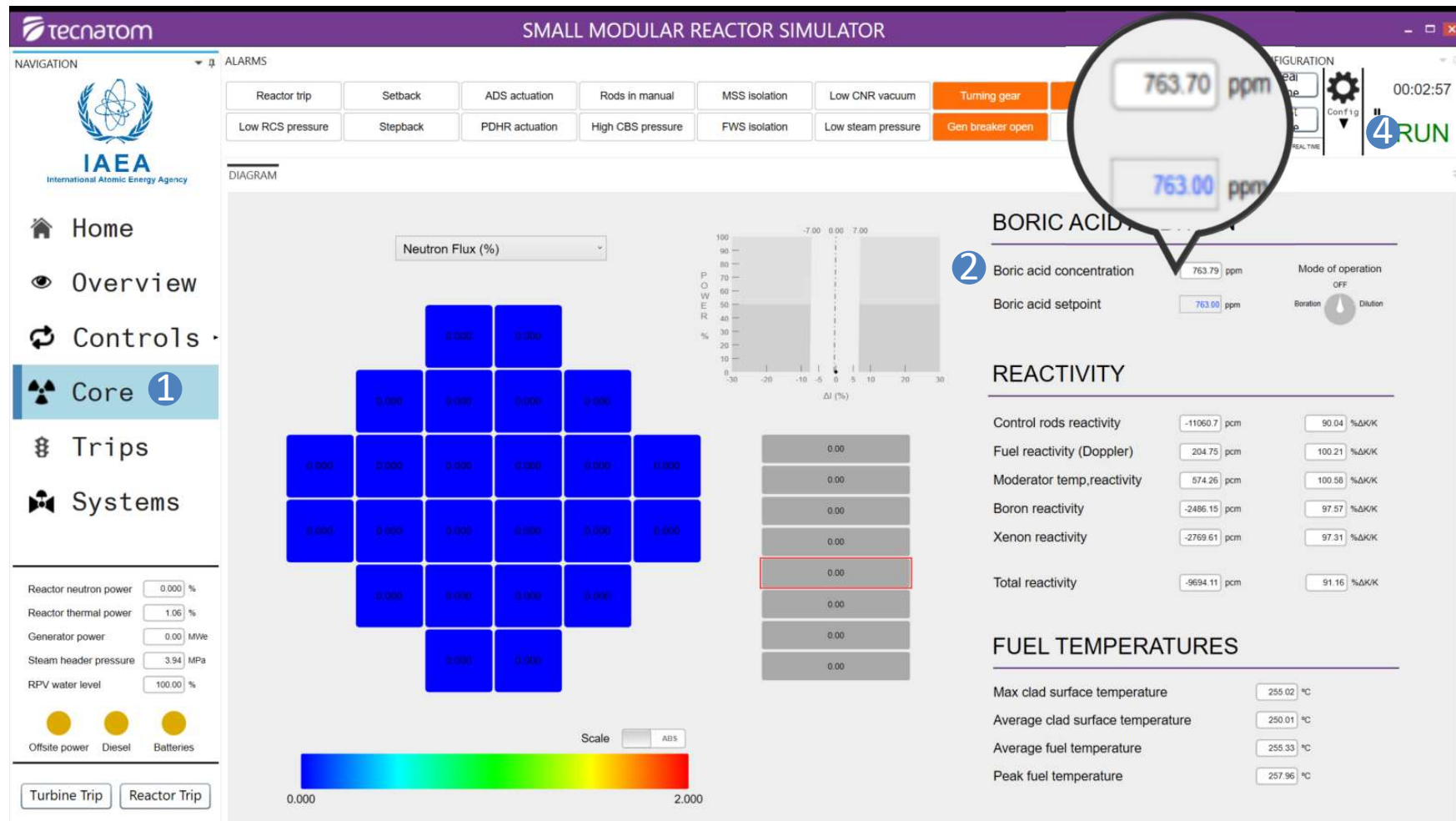
- Reactor neutron power: 0.000 %
- Reactor thermal power: 1.07 %
- Generator power: 0.00 MWe
- Steam header pressure: 3.70 MPa
- RPV water level: 100.00 %
- Offsite power: Diesel Batteries
- Turbine Trip: Reactor Trip

STEP 5 - Check boron concentration

Check Boron concentration stable.

- 1 Open Core display screen
- 2 Check Boron acid concentration
- 3 Observe the boron concentration over time to ensure its stability
- 4  Hint 1: Freeze the simulation run whenever needed to observe values or switch between displays

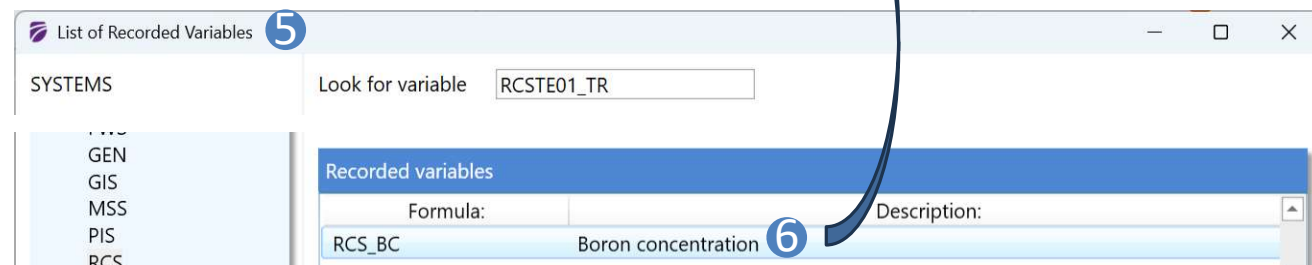
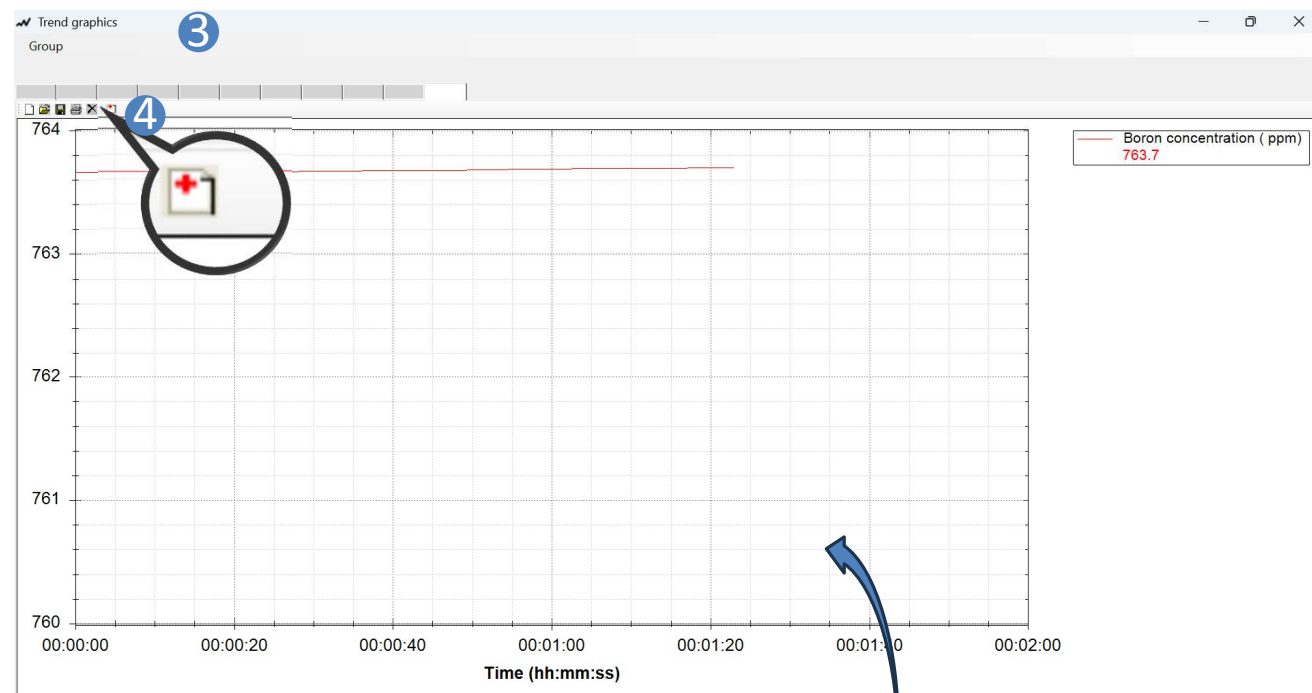
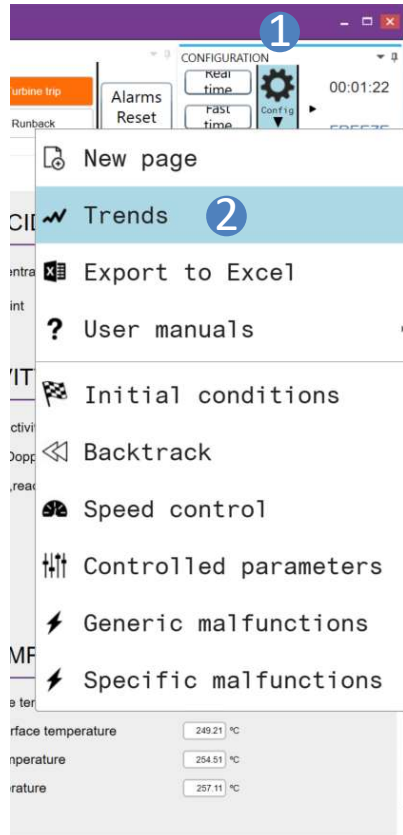
- 5  Hint 2: Visualize the boron concentration by graph for easier observation



STEP 5 - Check boron concentration

Hint: How to visualize the boron concentration by graph

- 1 Config
- 2 Trends
- 3 'Trend graphics' window opens
- 4 Press 'Adds a new variable' button
- 5 'List of recorded variables' window appears
- 6 Drag & drop one variable, for ex. RCS_BC (Boron concentration) to the 'Trend graphics'



STEP 6 - Withdraw shutdown bank A fully

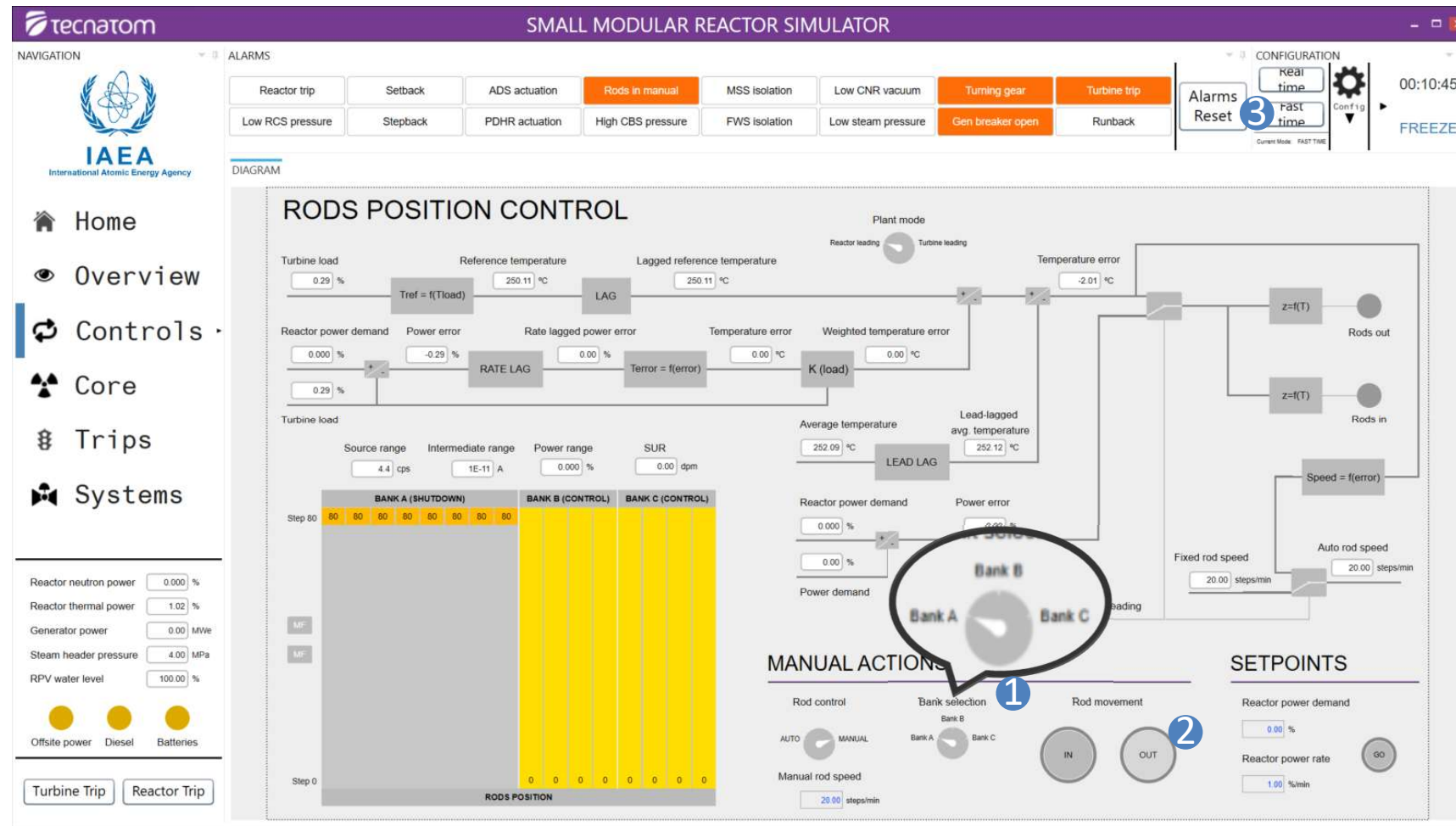
Withdraw shutdown bank A fully while monitoring neutron flux.

1 Ensure bank A is selected

2 Push OUT until bank A is **fully withdrawn (80 steps)**

3 Hint 3:

- In 'Real time' mode, it could be very slow to completely withdraw control rods out of reactor core.
- Use '**Fast time**' to accelerate simulation time.
- Switch to 'Real ime' mode to observe transient behaviors promptly when needed.

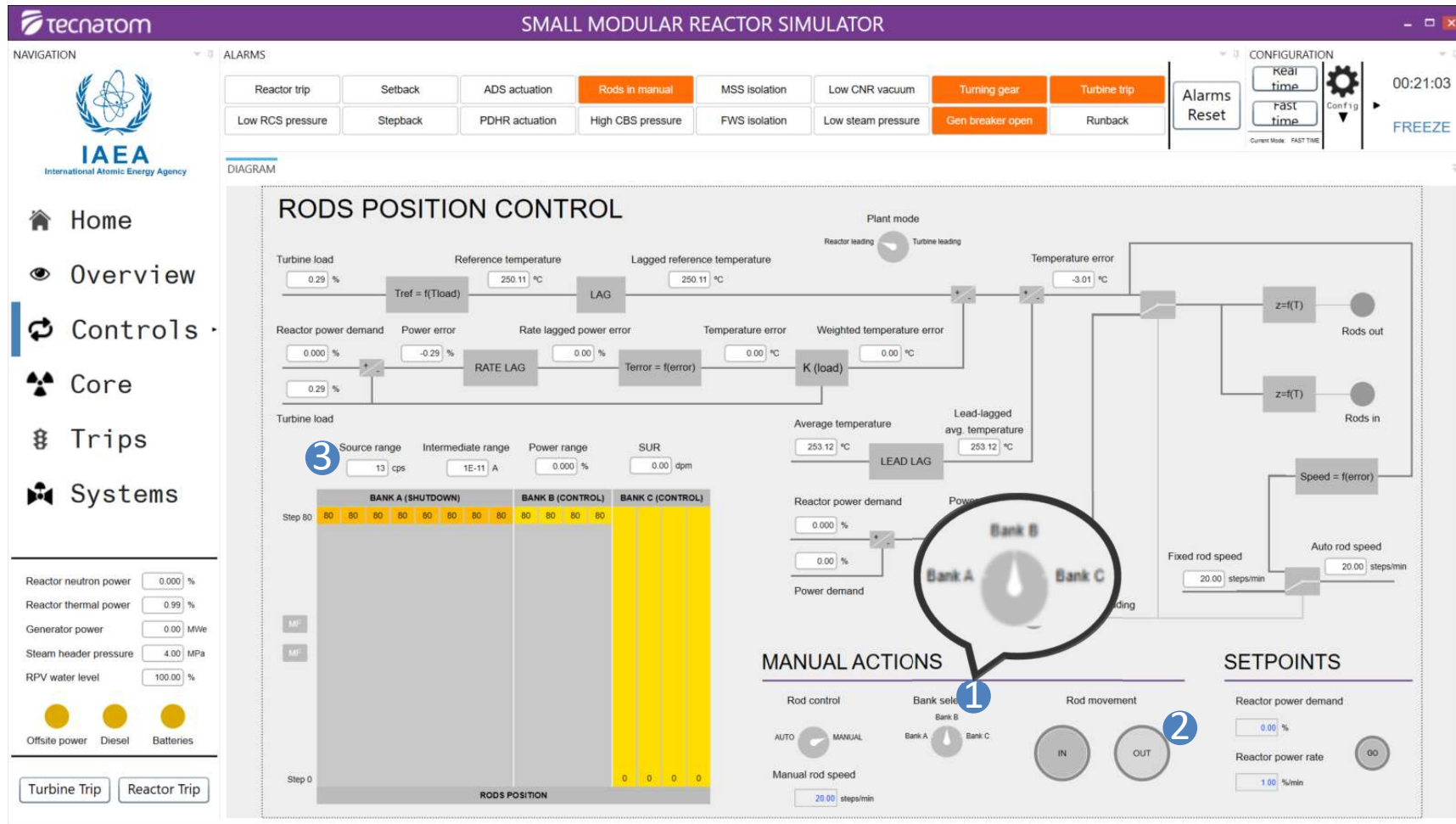


Controls → Rods position control

STEP 7 - Withdraw control bank B fully

Withdraw shutdown bank B fully while monitoring neutron flux.

- 1 Ensure bank B is selected
- 2 Push OUT until bank B is **fully withdrawn (80 steps)**
- 3 Source Range power (RCSNP03_TR) begins to rise but stabilises or falls when rod movement stops.

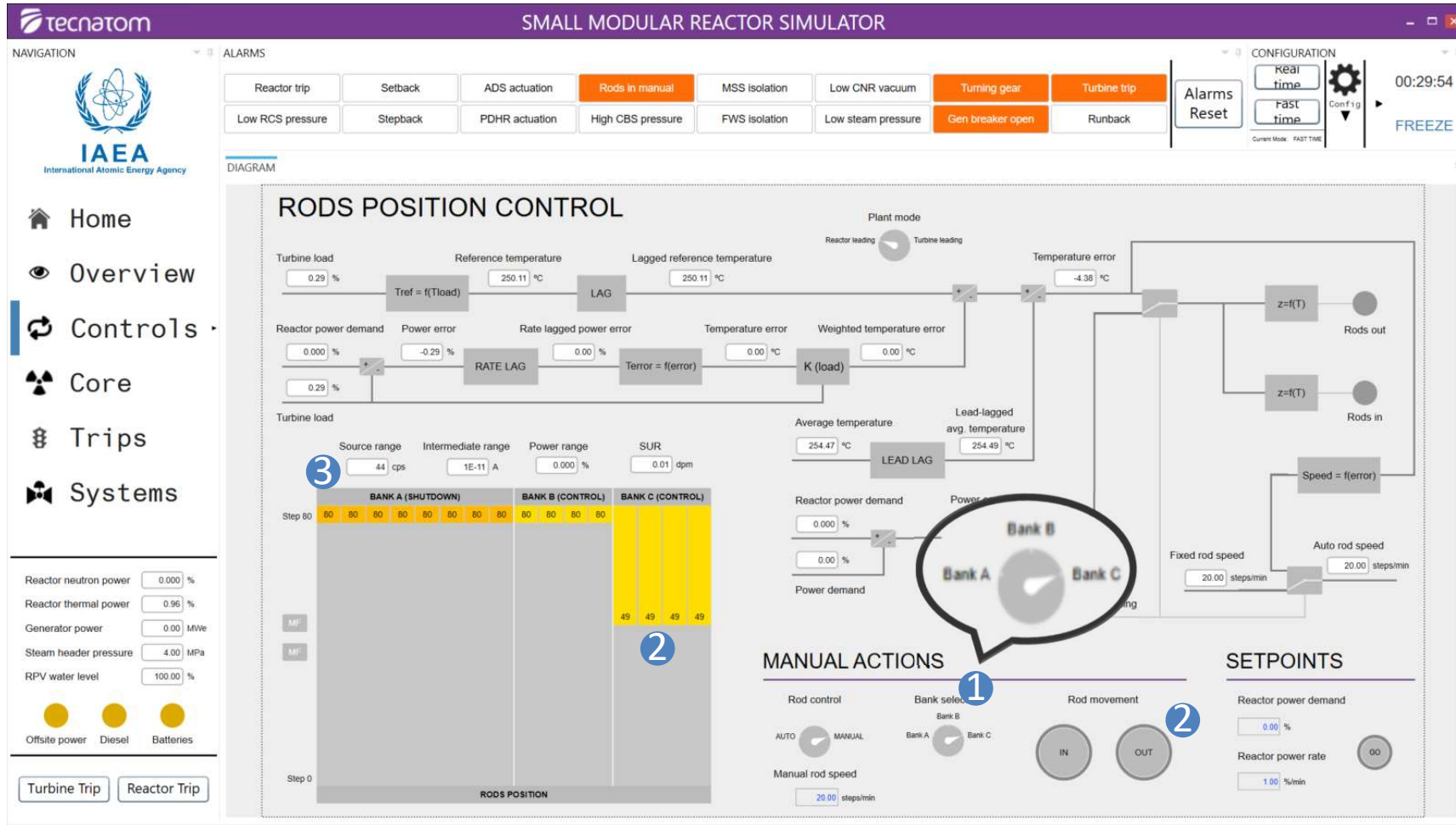


Controls → Rods position control

STEP 8 - Withdraw control bank C partially

Withdraw Bank C to the Estimated Condition while neutron flux for criticality monitoring.

