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International Atomic Energy Agency
Atoms for Peace

The Abdus Salam
International Centre
for Theoretical Physics

"Physics and Technology of Water-Cooled Reactors through the use of PC-based Simulators"

INTRODUCTION TO ADVANCED PASSIVE PWR SIMULATOR

International Centre for Theoretical Physics

Trieste

6th – 10th November 2017

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FUNDAMENTALS TO OPERATE A NUCLEAR POWER PLANT

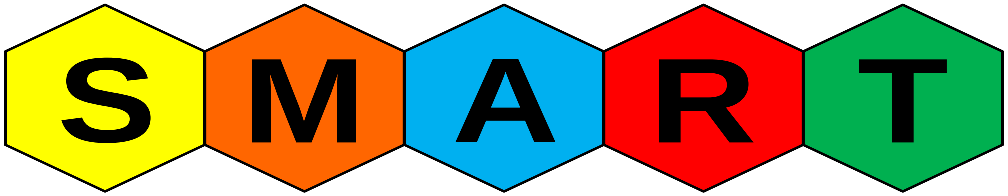
Key Parameters (*PWR*)

- Overall understanding of the reactor thermal conditions and core safety:
  - Reactor Power
  - RCS Temperature
  - Pressurizer Pressure
  - Pressurizer Level
  - Steam Generators Level
  - Steam Generators Pressure

Major Design Basis Accidents

PARAMETER	STEAM LINE BREAK (FAULTED SG)	STEAM GENERATOR TUBE RUPTURED (RUPTURED SG)	LOCA
RCS PRESS	↓	↓	↓
SG PRESS	↓	↑	→
CTMT PRESS	↑ OR →	→	↑
PZR LEVEL	↓	↓	↓
SG LEVEL	↓	↑	→
RCS TEMP	↓	↓	↓
CTMT TEMP	↑ OR →	→	↑
SG RAD	→	↑	→
CTMT RAD	→	→	↑

Operator Fundamentals (*INPO*)



- The essential knowledge, skills, behaviors, and practices that operating crews need to apply to operate the plant effectively.
  - **S**olid Knowledge of Plant Design and Theory
  - **M**onitoring the Plant Effectively
  - **A**ct with a Conservative Bias
  - **R**igorous Control of Plant Evolutions
  - **T**eamwork Excellence

Human Performance Tools

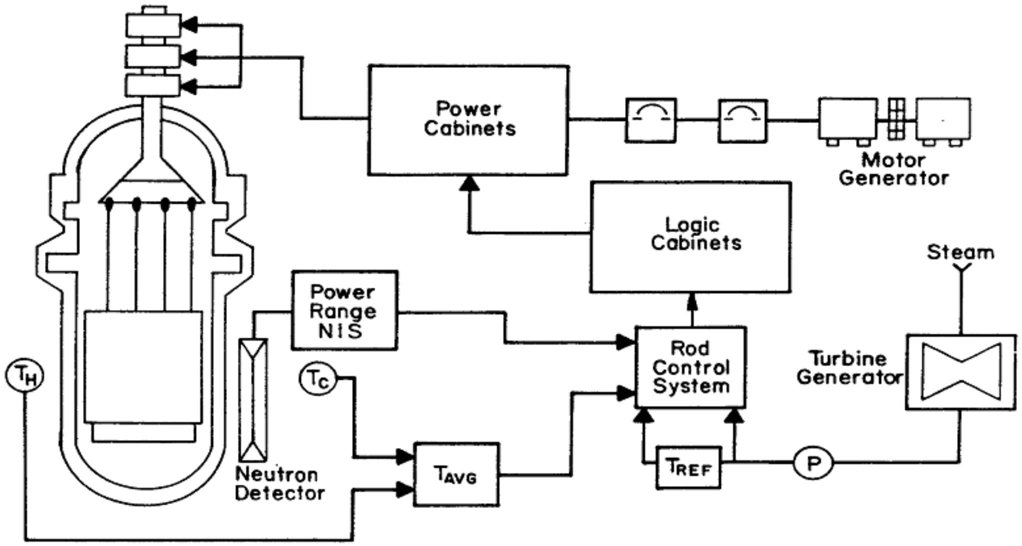
- Techniques to avoid errors and achieve high standards of performance:
  - Pre-Job Brief
  - Three-Way Communication
  - Phonetic Alphabet
  - Questioning Attitude
  - Time Out
  - Peer Checks
  - Self-Verification (STAR): **S**top – **T**hink – **A**ct – **R**eview
  - …