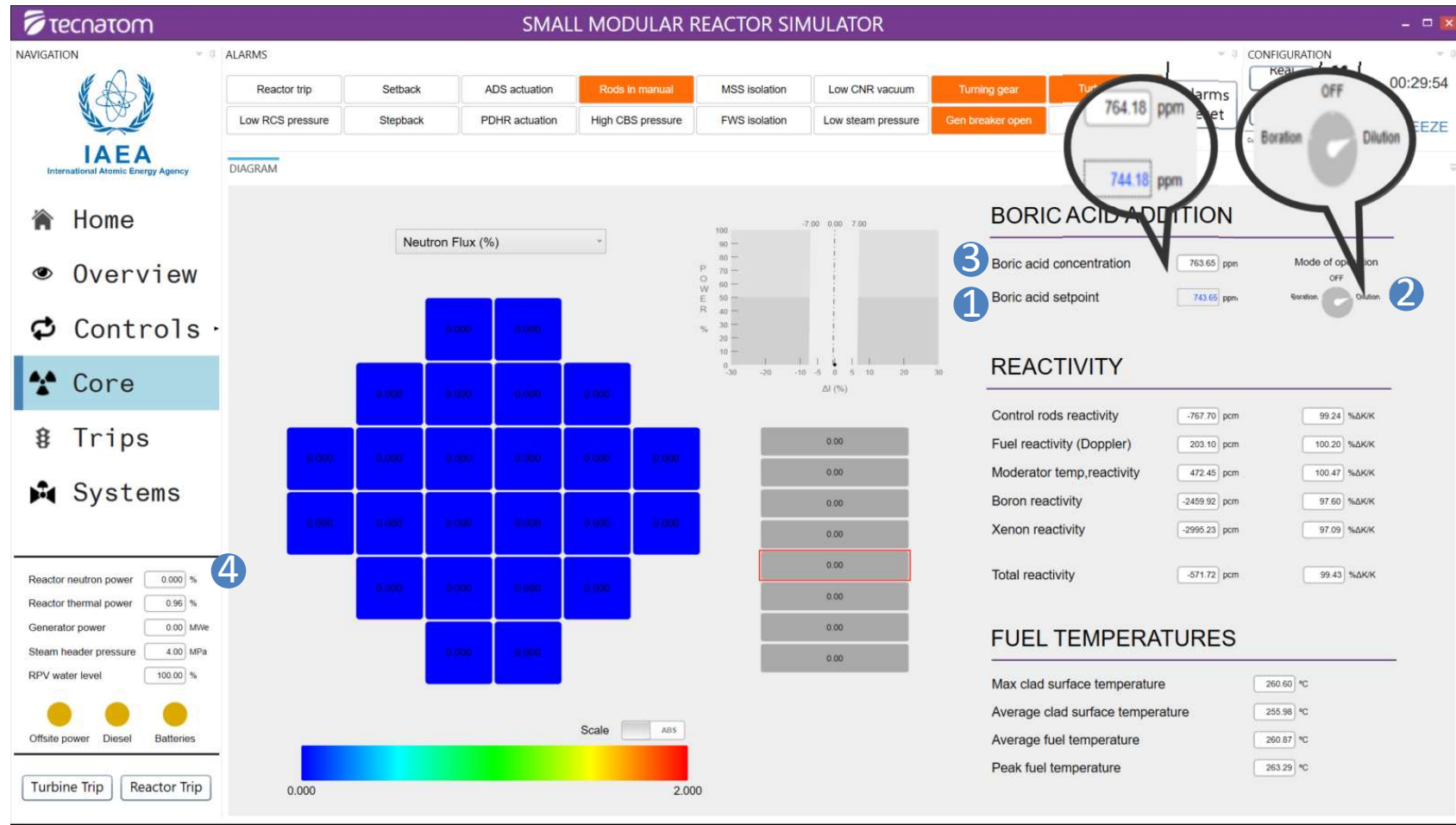
- 1 Ensure bank C is selected
- 2 Push OUT until bank C reaches **49 steps**
- 3 Source Range power (RCSNP03_TR) begins to rise but stabilises or falls when rod movement stops.



Controls → Rods position control

STEP 9 - Boron Dilution

Dilute RCS for criticality:



1 Introduce the new boron concentration setpoint (max 20 ppm per batch)

Hint 4: If the change exceeds 20 ppm, the setpoint will be automatically limited to a maximum difference of 20 ppm by default. If a smaller change is required, please enter the value directly.

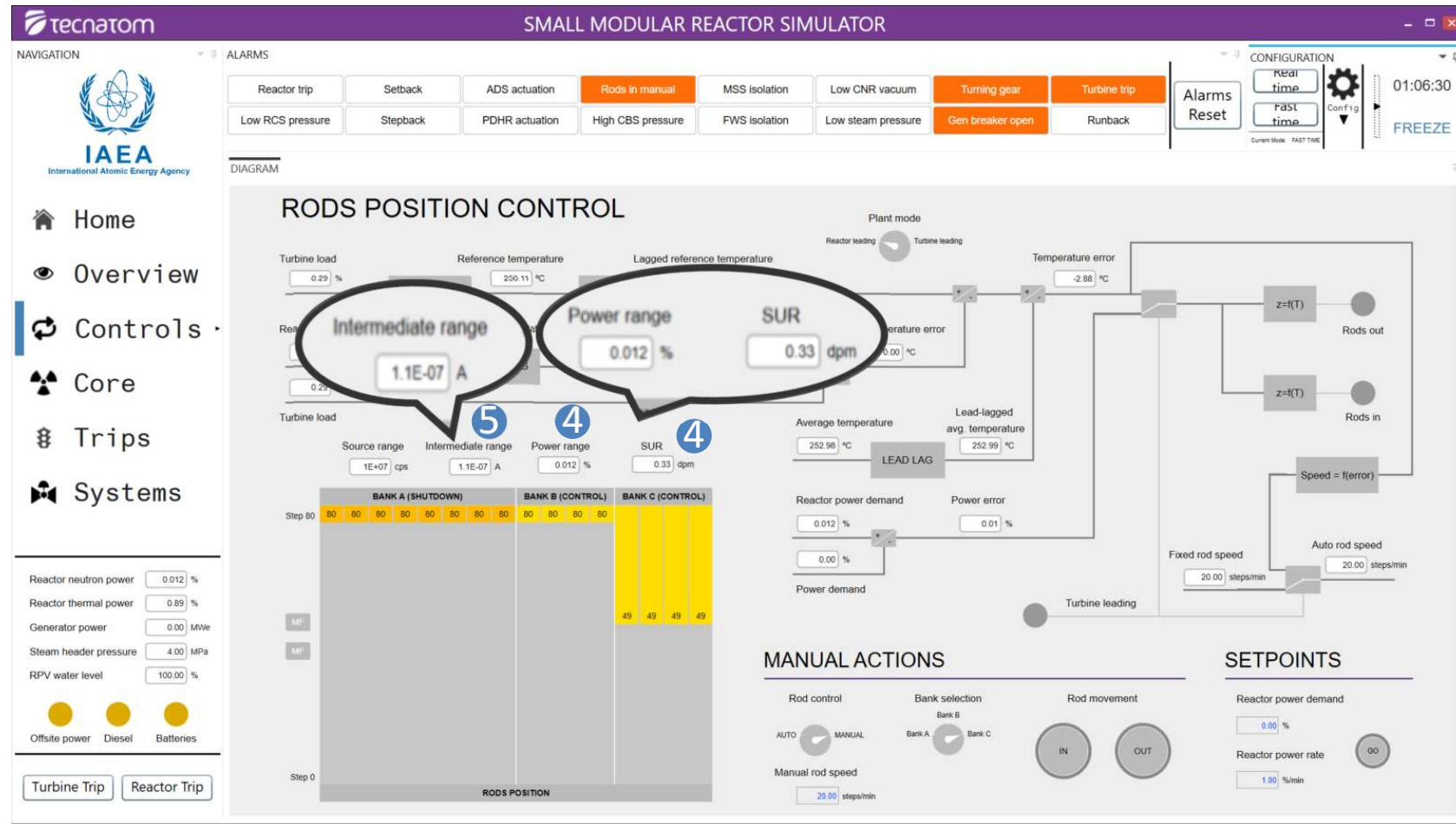
2 Place selector in 'dilution'

3 Check boron concentration (RCS_BC) decreases to the boron concentration setpoint

4 Repeat (1) and (3) until **neutron power (RCSNP01_TR) slowly rises without control rod movement** (criticality observed). Plot neutron power and SUR

STEP 9 - Boron Dilution

Dilute RCS for criticality:



1

Introduce the new boron concentration setpoint (max 20 ppm per batch)

Hint 4: If the change exceeds 20 ppm, the setpoint will be automatically limited to a maximum difference of 20 ppm by default. If a smaller change is required, please enter the value directly.

2

Place selector in 'dilution'

3

Check boron concentration (RCS_BC) decreases to the boron concentration setpoint

4

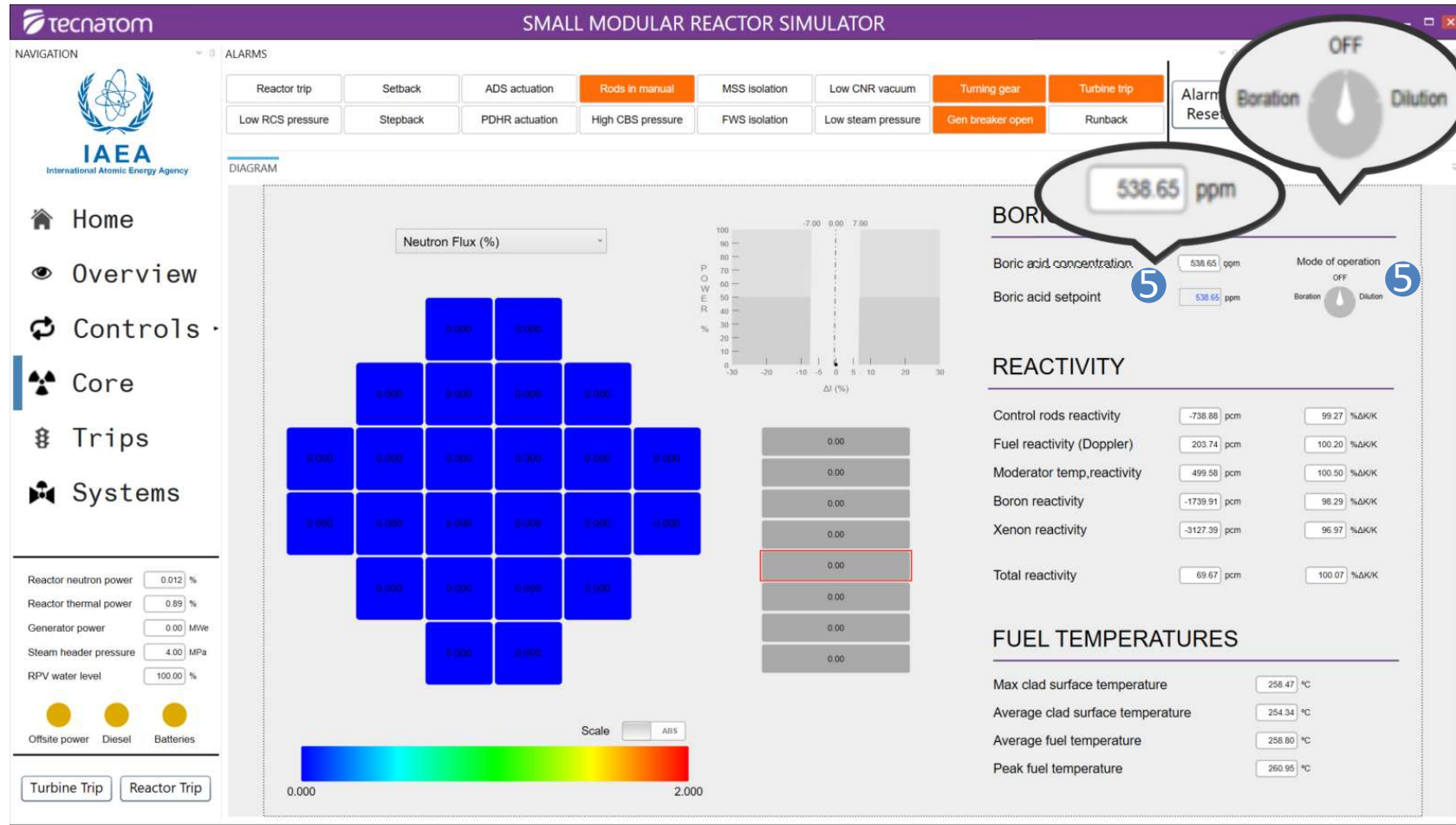
Repeat (1) and (3) until **neutron power (RCSNP01_TR) slowly rises without control rod movement** (criticality observed). Plot neutron power and SUR

5

Point of Adding Heat (POAH) occurs when Intermediate Range $\sim 10E-8$.

STEP 9 - Boron Dilution

Dilute RCS for criticality:



1

Introduce the new boron concentration setpoint (max 20 ppm per batch)

Hint 4: If the change exceeds 20 ppm, the setpoint will be automatically limited to a maximum difference of 20 ppm by default. If a smaller change is required, please enter the value directly.

2

Place selector in 'dilution'

3

Check boron concentration (RCS_BC) decreases to the boron concentration setpoint

4

Repeat (1) and (3) until neutron power (RCSNP01_TR) slowly rises without control rod movement (criticality observed). Plot neutron power and SUR

5

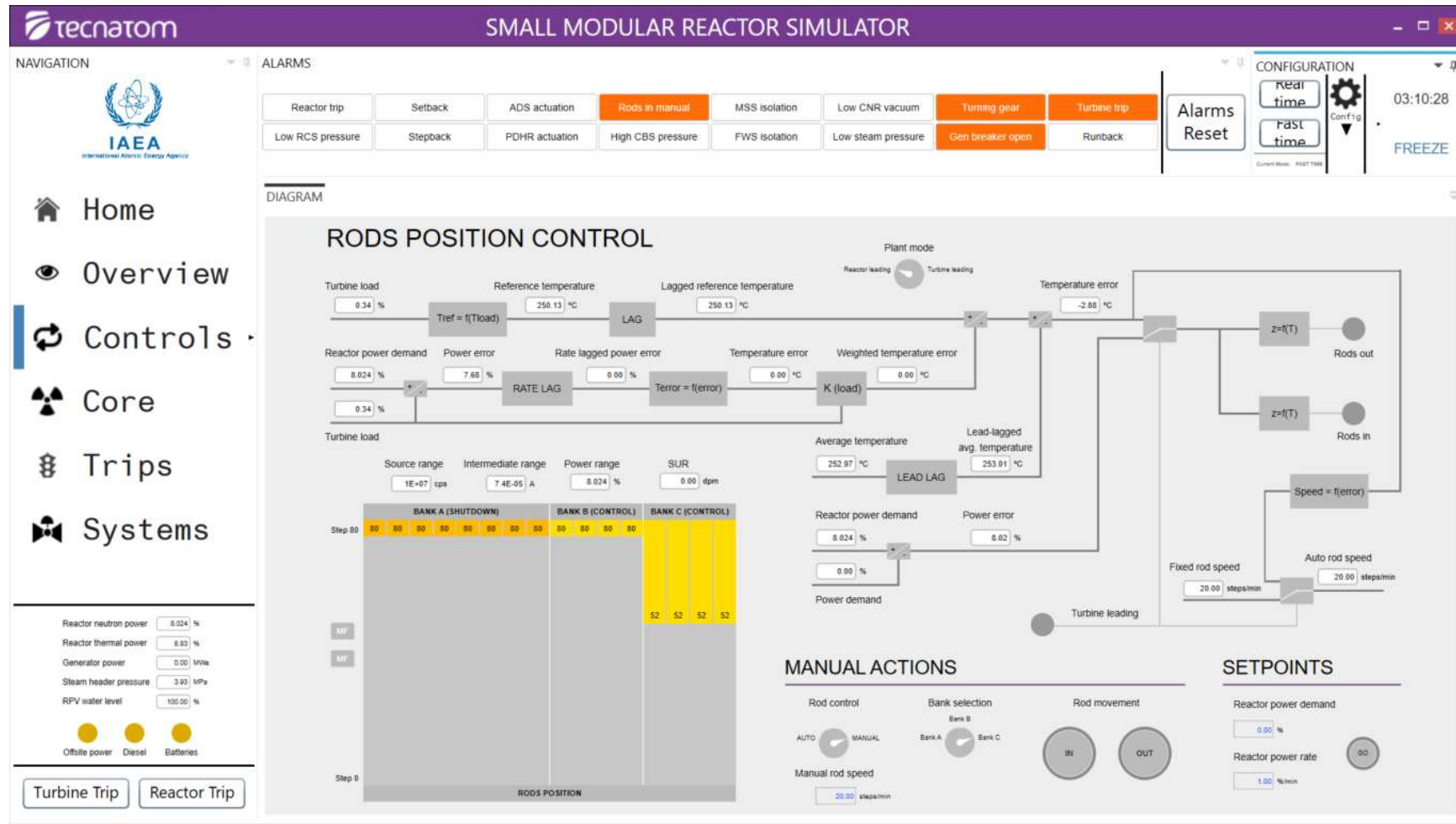
Place selector in 'OFF'.

Record the Boron concentration

STEP 9 - Boron Dilution

Dilute RCS for criticality:

Note: Above the Point of Adding Heat (POAH), ie. Intermediate Range $\geq 10E-8$, SUR should not exceed a sustained 0.5 dpm.



STEP 10 - Manually raise Reactor power to 8%

Raise Reactor power to 8% with Rod Control in Manual

1

Manually withdraw Control Rod Bank C to raise reactor power to 8% (Push OUT button)

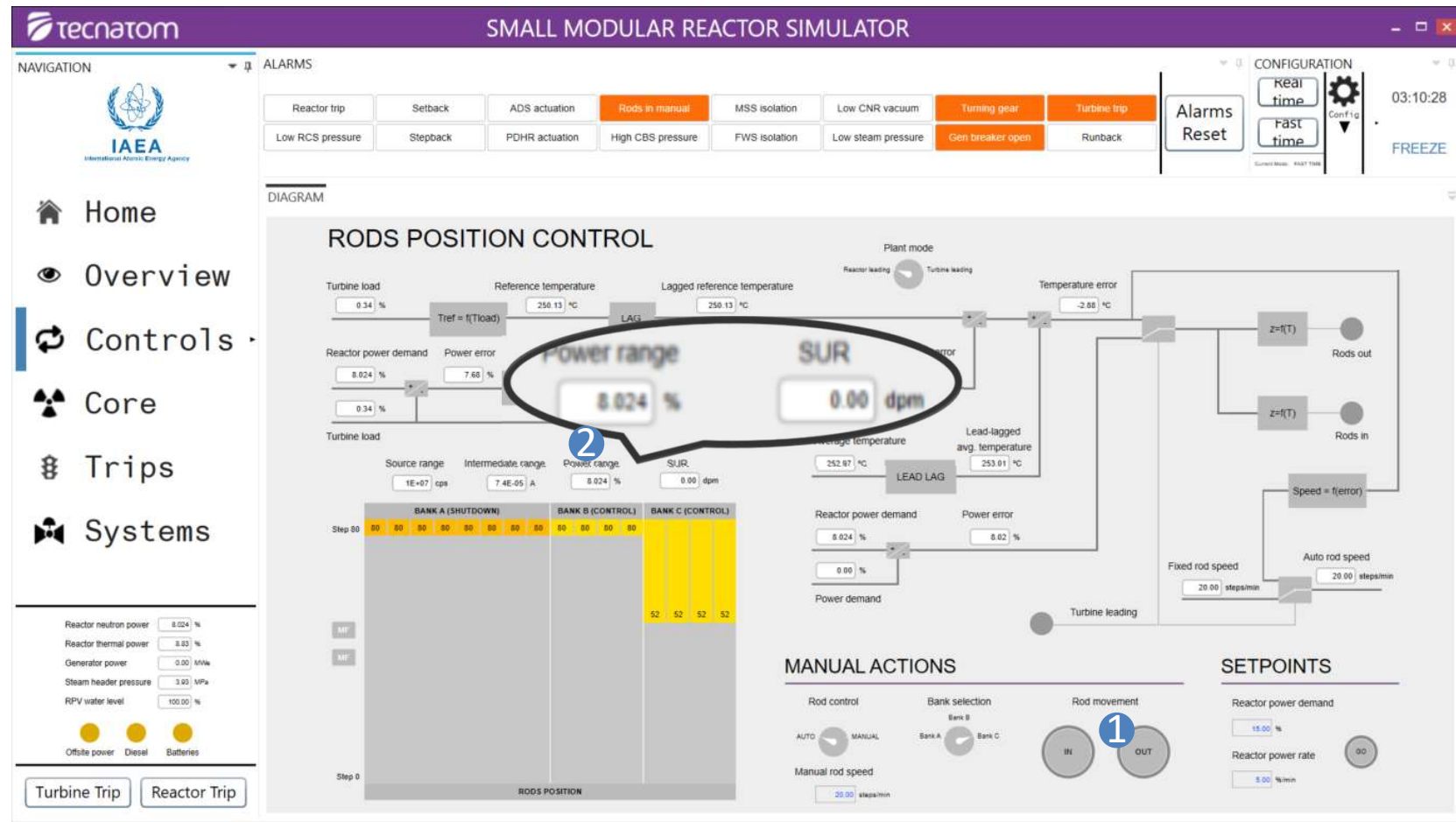
Hint 5:

- Above the **Point of Adding Heat (POAH)**, ie. Intermediate Range $\geq 10E-8$, **SUR should not exceed a sustained 0.5 dpm**

- Insert Control Rod Bank C into the core if reactor power far exceeds 8%

2

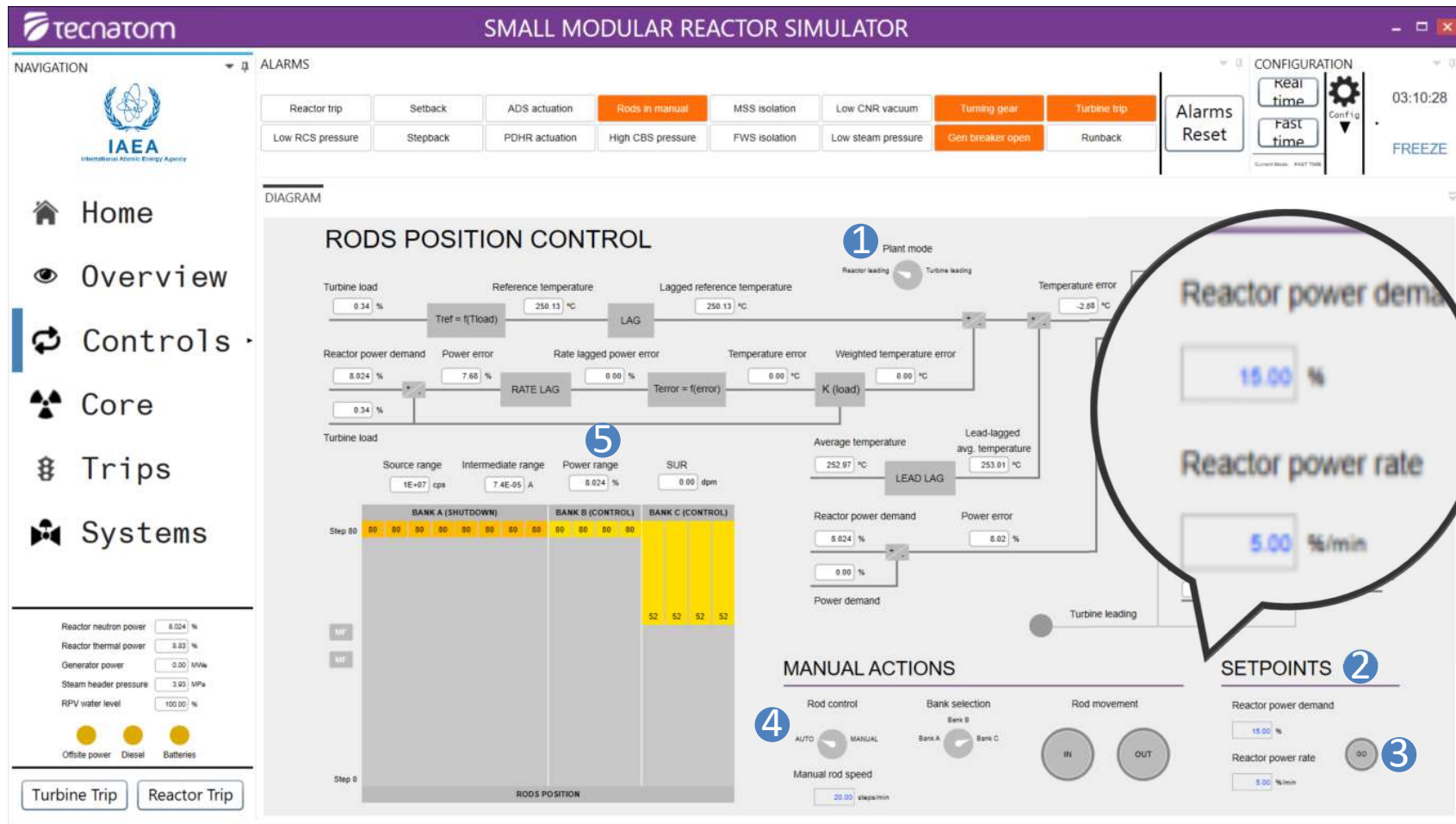
Neutron power (RCSNP01_TR) rises and stabilises at 8%. Check and record the Boric acid concentration.



STEP 11 - Automatically raise Reactor power to 15%

Raise Reactor power to 15% with Rod Control in Auto:

- 1 Verify Plant Mode is in Reactor Leading mode
- 2 Insert 15% in Reactor Power Demand and 5%/min in Reactor Power Rate
- 3 Press GO
- 4 Place Control Rods in Auto
- 5 Neutron power (RCSNP01_TR) rises and stabilises at 15%



STEP 12 - Start-up the Turbine

Start-up the Turbine:

- 1 Reset Turbine trip. Turbine trip alarm deactivates
- 2 Ensure Turbine Control valve (MSSV07) is in Auto
- 3 Push RUN-UP
- 4 Turbine Control valve opens around 3%
- 5 When 'Ready to Sync' light appears, push 'Sync' button to close Generator breaker
- 6 Check Turbine accepts a minimum Load
- 7 Check Turbine Control valve is in Manual

Trips

The screenshot displays the 'SMALL MODULAR REACTOR SIMULATOR' interface. The left sidebar contains navigation options: Home, Overview, Controls, Core, Trips (selected), and Systems. The main area is divided into several sections:

- ALARMS:** A top bar with buttons for various alarms, including 'Turning gear' and 'Gen breaker open', which are highlighted in orange.
- DIAGRAM:** A central section with multiple sub-sections:
 - REACTOR TRIPS:** Lists various trip conditions with current and setpoint values (e.g., Low pressure upper plenum at 15.49 MPa vs 11.00 MPa).
 - REACTOR SETBACKS:** Lists setback conditions (e.g., High PZR level at 25.27 % vs 87.00 %).
 - REACTOR STEPBACKS:** Lists stepback conditions (e.g., Turbine trip (60%), High zone flux (95%), Loss of 1 RCP (50%), Loss of 4 RCPs (30%).
 - TURBINE TRIPS:** Lists turbine trip conditions (e.g., Reactor trip, Manual).
 - TURBINE RUNBACK:** Lists runback conditions (e.g., Manual).
 - ADS ACTUATION:** Lists ADS actuation conditions (e.g., Low-low pressure upper plenum, Low-low level vessel, High-high pressure upper plenum, High-high pressure CBS, Manual).
 - PDHR ACTUATION:** Lists PDHR actuation conditions (e.g., Heat sink loss, Manual).

At the bottom left, there are status indicators for Reactor neutron power, Reactor thermal power, Generator power, Steam header pressure, and RPV water level, along with power source indicators (Offsite power, Diesel, Batteries).

Turbine speed increases (TURCN01_TR) from 5 rpm to 3600rpm. Turning gear and Generator Breaker alarms clear

STEP 12 - Start-up the Turbine

Start-up the Turbine:

- 1 Reset Turbine trip. Turbine trip alarm deactivates
- 2 Ensure Turbine Control valve (MSSV07) is in Auto
- 3 Push RUN-UP
- 4 Turbine Control valve opens around 3%
- 5 When 'Ready to Sync' light appears, push 'Sync' button to close Generator breaker
- 6 Check Turbine accepts a minimum Load
- 7 Check Turbine Control valve is in Manual

Systems

tecnaTom

NAVIGATION



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

Reactor neutron power: 15.160 %
Reactor thermal power: 15.95 %
Generator power: 0.00 MW
Steam header pressure: 4.00 MPa
RPV water level: 100.00 %
Offsite power: Diesel: Batteries

Turbine Trip Reactor Trip

SMALL MODULAR REACTOR SIMULATOR

ALARMS

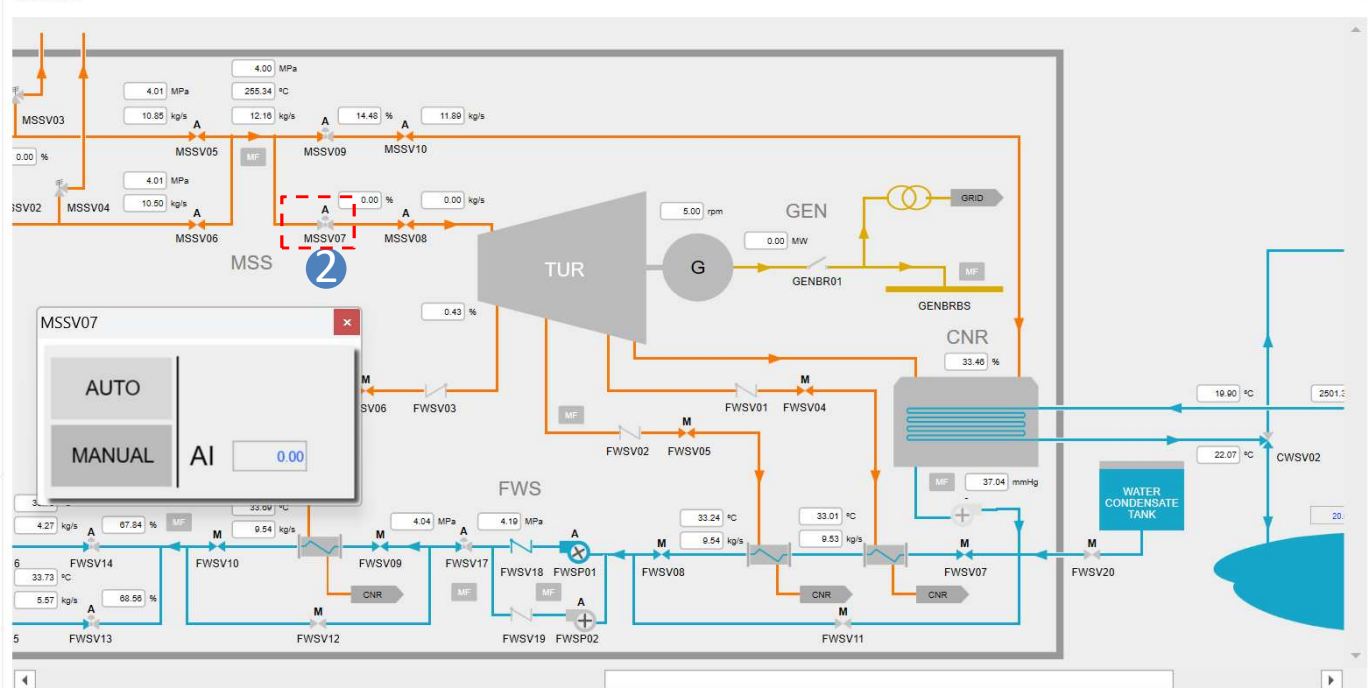
Reactor trip	Setback	ADS actuation	Rods in manual	MSS isolation	Low CNR vacuum	Turning gear	Turbine trip
Low RCS pressure	Stepback	PDHR actuation	High CBS pressure	FWS isolation	Low steam pressure	Gen breaker open	Runback

Alarms
Reset

CONFIGURATION

Real time
Fast time
03:25:09
FREEZE

DIAGRAM



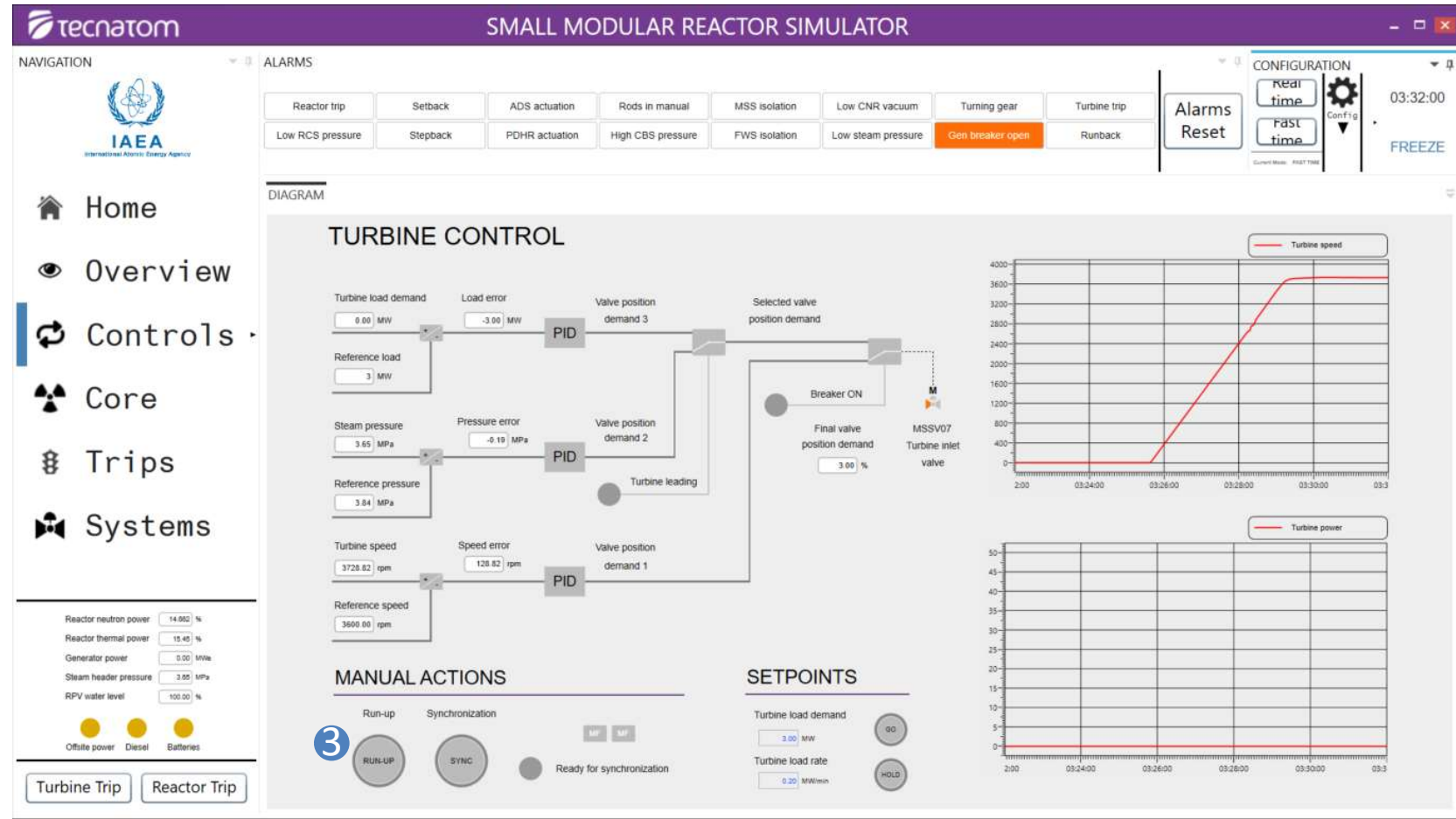
Click on MSSV07 valve → Dialog opens → Select AUTO

STEP 12 - Start-up the Turbine



Start-up the Turbine:

- 1 Reset Turbine trip. Turbine trip alarm deactivates
- 2 Ensure Turbine Control valve (MSSV07) is in Auto
- 3 Push RUN-UP
- 4 Turbine Control valve opens around 3%
- 5 When 'Ready to Sync' light appears, push 'Sync' button to close Generator breaker
- 6 Check Turbine accepts a minimum Load
- 7 Check Turbine Control valve is in Manual



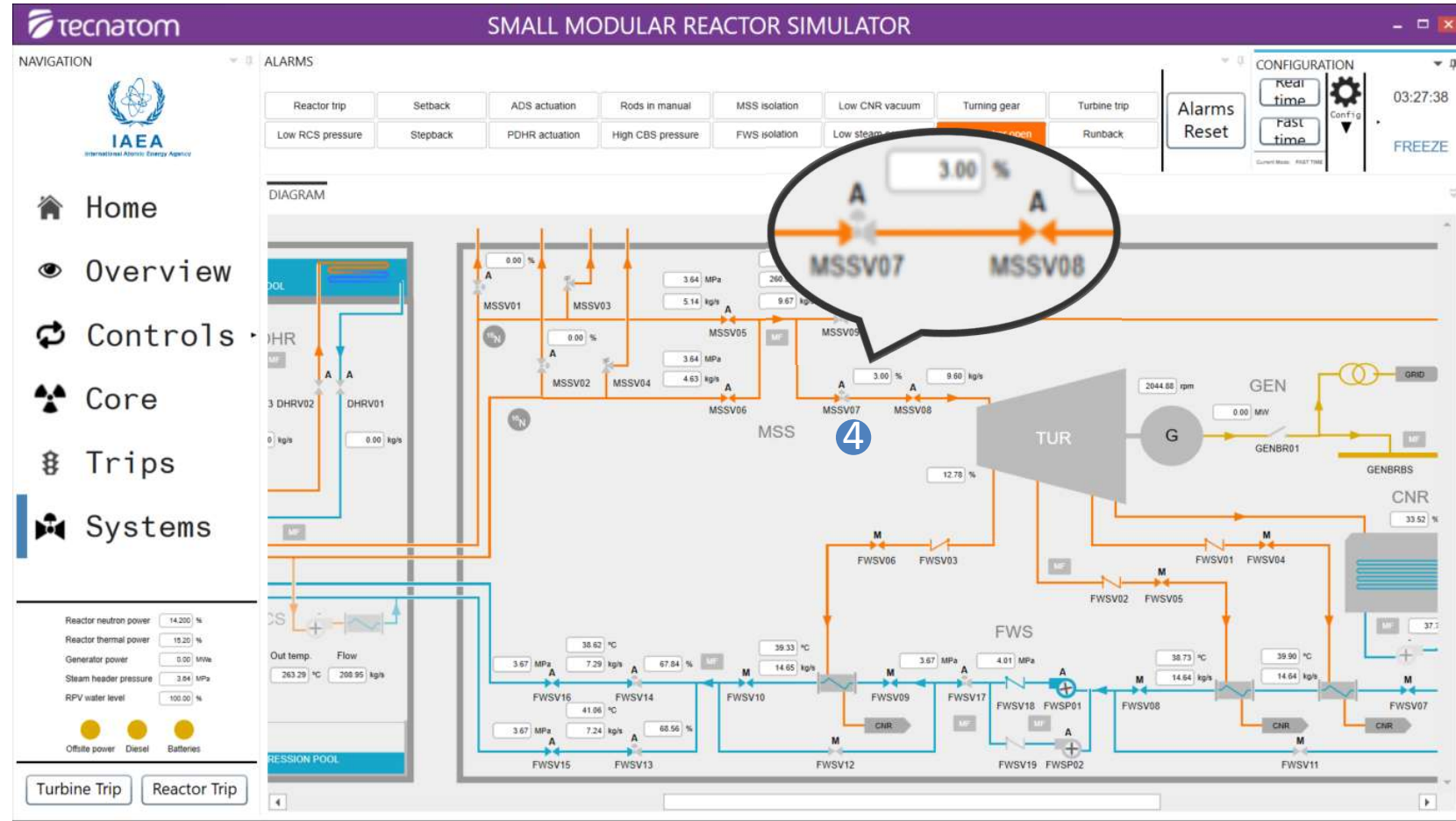
Controls → Turbine control

STEP 12 - Start-up the Turbine

Start-up the Turbine:

- 1 Reset Turbine trip. Turbine trip alarm deactivates
- 2 Ensure Turbine Control valve (MSSV07) is in Auto
- 3 Push RUN-UP
- 4 Turbine Control valve (MSSV07) opens around 3%
- 5 When 'Ready to Sync' light appears, push 'Sync' button to close Generator breaker
- 6 Check Turbine accepts a minimum Load
- 7 Check Turbine Control valve is in Manual

Systems

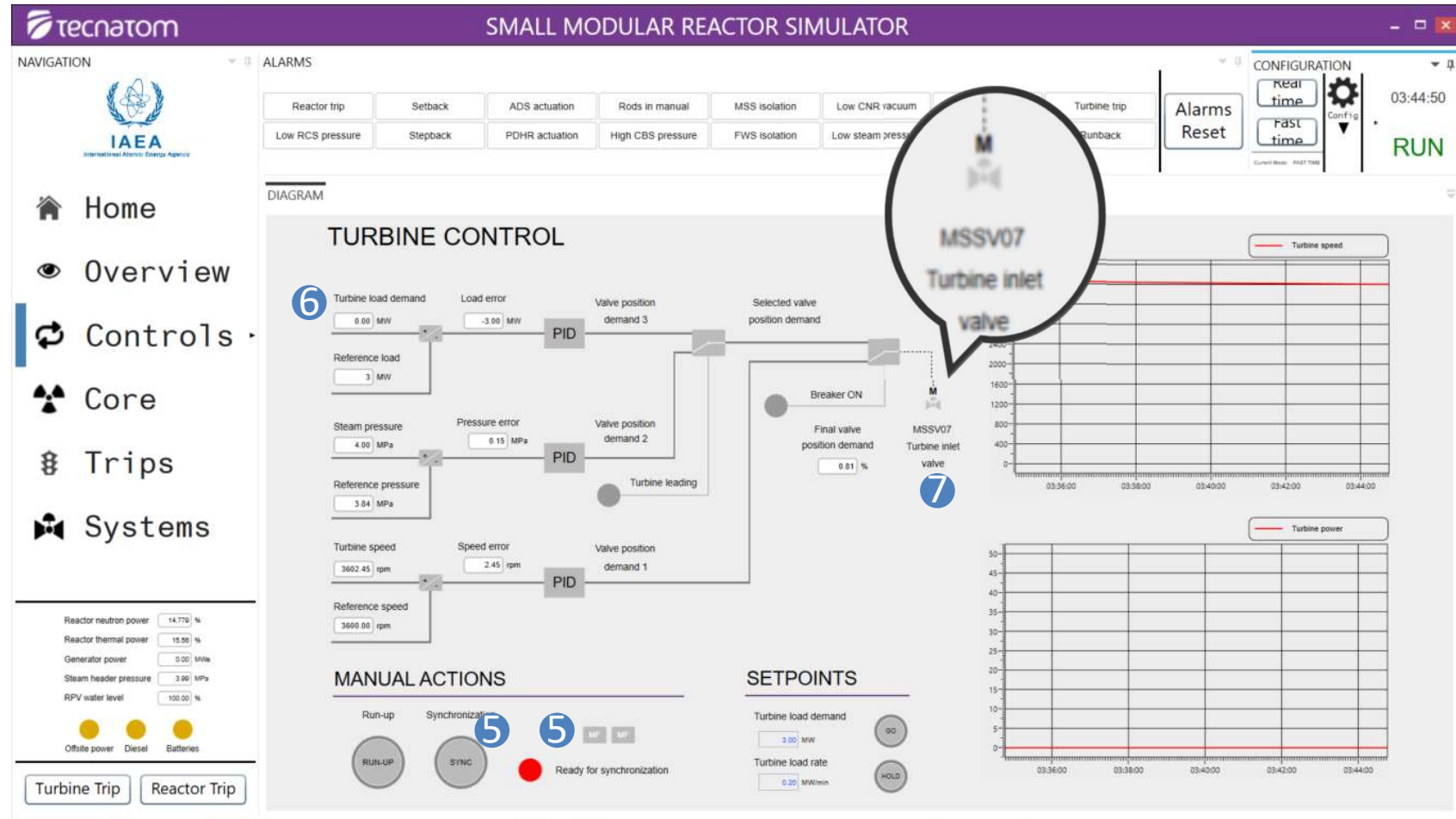


STEP 12 - Start-up the Turbine



Start-up the Turbine:

- 1 Reset Turbine trip. Turbine trip alarm deactivates
- 2 Ensure Turbine Control valve (MSSV07) is in Auto
- 3 Push RUN-UP
- 4 Turbine Control valve (MSSV07) opens around 3%
- 5 When 'Ready to Sync' light appears, push 'Sync' button to close Generator breaker
- 6 Check Turbine accepts a minimum Load
- 7 Check Turbine Control valve is in Manual



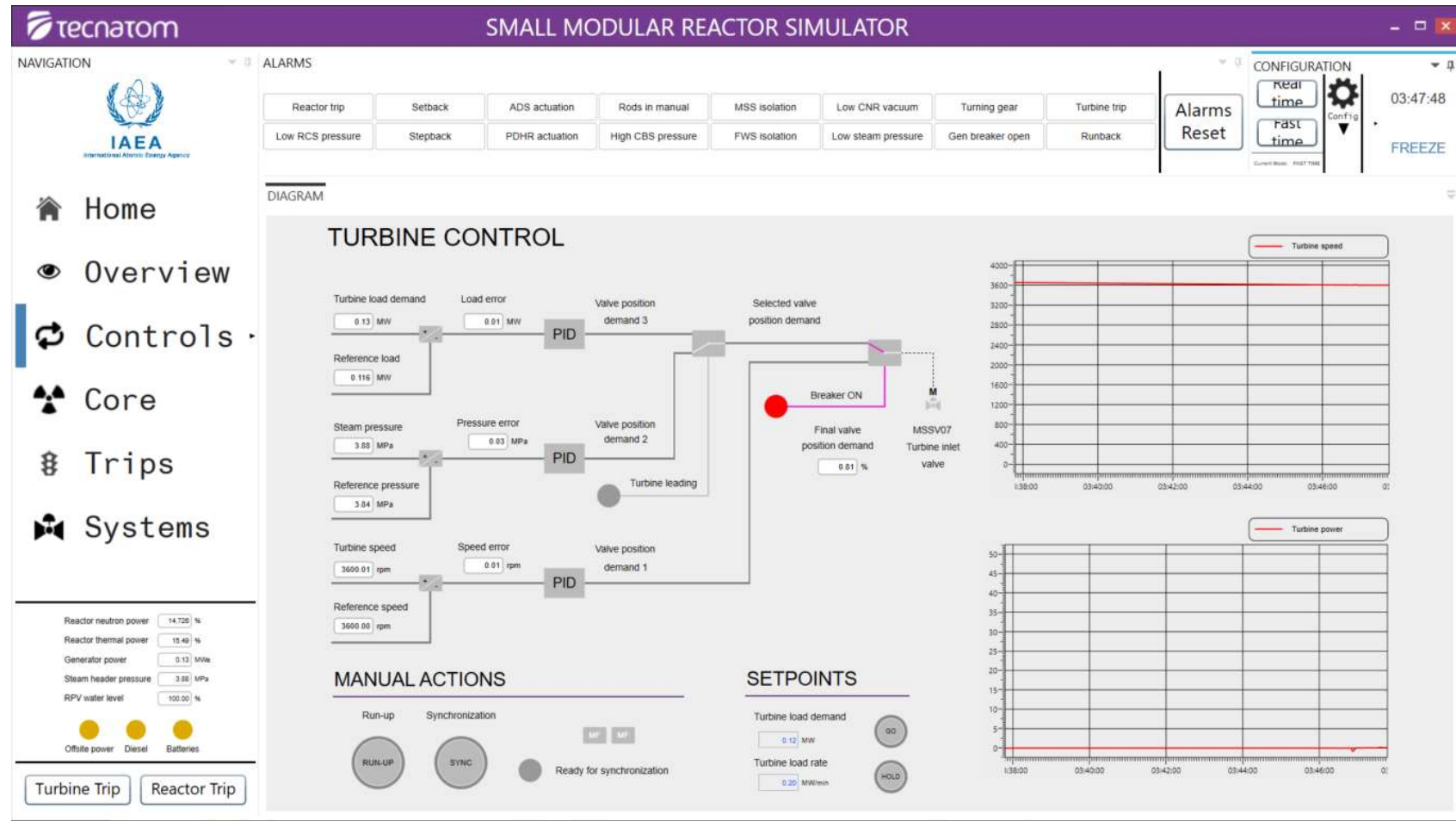
Turbine speed increases (TURCN01_TR) from 5 rpm to 3600rpm. Turning gear and Generator Breaker alarms clear

STEP 12 - Start-up the Turbine



Start-up the Turbine:

- 1 Reset Turbine trip. Turbine trip alarm deactivates
- 2 Ensure Turbine Control valve (MSSV07) is in Auto
- 3 Push RUN-UP
- 4 Turbine Control valve (MSSV07) opens around 3%
- 5 When 'Ready to Sync' light appears, push 'Sync' button to close Generator breaker
- 6 Check Turbine accepts a minimum Load
- 7 Check Turbine Control valve is in Manual

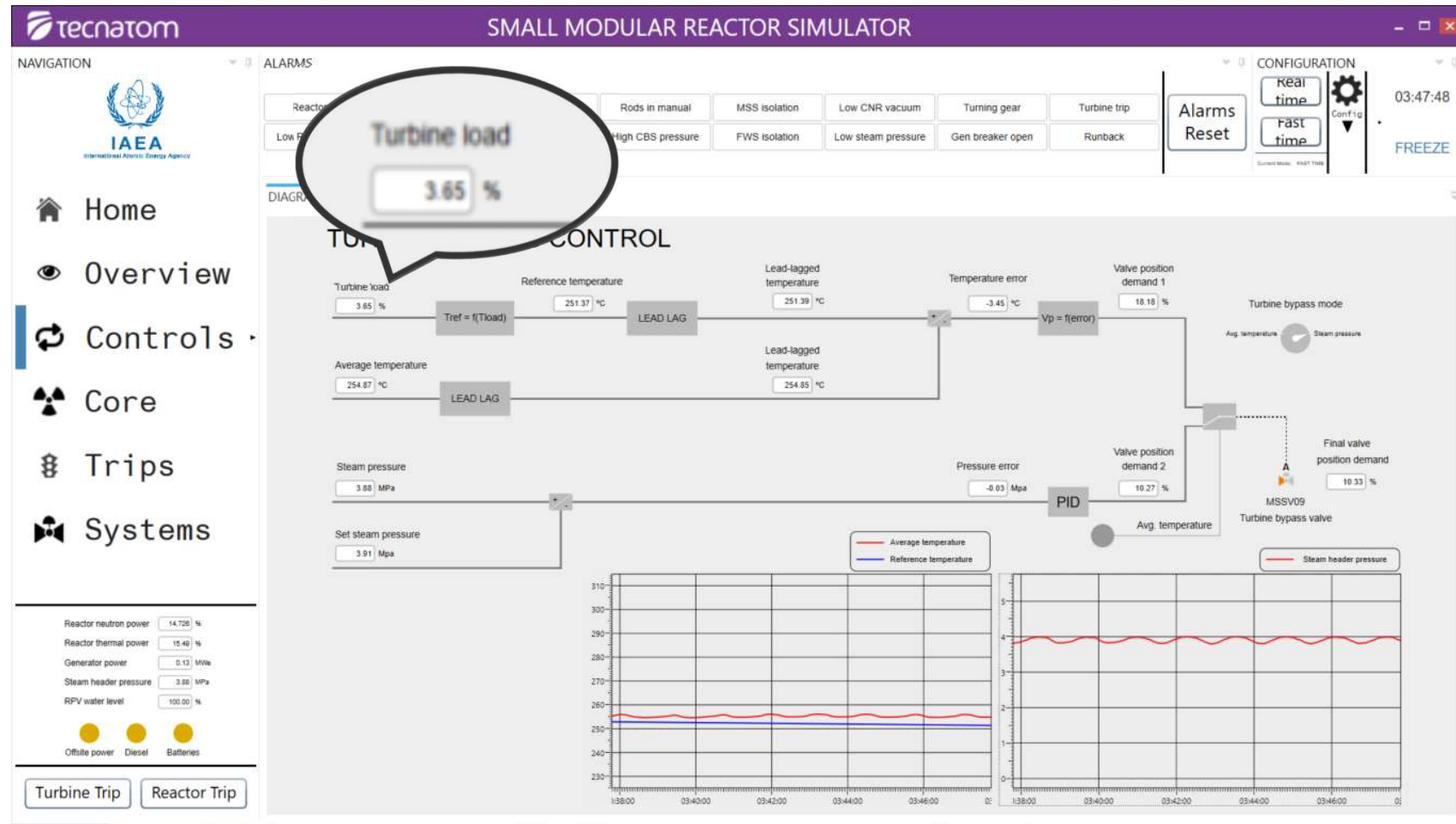


Turbine speed increases (TURCN01_TR) from 5 rpm to 3600rpm. Turning gear and Generator Breaker alarms clear

STEP 12 - Start-up the Turbine

Start-up the Turbine:

- 1 Reset Turbine trip. Turbine trip alarm deactivates
- 2 Ensure Turbine Control valve (MSSV07) is in Auto
- 3 Push RUN-UP
- 4 Turbine Control valve (MSSV07) opens around 3%
- 5 When 'Ready to Sync' light appears, push 'Sync' button to close Generator breaker
- 6 Check Turbine accepts a minimum Load
- 7 Check Turbine Control valve is in Manual



Turbine speed increases (TURCN01_TR) from 5 rpm to 3600rpm. Turning gear and Generator Breaker alarms clear
Upon closing the Generator breaker, Turbine load should be raised to 3% to prevent motoring of the generator

STEP 13 - Raise Turbine load manually to 3%

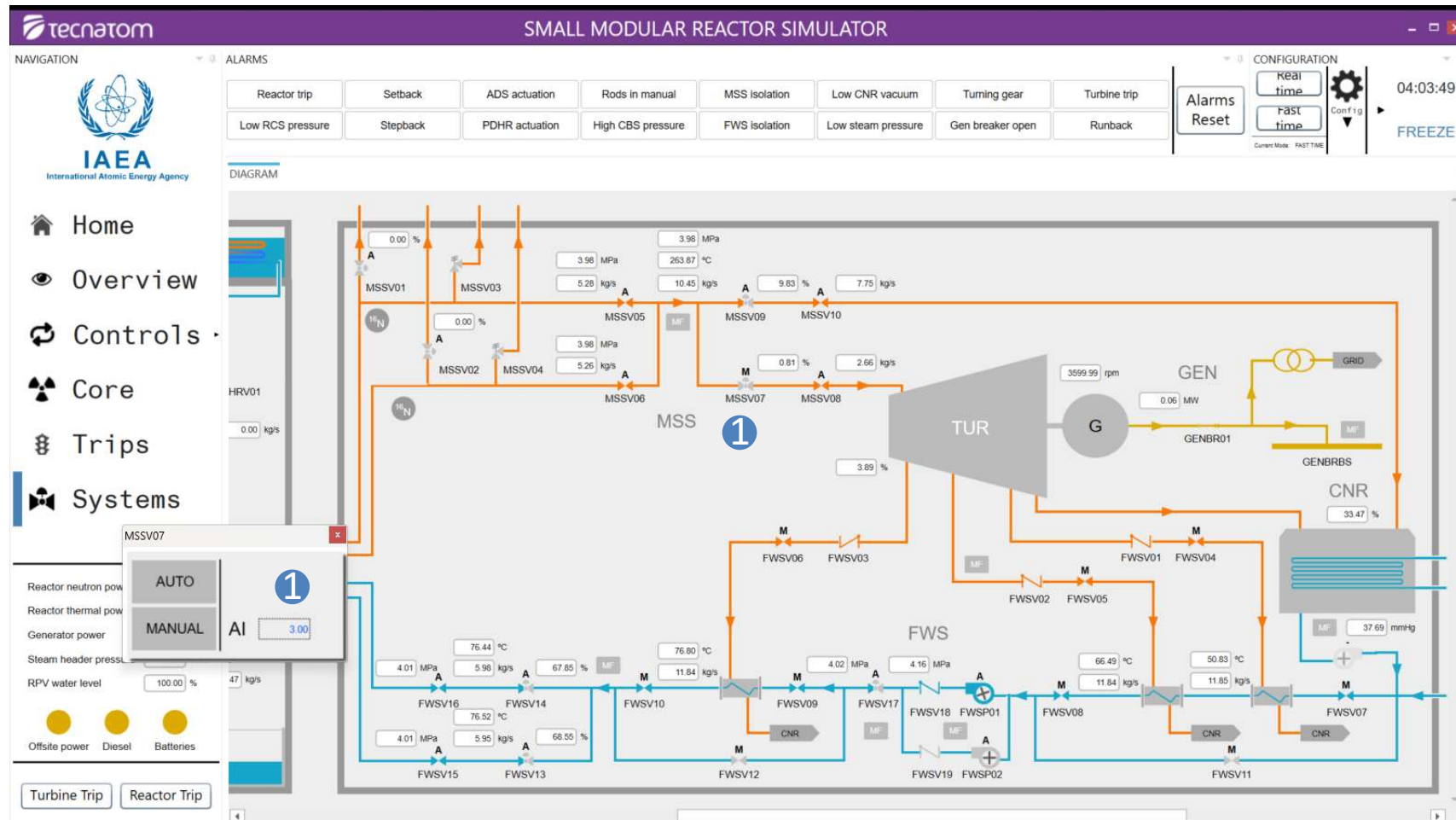
Raise Turbine load manually to 3%

1

Manually open Turbine Control valve MSSV07 to 3%

2

Check Generator load begins to rise.
- Generator load (GENPT02_CS) would be around 3.5 MWe when MSSV07 is 3% open
- Steam through MSB lowers



STEP 13 - Raise Turbine load manually to 3%

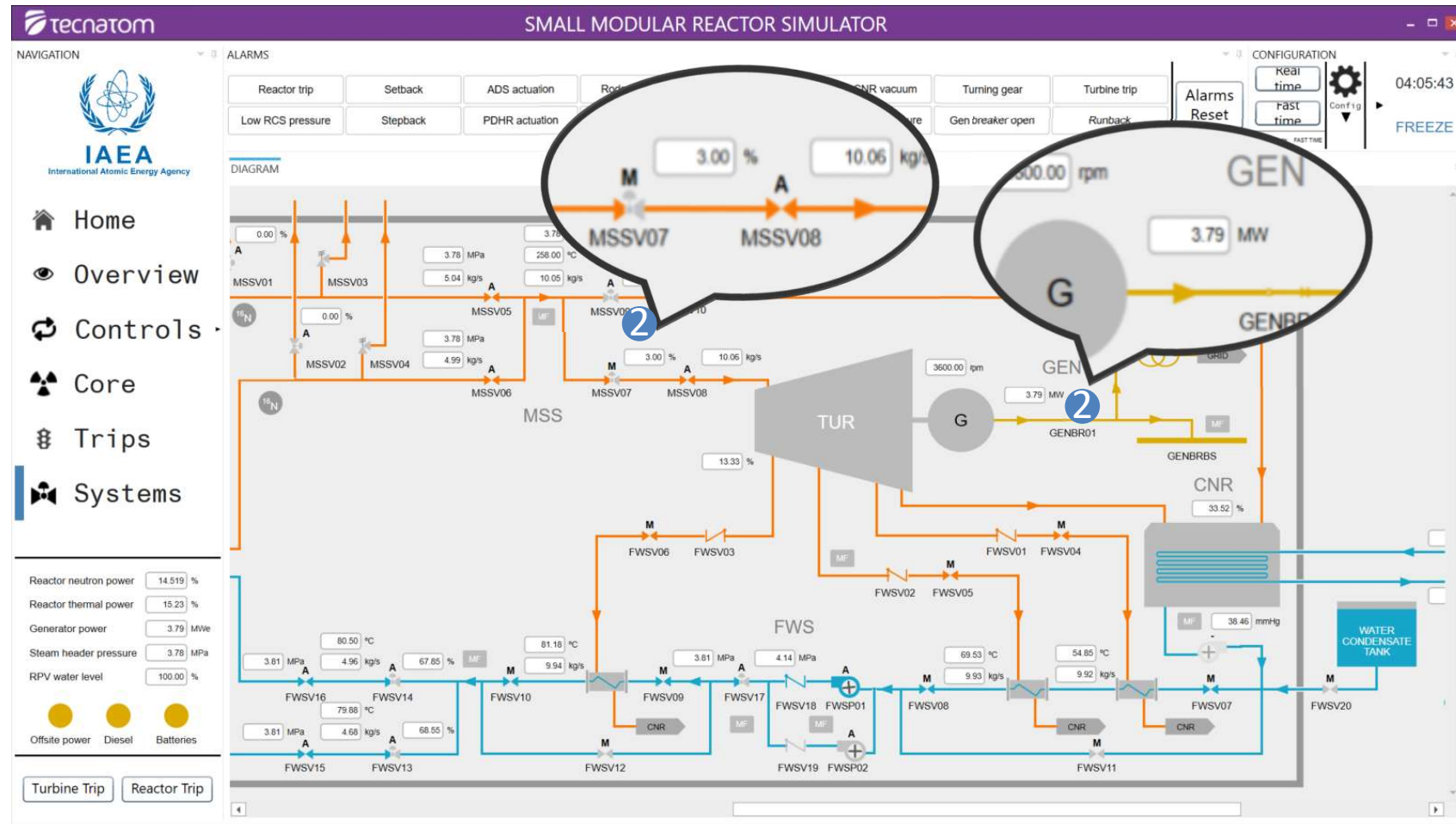
Raise Turbine load manually to 3%

1

Manually open Turbine Control valve MSSV07 to 3%

2

Check Generator load begins to rise.
- Generator load (GENPT02_CS) would be around 3.5 MWe when MSSV07 is 3% open
- Steam through MSB lowers



STEP 14 - Place Turbine control in AUTO

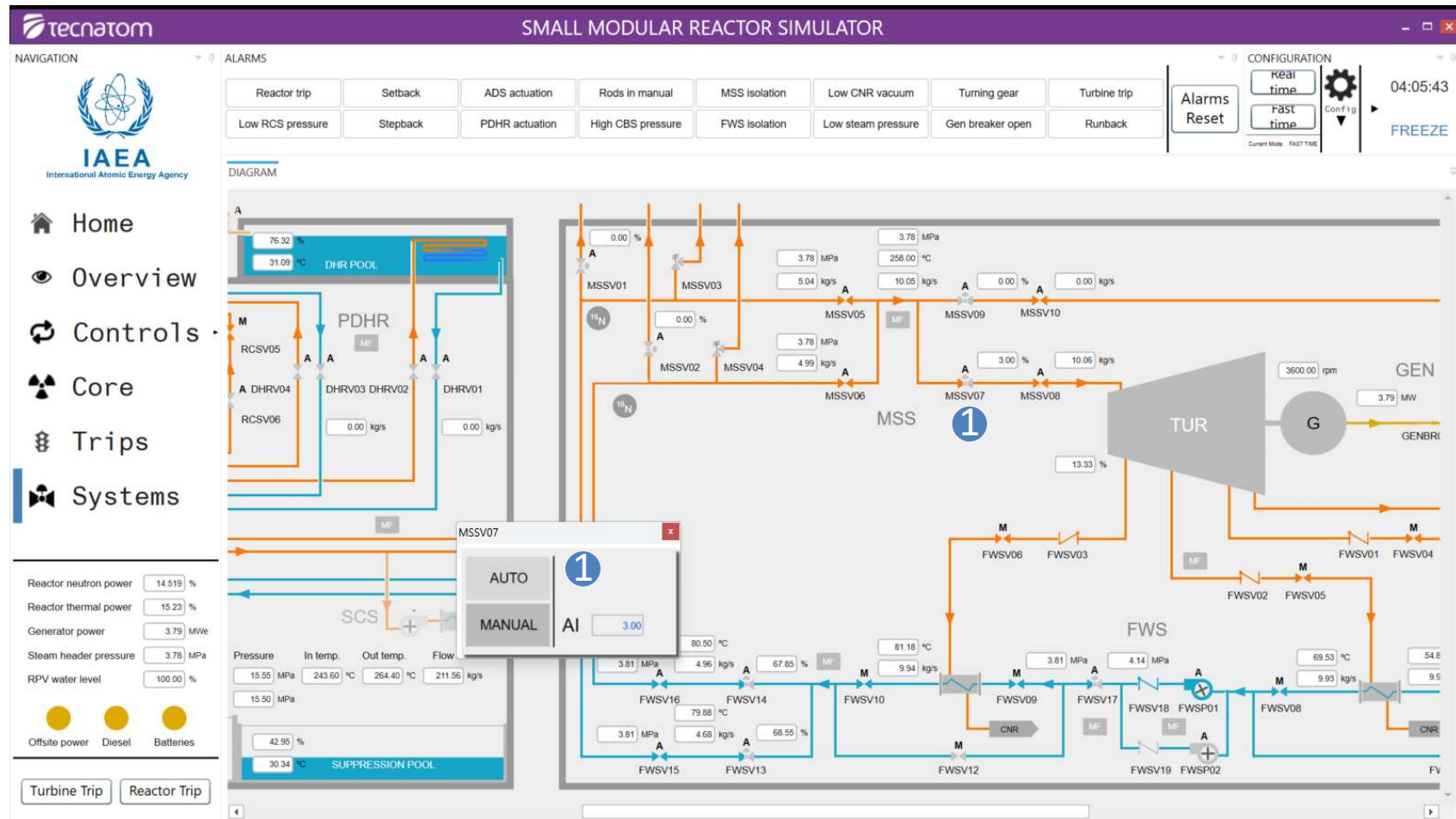
Place Turbine control in AUTO:

1

Place Turbine Control valve in Auto

2

Check Turbine Control is controlling Steam pressure (Plant Mode in Reactor Leading)



STEP 14 - Place Turbine control in AUTO

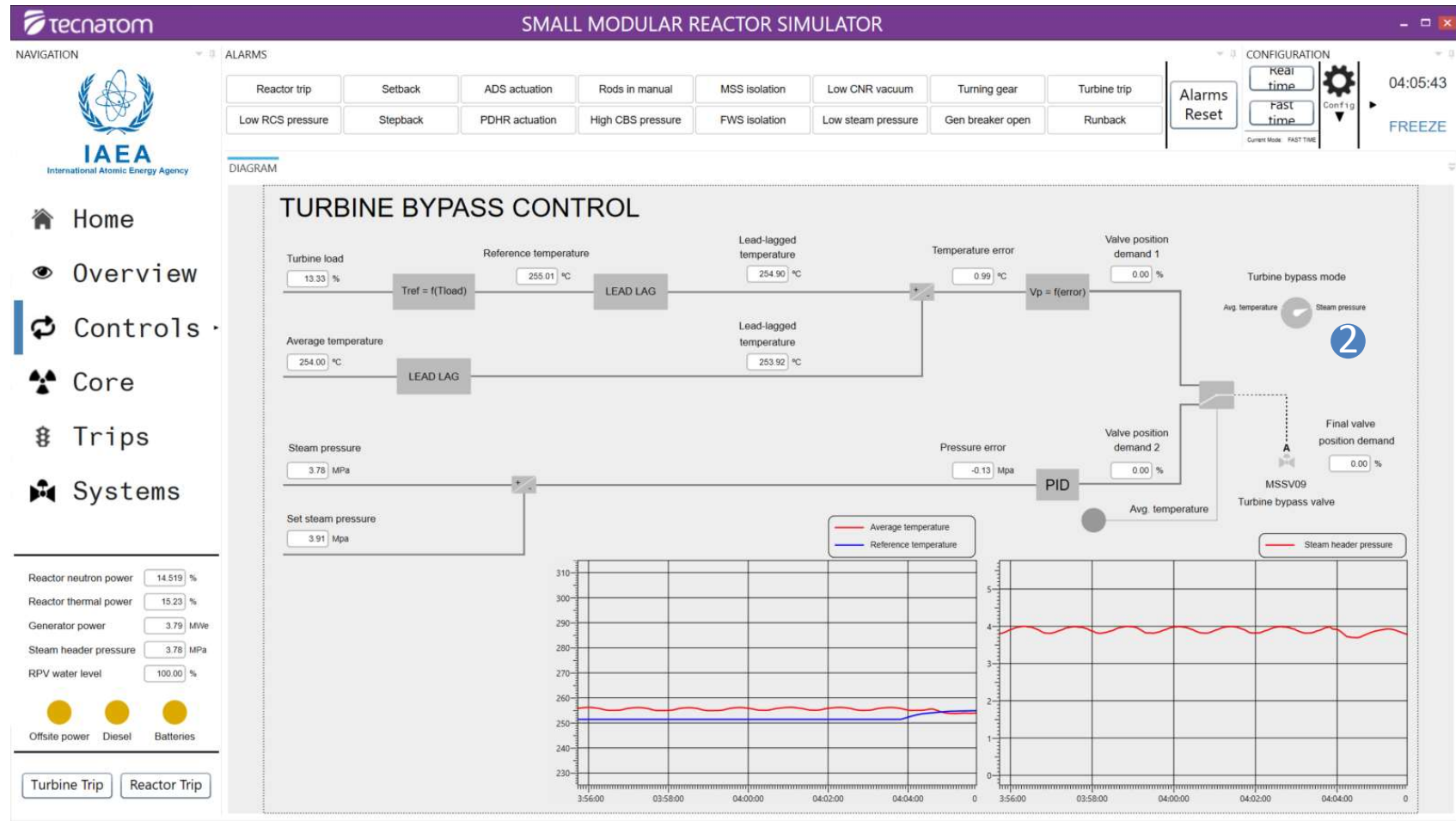
Place Turbine control in AUTO:

1

Place Turbine Control valve in Auto

2

Check Turbine Control is controlling Steam pressure (Plant Mode in Reactor Leading)



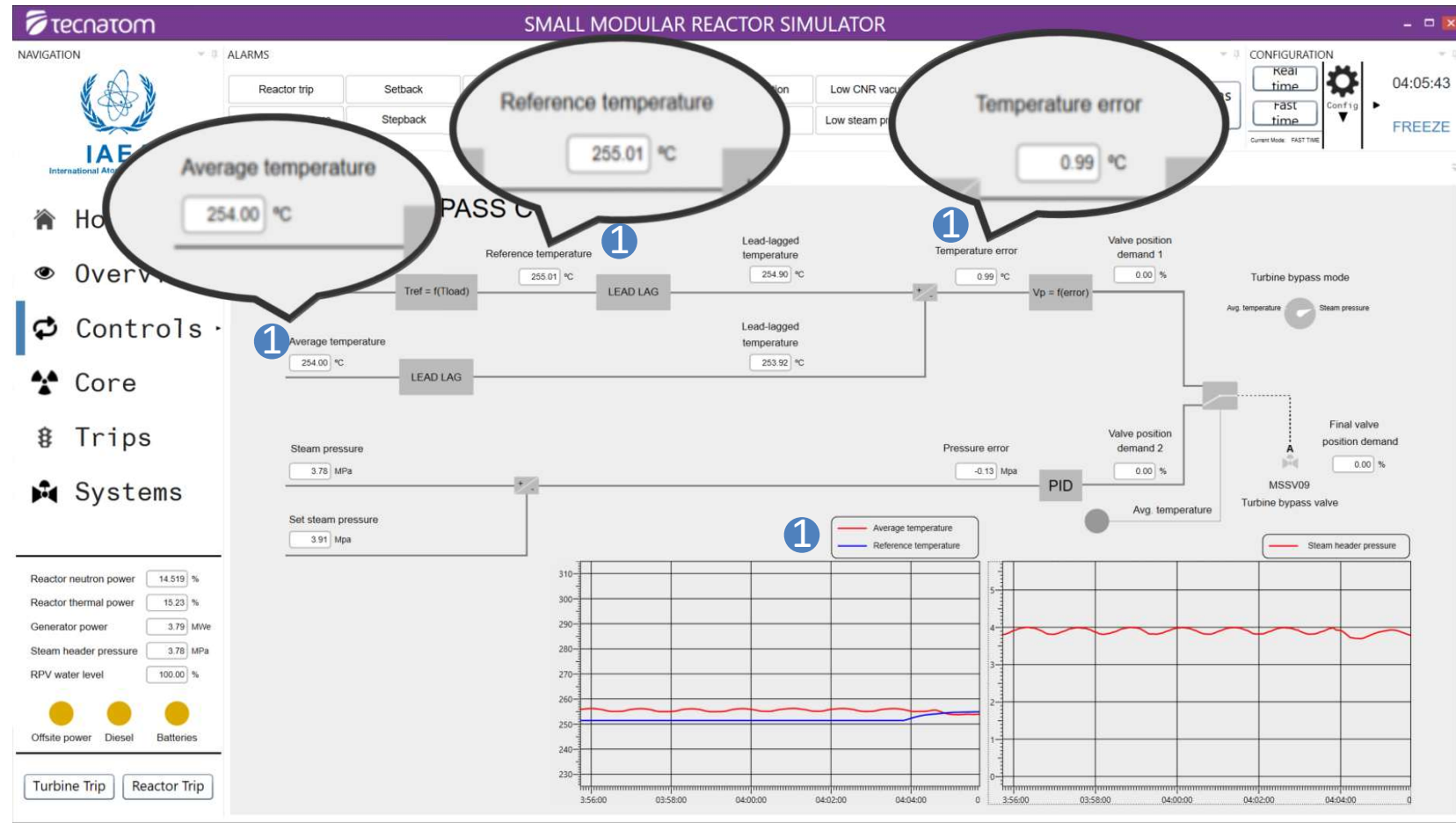
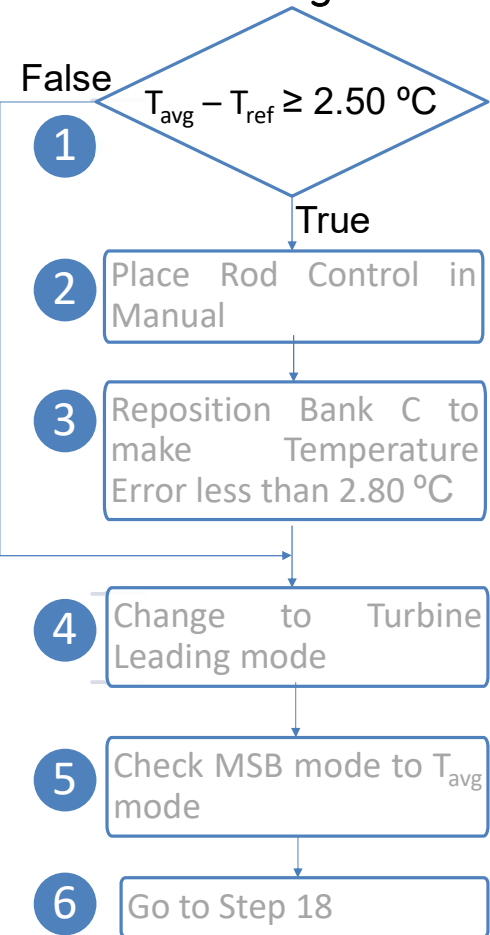
1

2

[illegible]

STEP 15, 16, 17 - Switch to Turbine Leading mode

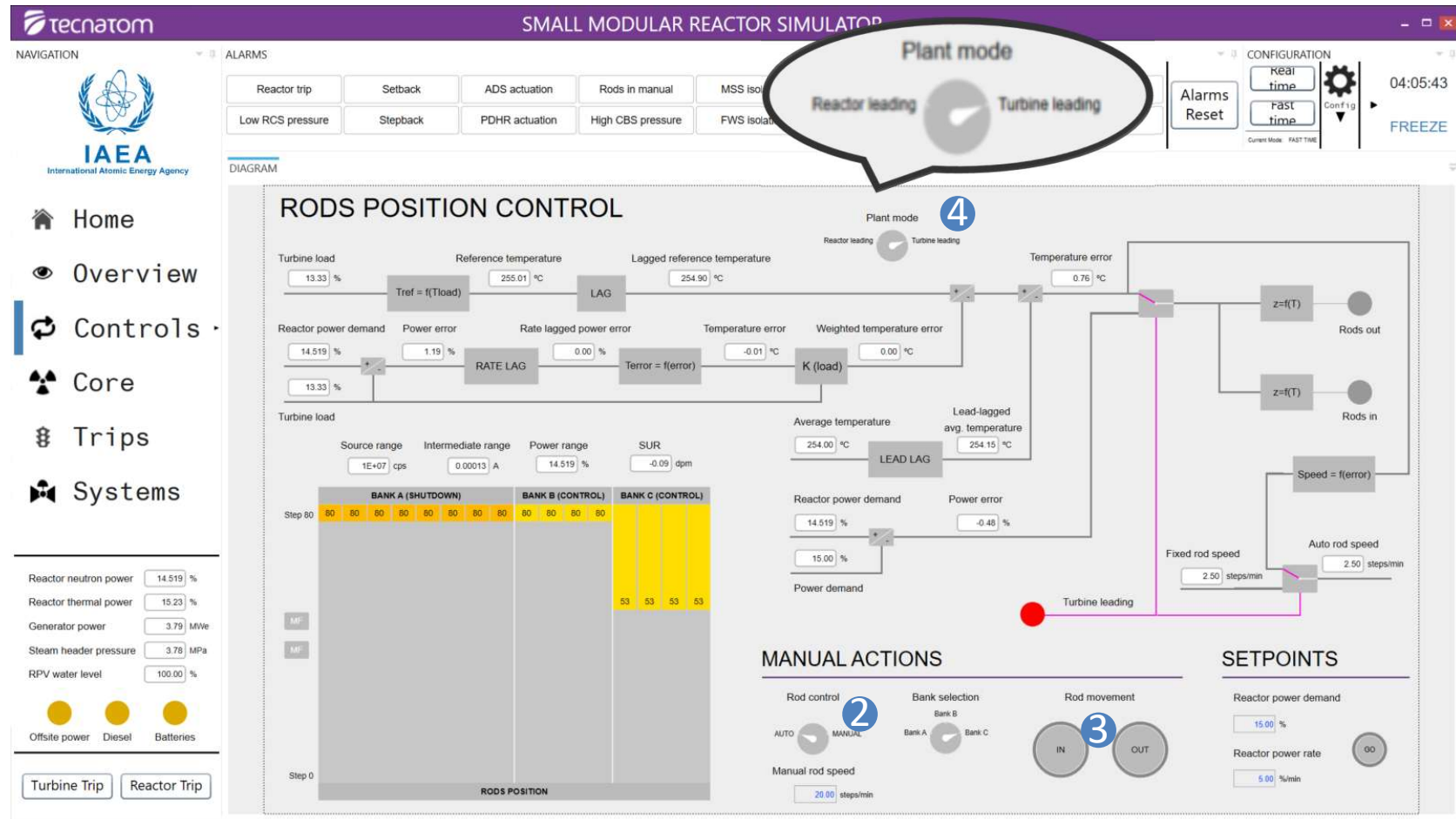
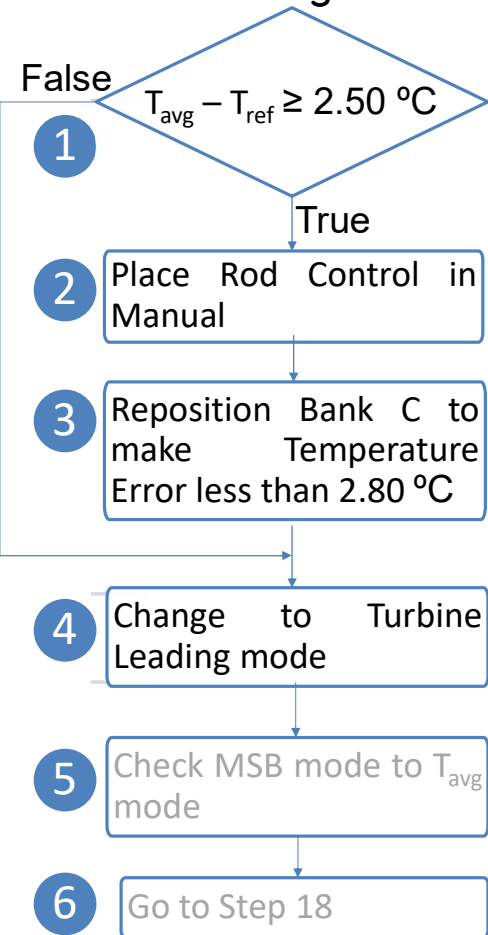
Check Temperature Error before switching to Turbine Leading mode:



Caution: Switching to Turbine Leading mode with a big Temperature Error may lead to power oscillations and Turbine trip (Reactor power < 4%)

STEP 15, 16, 17 - Switch to Turbine Leading mode

Check Temperature Error before switching to Turbine Leading mode:



Caution: Switching to Turbine Leading mode with a big Temperature Error may lead to power oscillations and Turbine trip (Reactor power < 4%)

STEP 15, 16, 17 - Switch to Turbine Leading mode

Check Temperature Error before switching to Turbine Leading mode:

False $T_{avg} - T_{ref} \geq 2.50\text{ }^{\circ}\text{C}$

1

True

2

Place Rod Control in Manual

3

Reposition Bank C to make Temperature Error less than $2.80\text{ }^{\circ}\text{C}$

4

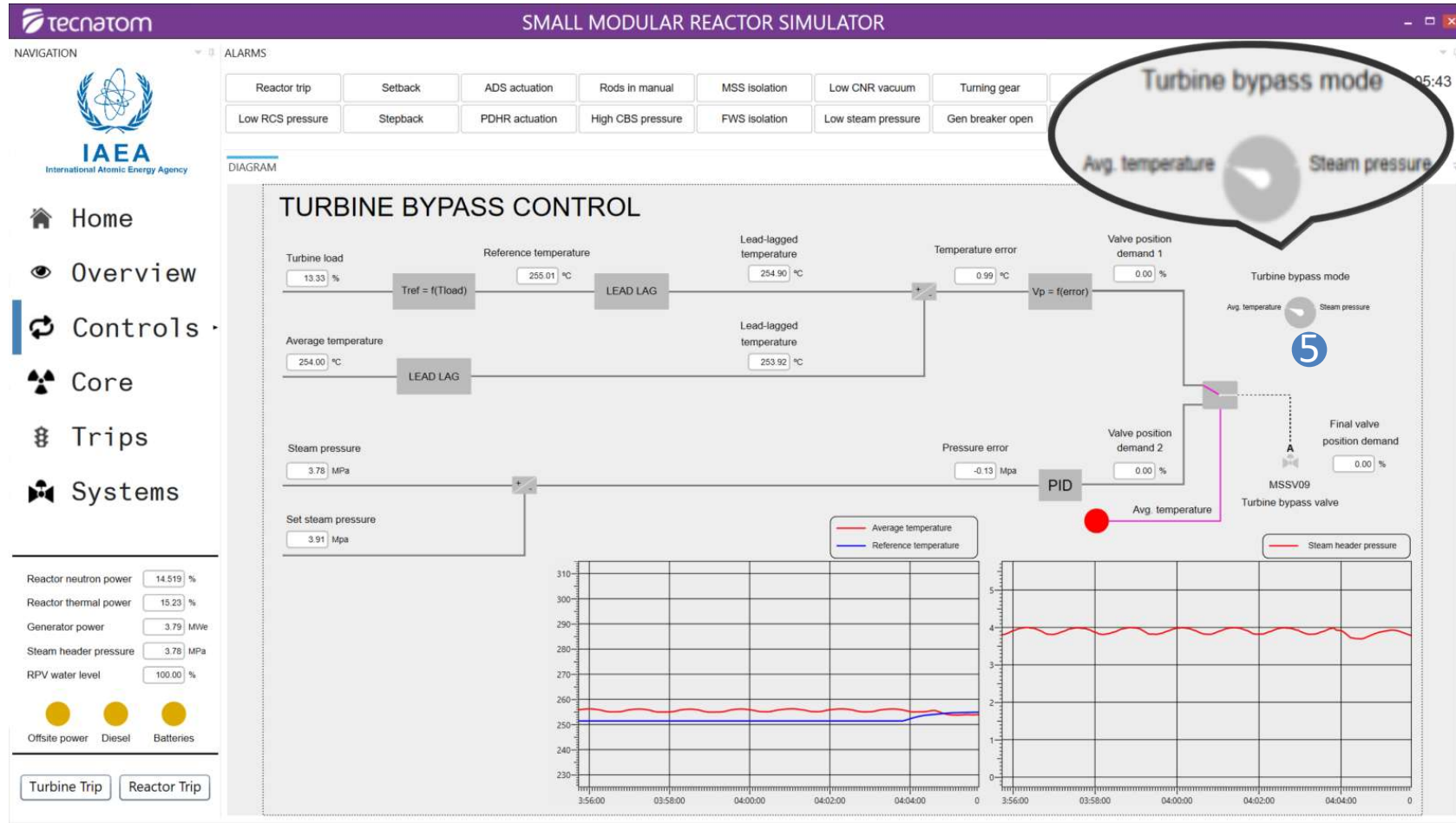
Change to Turbine Leading mode

5

Check MSB mode to T_{avg} mode

6

Go to Step 18



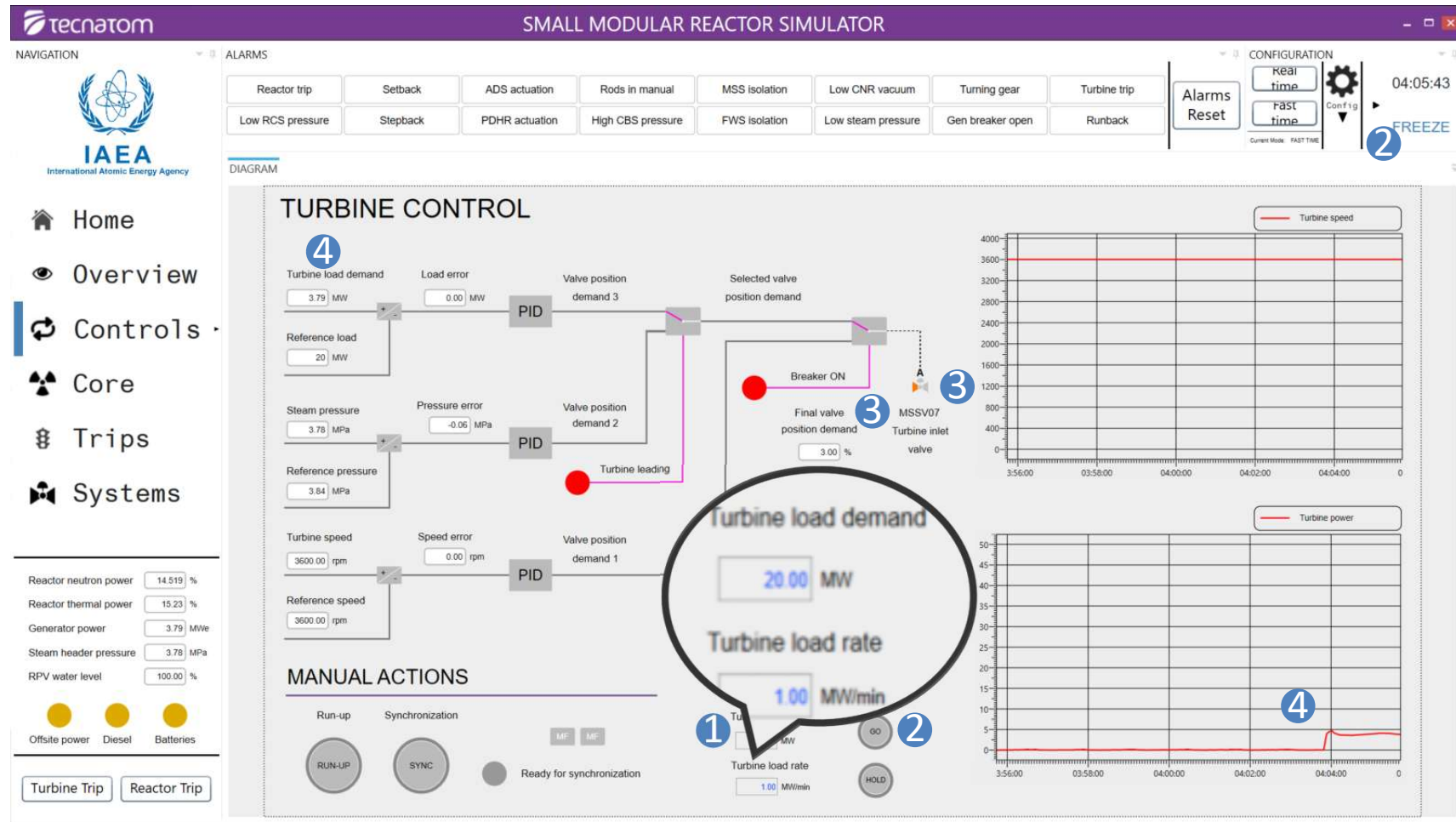
Caution: Switching to Turbine Leading mode with a big Temperature Error may lead to power oscillations and Turbine trip (Reactor power < 4%)

STEP 18 - Raise Turbine load to full power conditions



Raise Turbine load to full power conditions:

- 1 Introduce Turbine Load Demand (20 MW) and Turbine Load Rate (1 MW/min) in Turbine Display
- 2 Press GO
- 3 Check Turbine Control valve MSSV07 begins to open
- 4 Check Generator load begins to rise. Generator load (GENPT02_CS) begins to rise.
- 5 When Turbine Load reaches 20 MW, check Step 1 variables are stable



STEP 18 - Raise Turbine load to full power conditions

Raise Turbine load to full power conditions:

5

When Turbine Load reaches 20 MW, check Step 1 variables are stable and record their values:

Thermal power

MW_t

Neutron power

%

SUR

dpm

Primary temperature

°C

Primary pressure

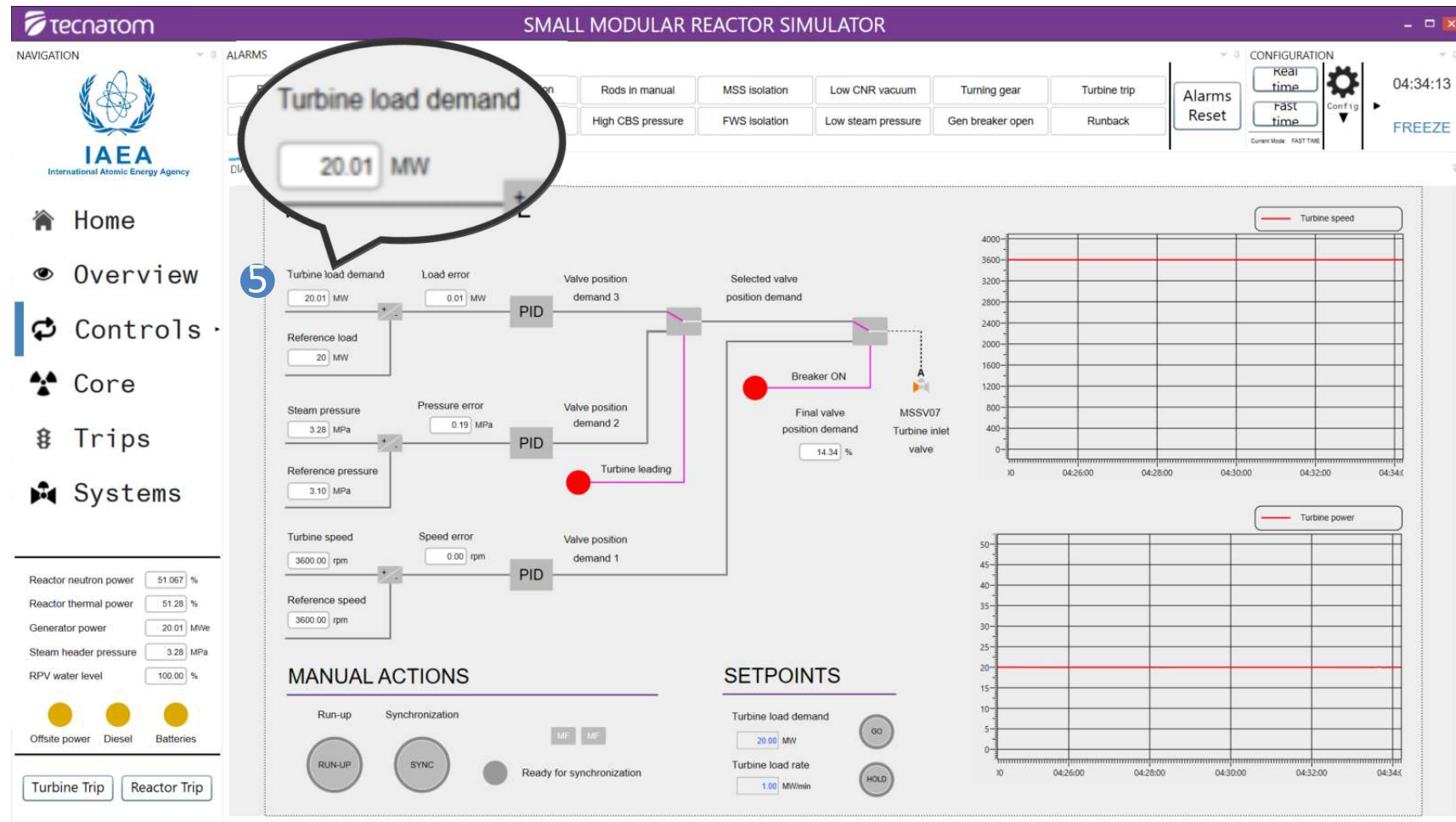
MPa

Primary level

%

FW flow

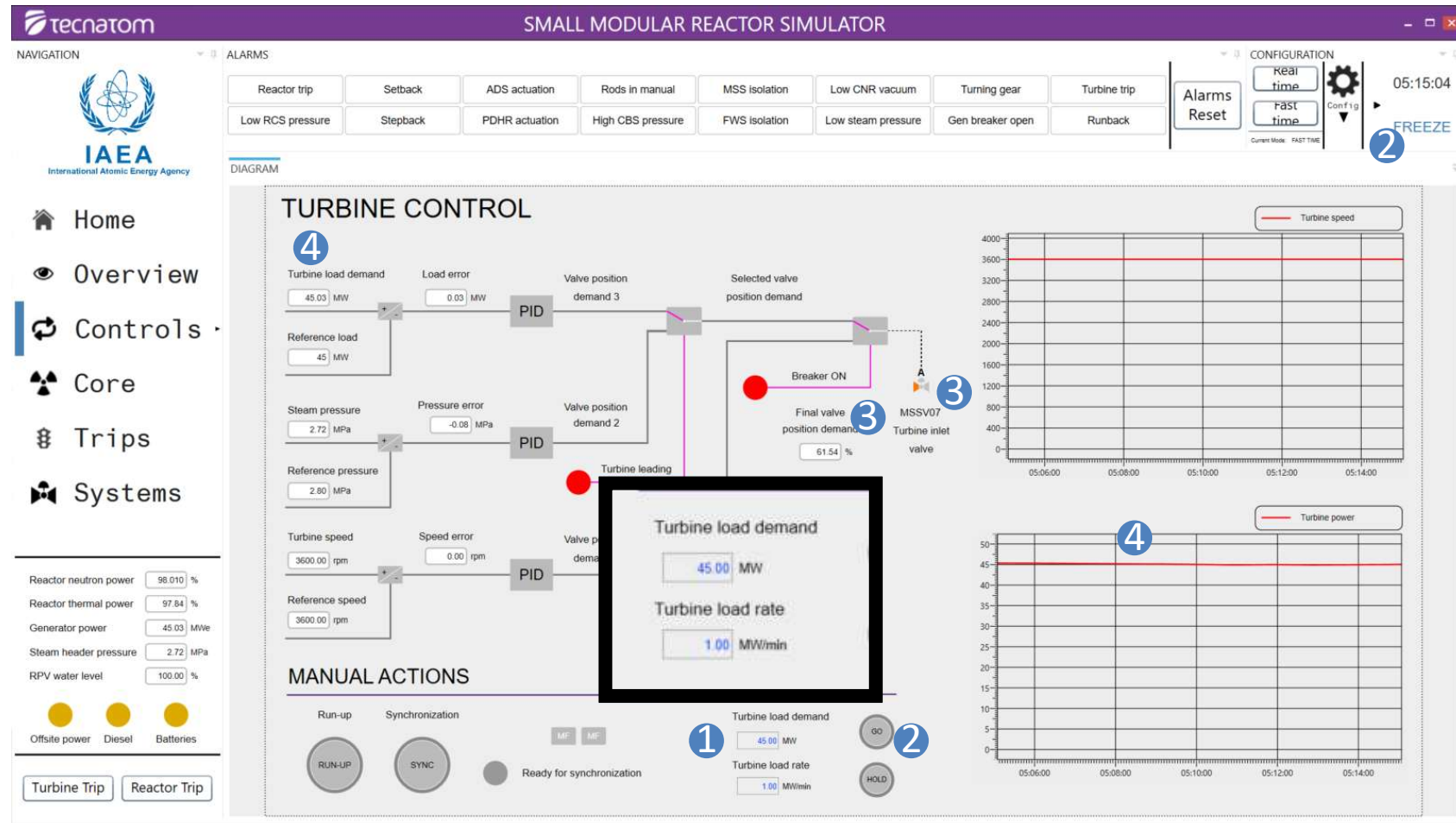
kg/s



STEP 18 – Raise Turbine load to full power conditions

Raise Turbine load to full power conditions:

- 1 Introduce Turbine Load Demand (45 MW) and Turbine Load Rate (1 MW/min) in Turbine Display
- 2 Press GO
- 3 Check Turbine Control valve MSSV07 begins to open
- 4 Check Generator load begins to rise. Generator load (GENPT02_CS) begins to rise.
- 5 When Turbine Load reaches 45 MW, check Step 1 variables are stable



STEP 18 – Raise Turbine load to full power conditions

Raise Turbine load to full power conditions:

5

When Turbine Load reaches 45 MW, check Step 1 variables are stable and record their values:

Thermal power

MW_t

Neutron power

%

SUR

dpm

Primary temperature

°C

Primary pressure

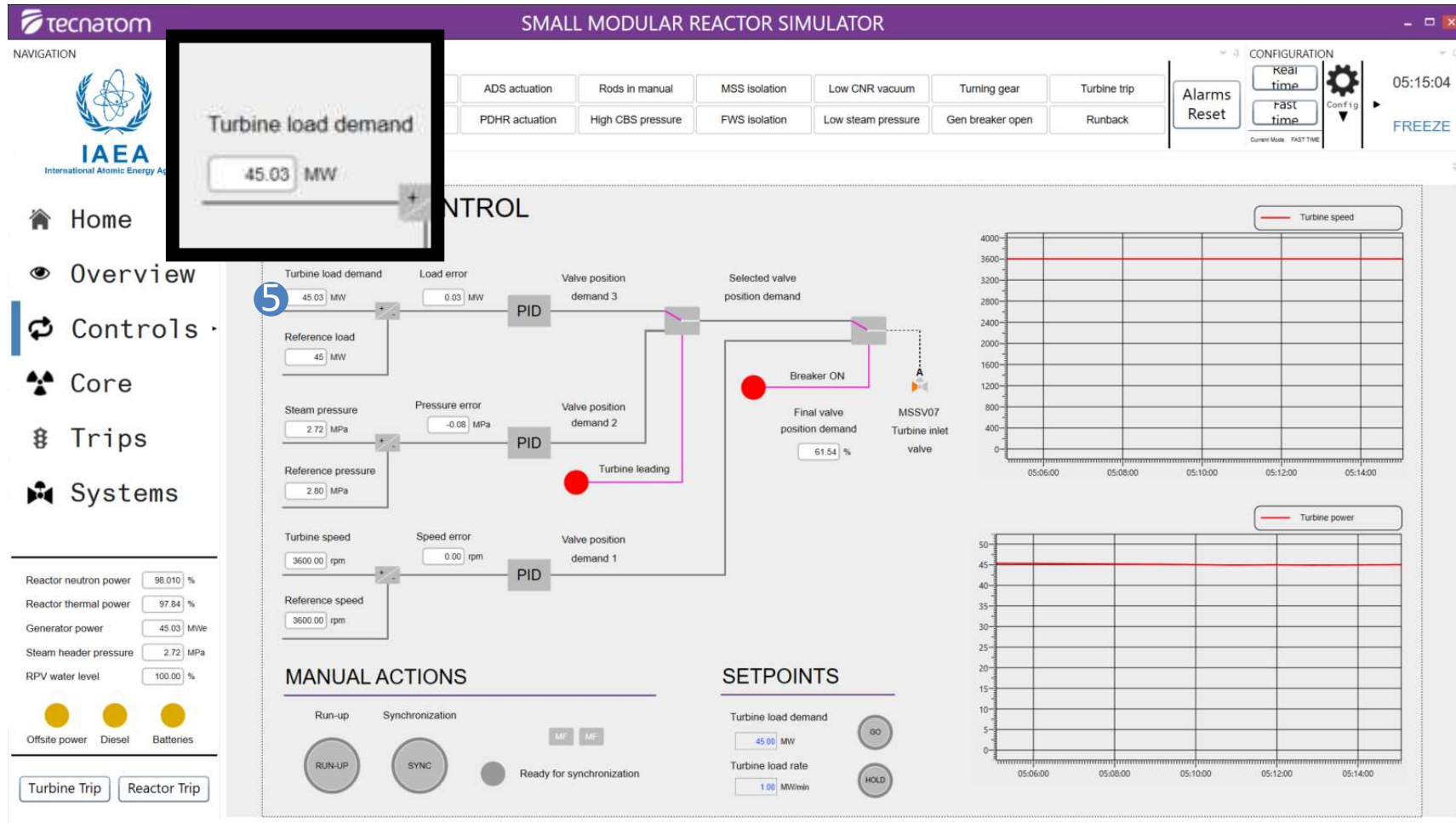
MPa

Primary level

%

FW flow

kg/s



STEP 19 - Continuous Action - Dilute RCS

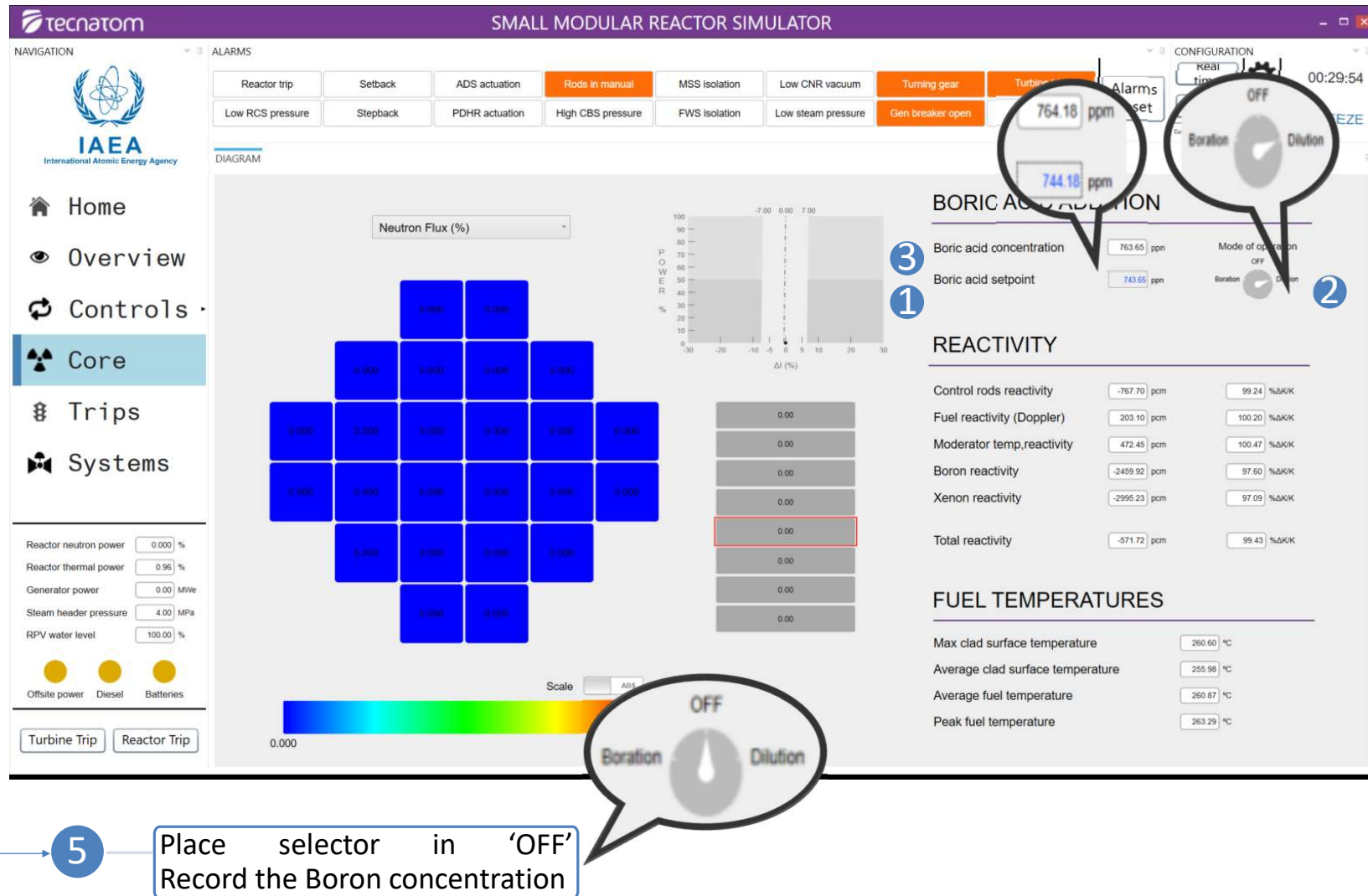
Dilute RCS to compensate for the power defect, Xe concentration and Rod position reactivity changes:

1 Introduce the new Boron concentration setpoint (max 20 ppm per batch)

2 Place selector in 'Dilution'

3 Check Boron concentration decreases to the Boron concentration setpoint

4 Repeat 1. and 3. as desired. During boron dilution, control bank C will automatically withdraw to compensate negative boron reactivity. When bank C reaches 80 steps, go to Step 20



STEP 20 - Continuous Action - Bank C reaches 80 steps

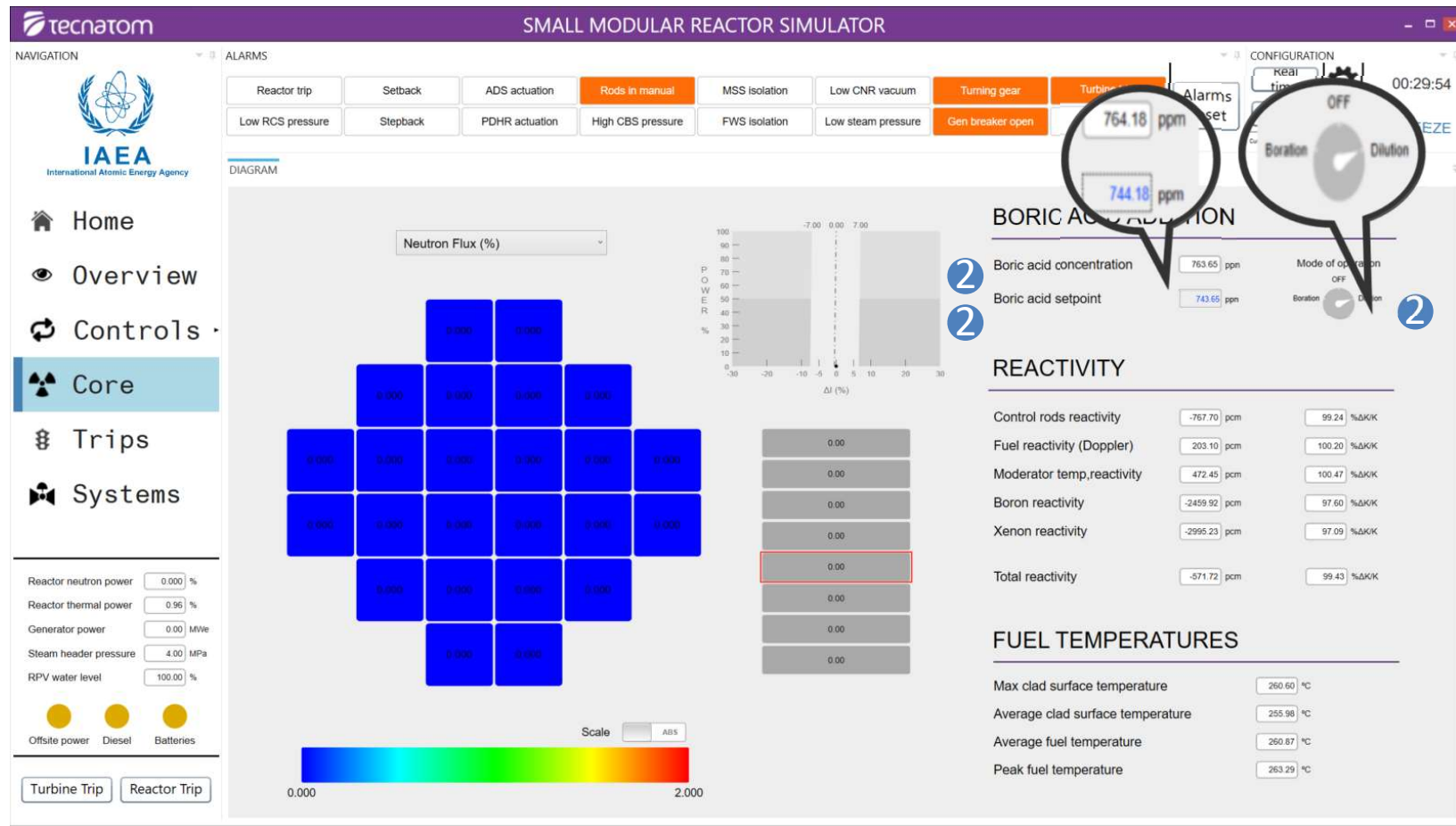
This step would not normally be performed. However, when Bank C reaches 80 steps (fully withdrawn in Auto mode):

1 Hold the Turbine Load by pressing on HOLD in the Turbine Control Display

2 Dilute the RCS to reposition Bank C

- Introduce the new Boron concentration setpoint (max 20 ppm per batch)
- Check Boron concentration decreases to the Boron concentration setpoint

3 Continue increasing Turbine Load by clicking on GO in the Turbine Control Display



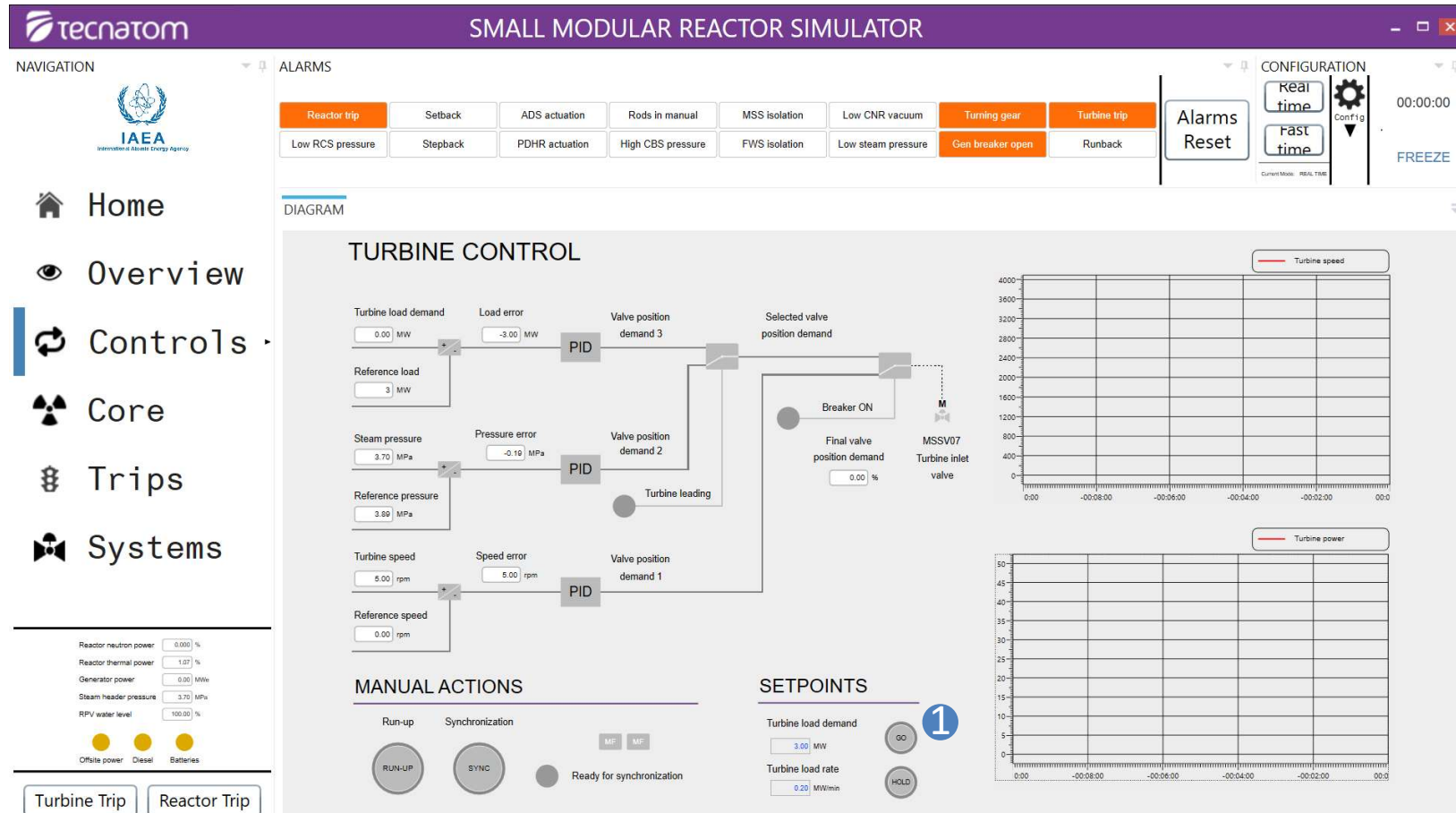
STEP 20 - Continuous Action - Bank C reaches 80 steps

This step would not normally be performed. However, when Bank C reaches 80 steps (fully withdrawn in Auto mode):

1 Hold the Turbine Load by pressing on HOLD in the Turbine Control Display

2 Dilute the RCS to reposition Bank C
- Introduce the new Boron concentration setpoint (max 20 ppm per batch)
- Check Boron concentration decreases to the Boron concentration setpoint

3 Continue increasing Turbine Load by clicking on GO in the Turbine Control Display

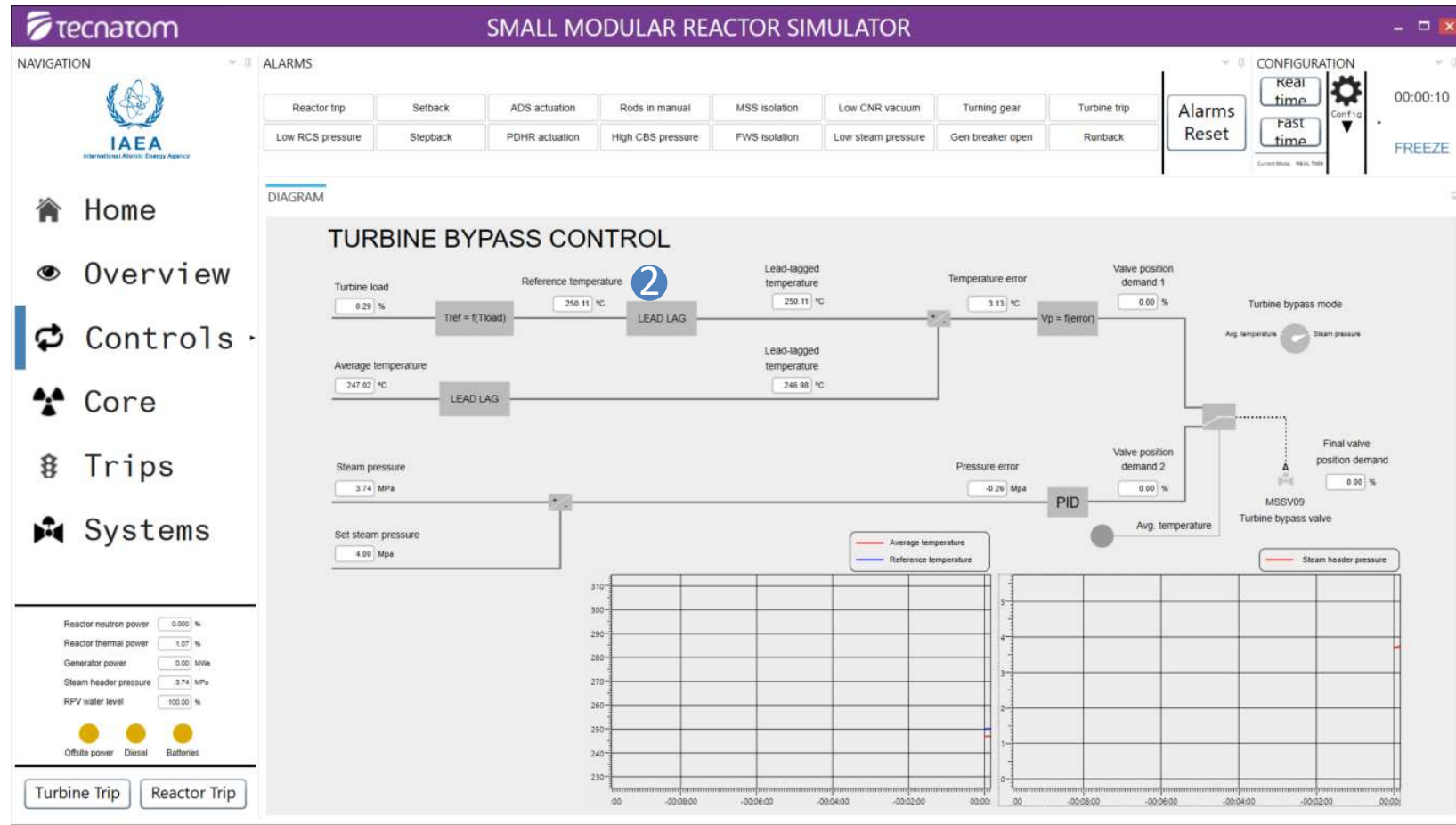


STEP 21 - Check Main Steam flow

Check Main Steam flow begins to rise due to rise in Load increase:

1 Main Steam flow (MSSFT01_TR and MSSFT02_TR) rises (Check directly in 'Systems' display or by graph in 'Trend graphics')

2 Reference temperature begins to rise



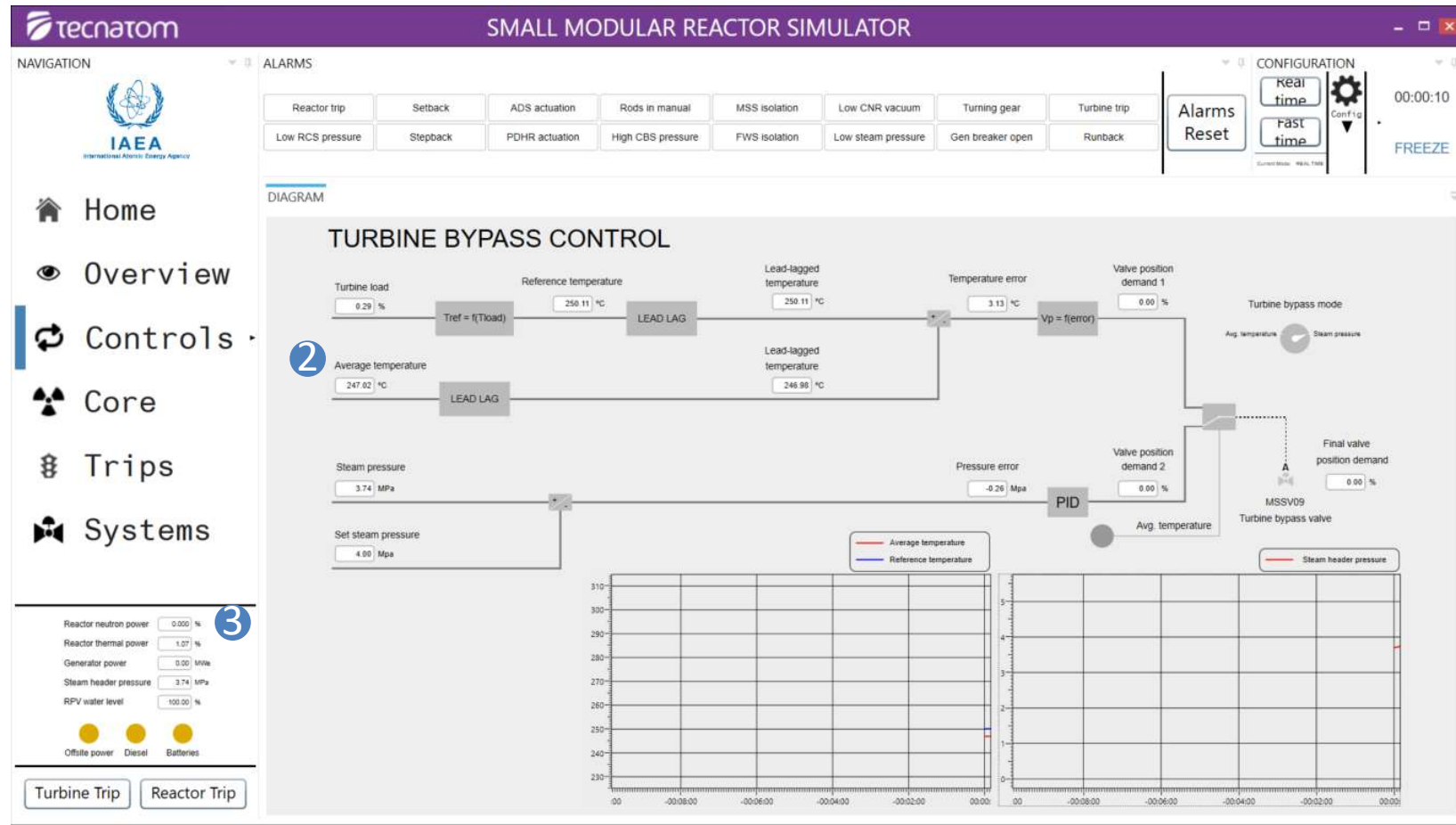
STEP 22 - Verify Control Rods withdraw

Verify Control Rods withdraw in order to rise average temperature:

1 Control Rod position changes (Check control rod position in 'Core' display)

2 Average temperature begins to rise

3 Neutron power (RCSNP01_TR) increases



STEP 23 - Check PZR level

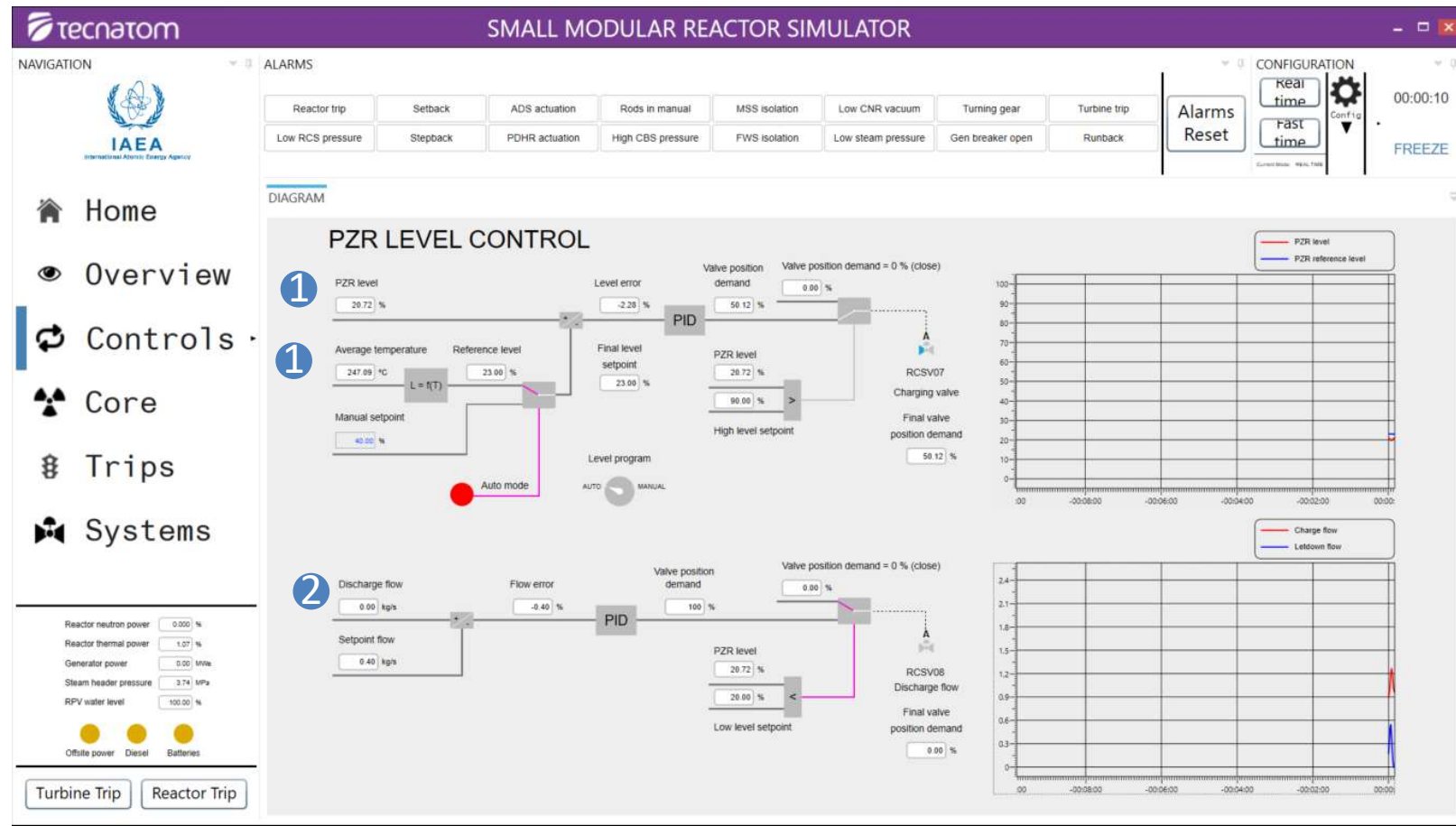
Check PZR level begins to rise due to coolant expansion and how level control recovers the level:

1

PZR level (RCSLT02_TR) begins to rise due to coolant expansion (check coolant average temperature increase). Please check the trends in 'PZR Level Control' display or by graphs in 'Trend graphics'

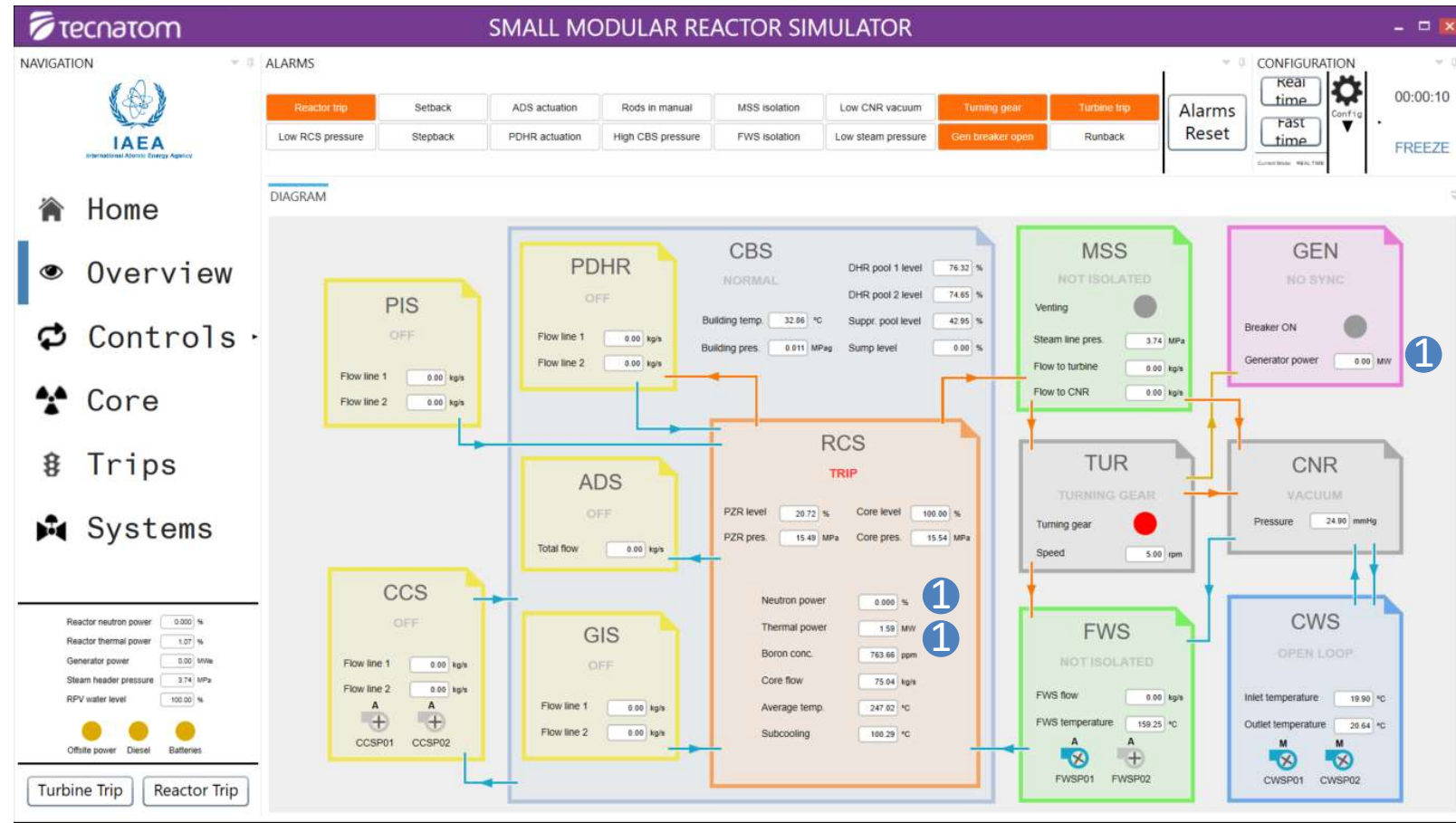
2

Check charge/discharge flows. Additionally check in 'Systems' display (charging valve RCSV07 and discharging valve RCSV08)



- 1 Neutron power (RCSNP01_TR) and Generator load (GENPT02_CS) changing at similar rates

2 Additionally check the trends in 'Systems' display and by graphs in 'Trend graphics'



STEP 25 - Verify the stable conditions

Once Turbine load reaches Turbine Load Demand (45 MW), verify there is no further change:

Thermal power

MW_t

Neutron power

%

SUR

dpm

Primary temperature

°C

Primary pressure

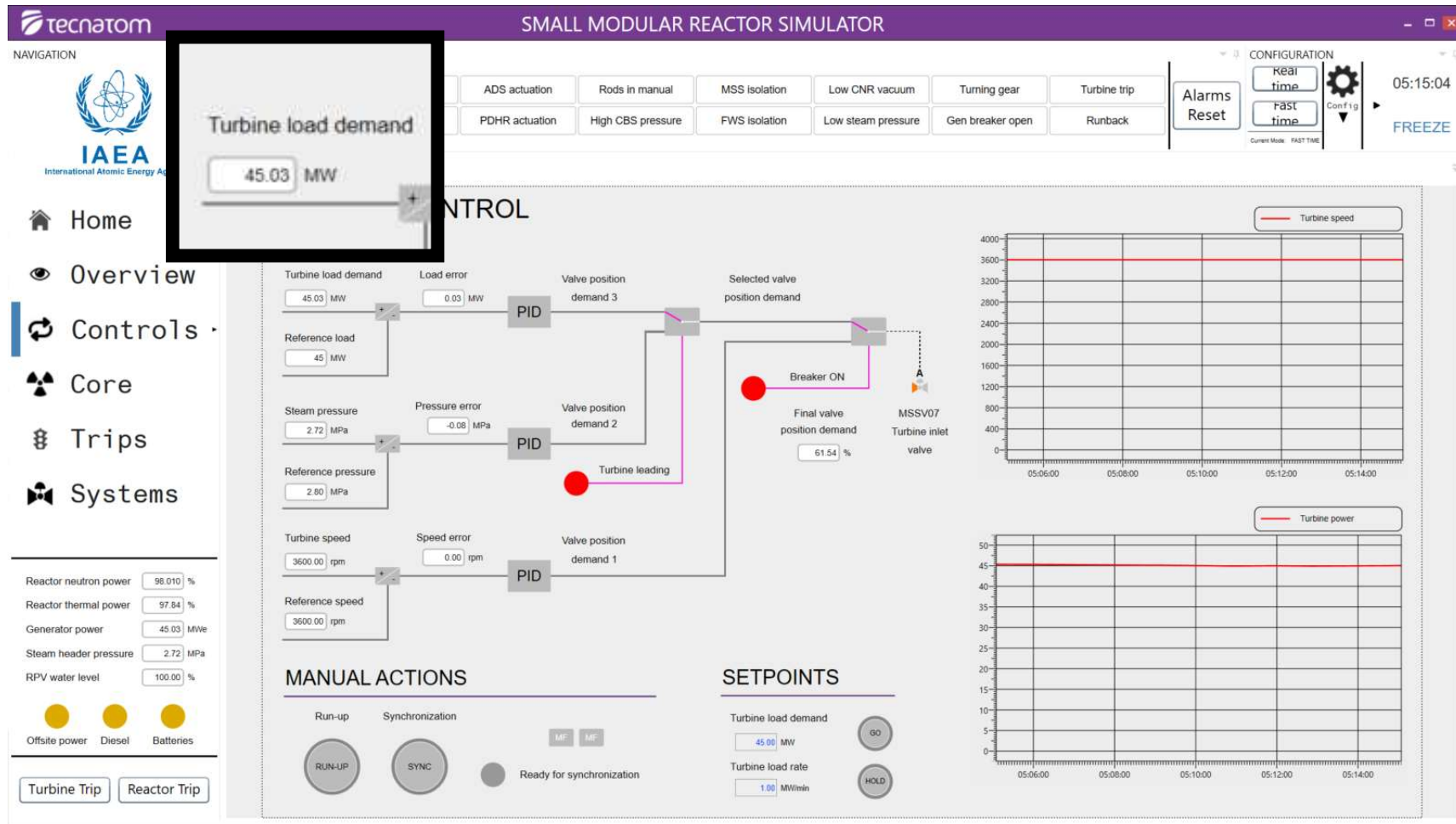
MPa

Primary level

%

FW flow

kg/s



STEP 25 - Verify the stable conditions

Once Turbine load reaches Turbine Load Demand (45 MW), verify there is no further change:

Thermal power

MW_t

Neutron power

%

SUR

dpm

Primary temperature

$^{\circ}\text{C}$

Primary pressure

MPa

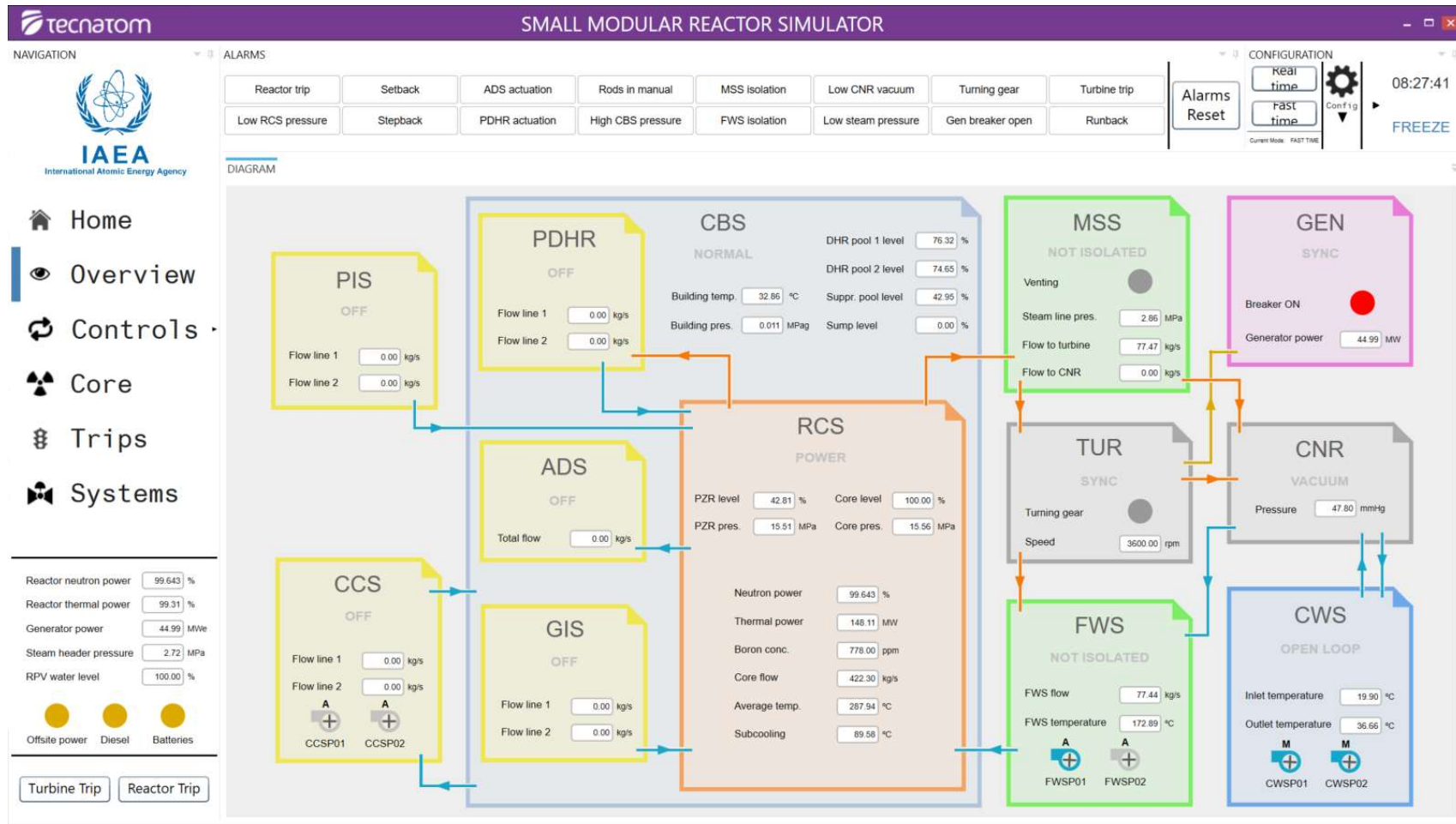
Primary level

%

FW flow

kg/s

Generator load settles at
Turbine Load Demand



STEP 26 - Check ΔI within the target band

Check ΔI is maintained within the target band:

1 If ΔI is at the **left side** of the target band, rods are excessively inserted. This means that rods depress neutron flux in the upper half of the core and force a high flux to exist in the lower half. To make ΔI return to the target band, **borate the RCS** to make rods withdraw from the core.

2 If ΔI is at the **right side** of the target band, rods are excessively withdrawn. This means that a higher flux exist in the upper half of the core compared to the lower half. To make ΔI return to the target band, **dilute the RCS** to make rods insert into the core.



STEP 27 - Check Neutron power's stability

1

Check that Neutron power (RCSNP01_TR) settles at correct value (100%)

2

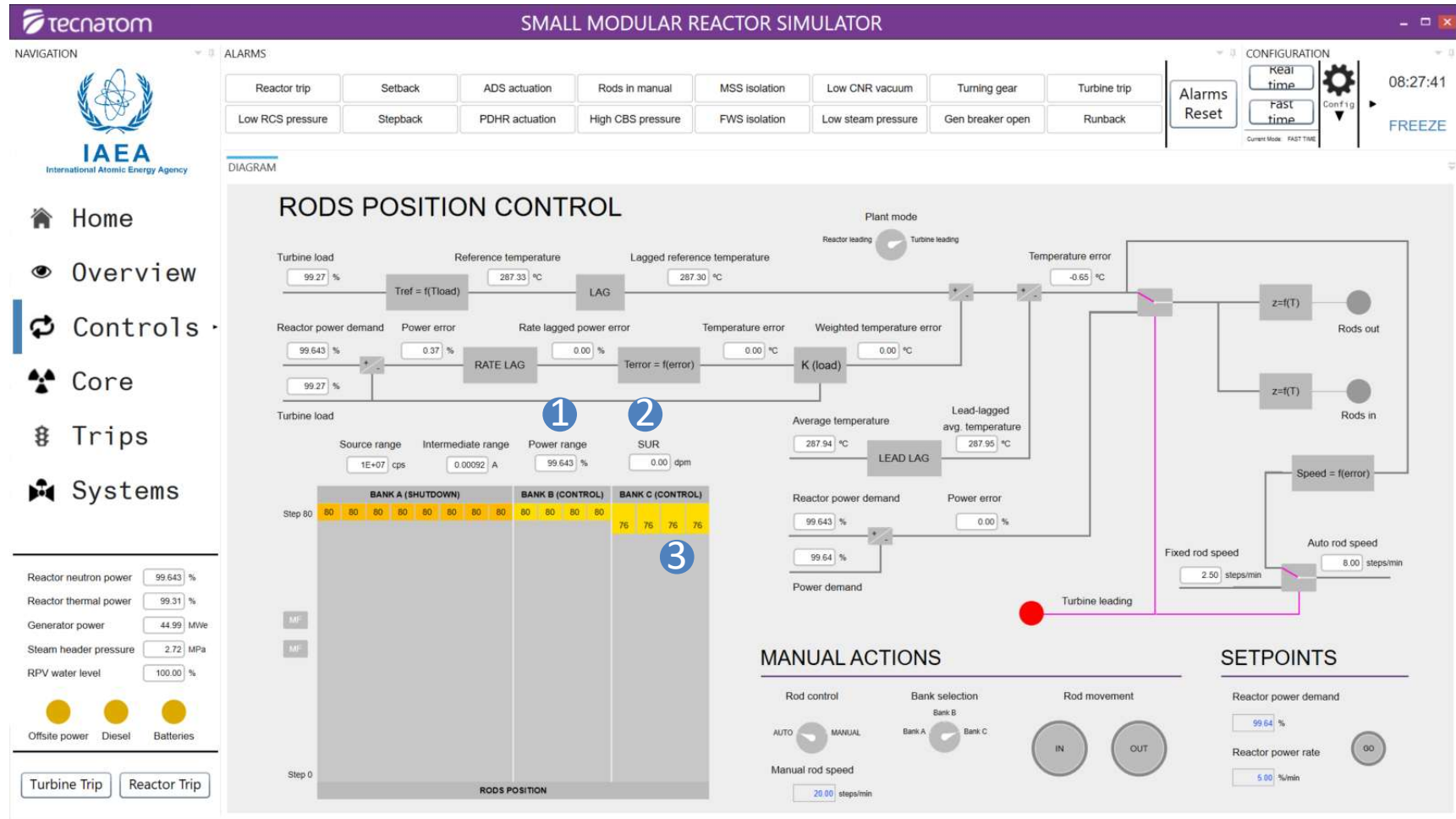
Verify using SUR (dpm) there is no further change

3

Control rod bank C still inserted into the core (as much as possible)

4

Check ΔI is maintained within the target band (as close to the center line as possible)



STEP 27 - Check Neutron power's stability

1

Check that Neutron power (RCSNP01_TR) settles at correct value (100%)

2

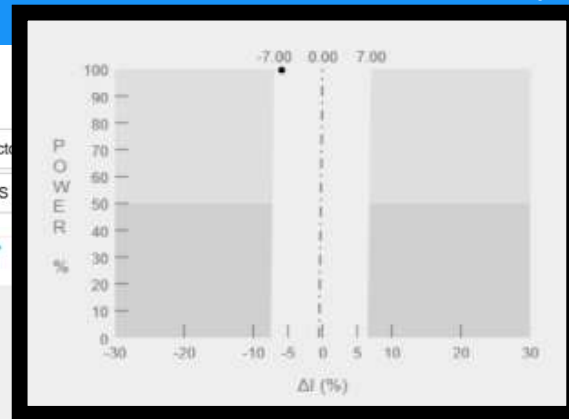
Verify using SUR (dpm) there is no further change

3

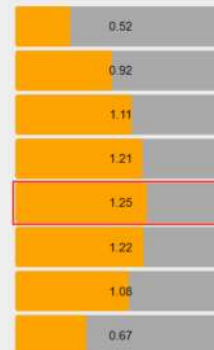
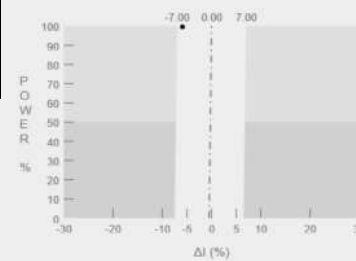
Control rod bank C still inserted into the core (as much as possible)

4

Check ΔI is maintained within the target band (as close to the center line as possible)



4



MSS isolation Low CNR vacuum Turning gear Turbine trip
FWS isolation Low steam pressure Gen breaker open Runback

Alarms Reset

CONFIGURATION
Real time
Fast time
Config

08:27:41
FREEZE

BORIC ACID ADDITION

Boric acid concentration 778.00 ppm
Boric acid setpoint 781.77 ppm
Mode of operation OFF
Boration Dilution

REACTIVITY

Control rods reactivity -98.79 pcm 99.90 %ΔK/K
Fuel reactivity (Doppler) 77.98 pcm 100.08 %ΔK/K
Moderator temp, reactivity -431.72 pcm 99.57 %ΔK/K
Boron reactivity -2287.81 pcm 97.76 %ΔK/K
Xenon reactivity -2275.95 pcm 97.77 %ΔK/K
Total reactivity 0.13 pcm 100.00 %ΔK/K

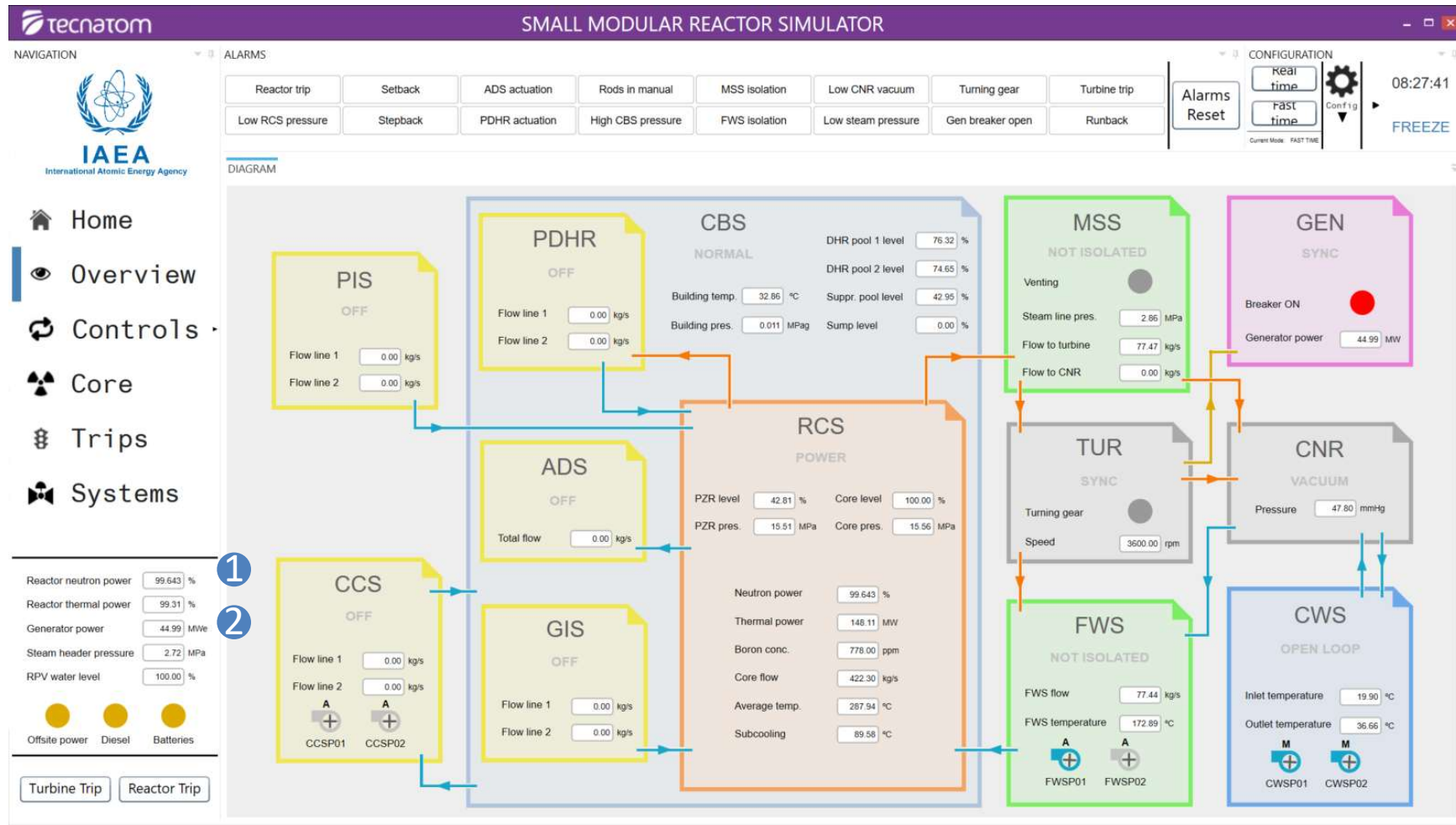
FUEL TEMPERATURES

Max clad surface temperature 545.23 °C

STEP 28 - Check the final conditions

Check the following conditions:

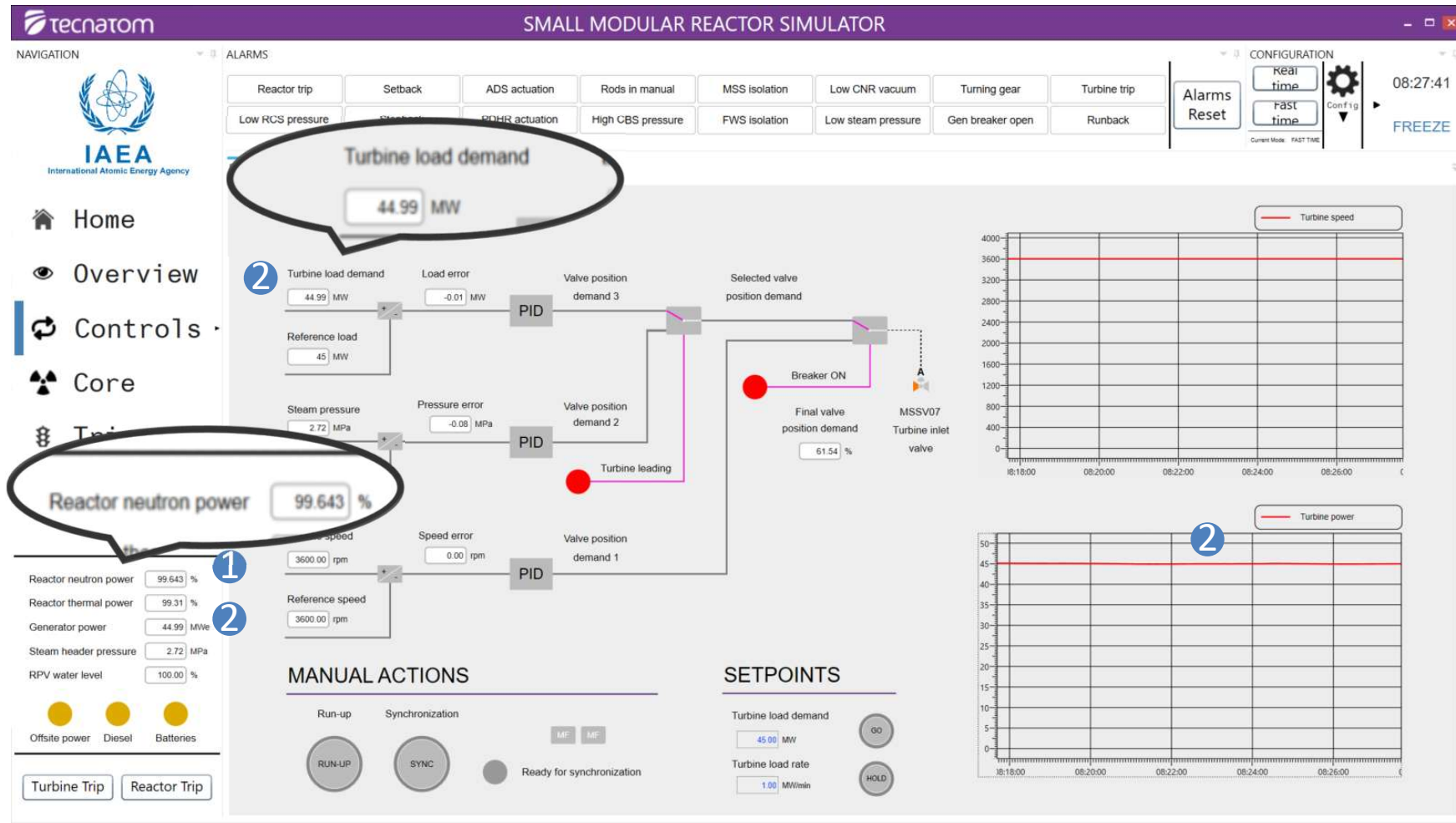
- 1 **Reactor power**
~100%
- 2 **Turbine load**
45 MW
- 3 **Plant Mode**
Turbine Leading Mode
- 4 **Control Rods**
Auto
- 5 **MSB**
 T_{avg} Mode
- 6 **FW System**
Auto
- 7 **CWS and CNR systems**
In service
- 8 **Alarms**
No active



STEP 28 - Check the final conditions

Check the following conditions:

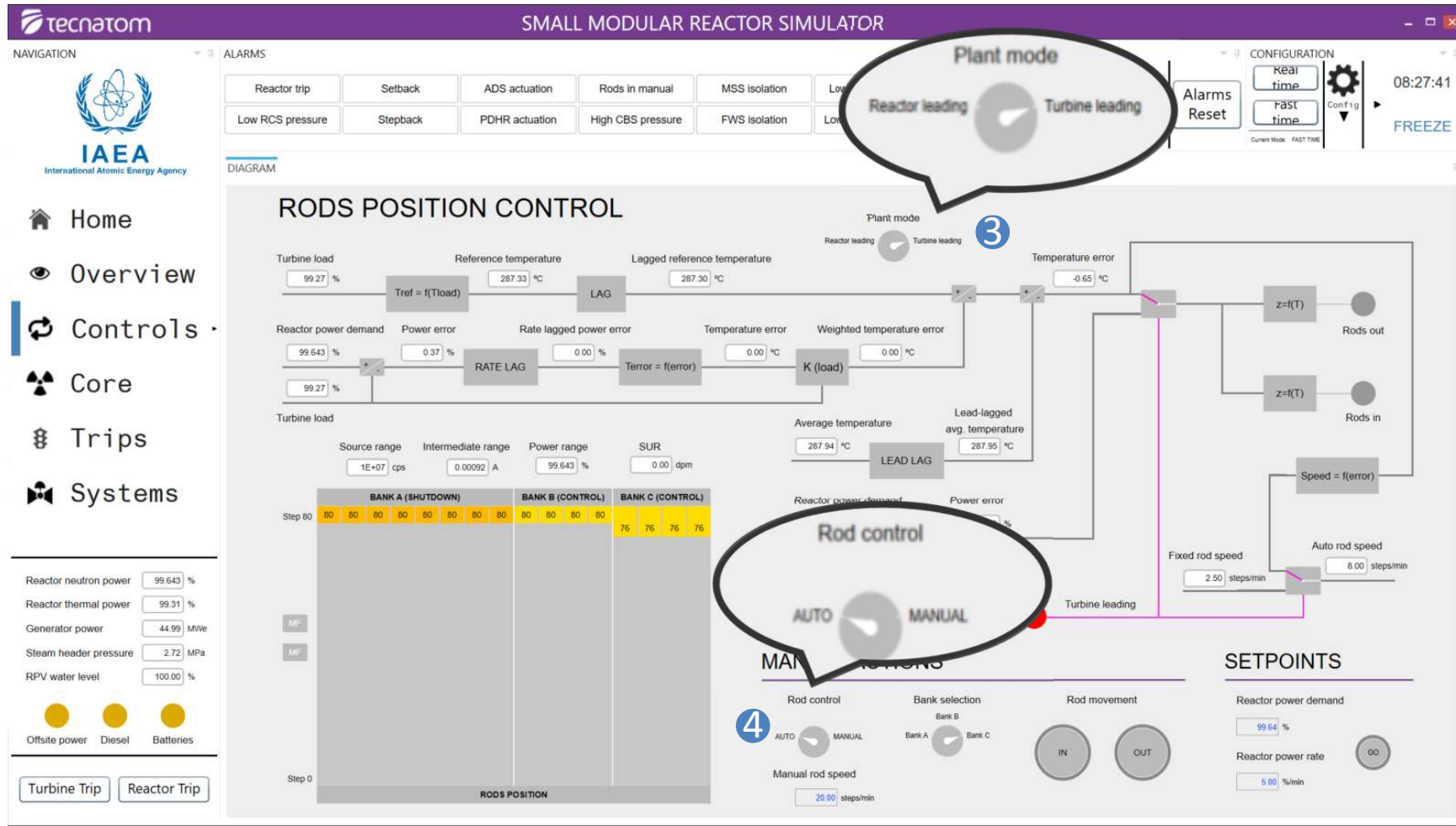
- 1 **Reactor power**
~100%
- 2 **Turbine load**
45 MW
- 3 **Plant Mode**
Turbine Leading Mode
- 4 **Control Rods**
Auto
- 5 **MSB**
 T_{avg} Mode
- 6 **FW System**
Auto
- 7 **CWS and CNR systems**
In service
- 8 **Alarms**
No active



STEP 28 - Check the final conditions

Check the following conditions:

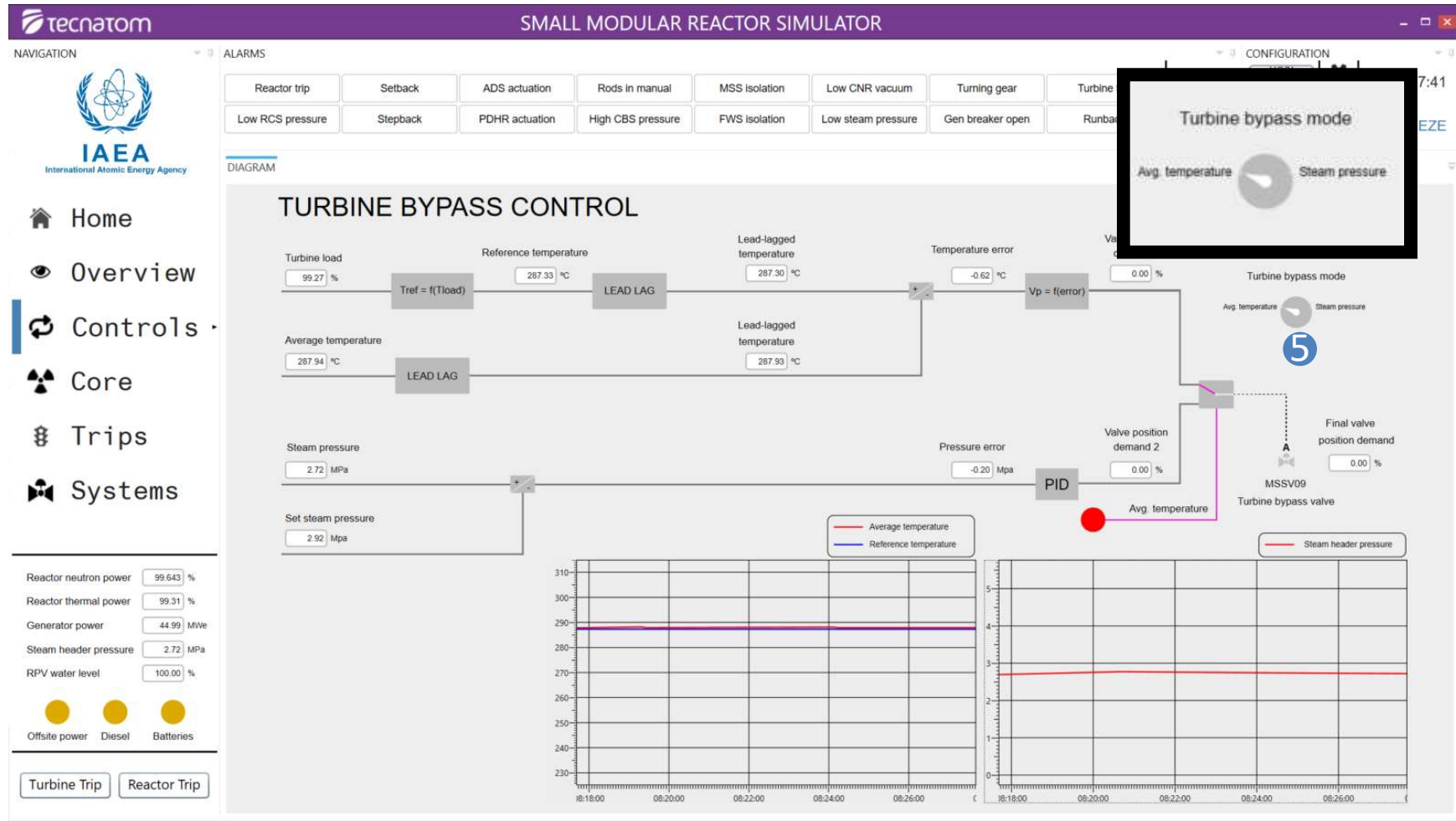
- 1 Reactor power
~100%
- 2 Turbine load
45 MW
- 3 **Plant Mode**
Turbine Leading Mode
- 4 **Control Rods**
Auto
- 5 MSB
 T_{avg} Mode
- 6 FW System
Auto
- 7 CWS and CNR systems
In service
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No active



STEP 28 - Check the final conditions

Check the following conditions:

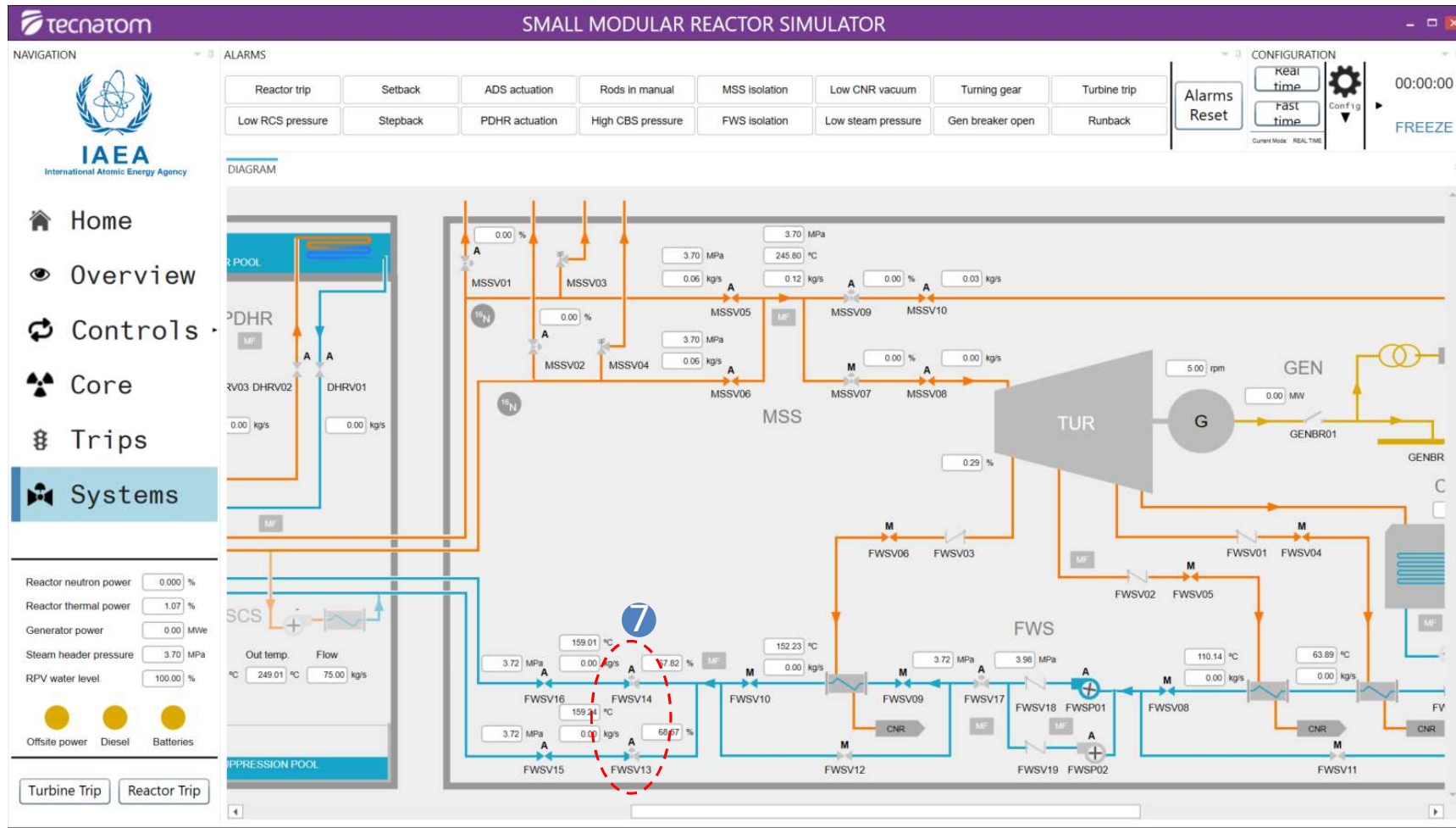
- 1 Reactor power
~100%
- 2 Turbine load
45 MW
- 3 Plant Mode
Turbine Leading Mode
- 4 Control Rods
Auto
- 5 MSB
 T_{avg} Mode
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Auto
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