Communications

- Direct, clear and concise.
- 3-way communication for all communications that direct the operation of the plant.
- When reporting plant parameters:
  - Plant Parameter
  - Current numeric Value
  - Trend
- Use of phonetic alphabet when applicable.
- Repeat backs not required for simple exchange of information which does not direct specific actions.
- Avoid confusing words: ~~increase/decrease~~

  Raise/Lower

SIMULATOR DESIGN & MAJOR CONTROLS



Control Rods

- **Shutdown Banks (SD 1 & SD 2)**
  - Ensure Shutdown Margin.
  - Fully inserted at shutdown and fully withdrawn at power.
- **Dark Rods (1D, 2D, 3D, 4D)**
  - Control Power Distribution → ΔI.
  - Partially inserted.
- **Gray Rods (1G, 2G, 3G, 4G)**
  - Control Power level / Coolant Temperature
  - Lower worth.
  - Insertion Limits*

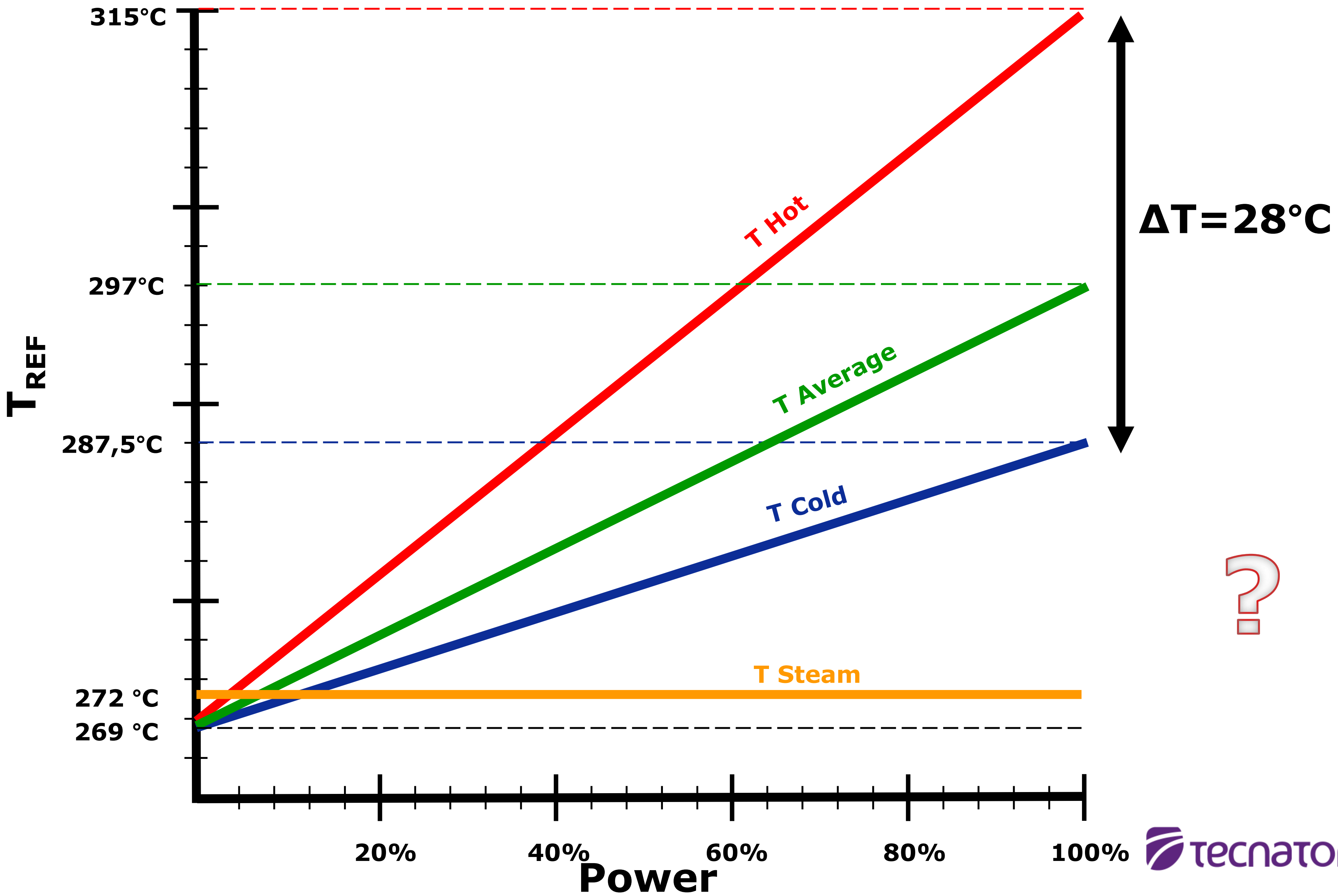
Control Rods

- Gray Rods Limits

Reactor Power (%)	Average Gray Rods Position (average of the rod positions for the individual four banks)
0 – 10 %	93 % - 87 % in core
10 – 20 %	87 % - 83 % in core
20 – 30 %	83 % - 70 % in core
30 – 40%	70 % - 60 % in core
40 – 50 %	60 % - 53 % in core
50 – 60 %	53 % - 48 % in core
60 – 70 %	48 % - 44 % in core
70 – 80%	44 % - 40 % in core
80 – 90 %	40 % - 35 % in core
90 – 100 %	35 % - 30 % in core

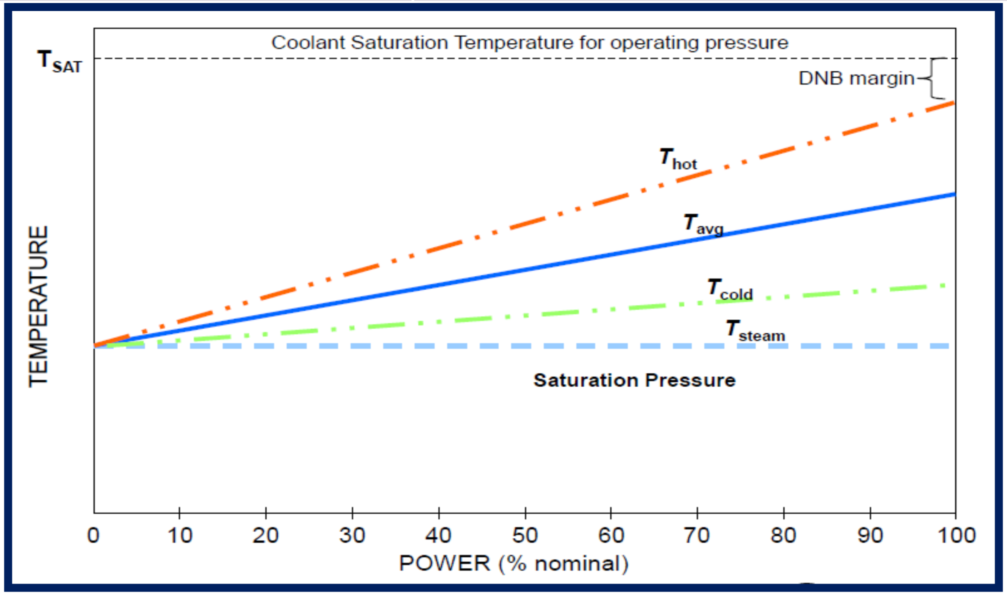
- Proper power maneuvering & sufficient shutdown margin.
- If limits reached before target → boration/dilution

Programmed Temperature - T_{REF}

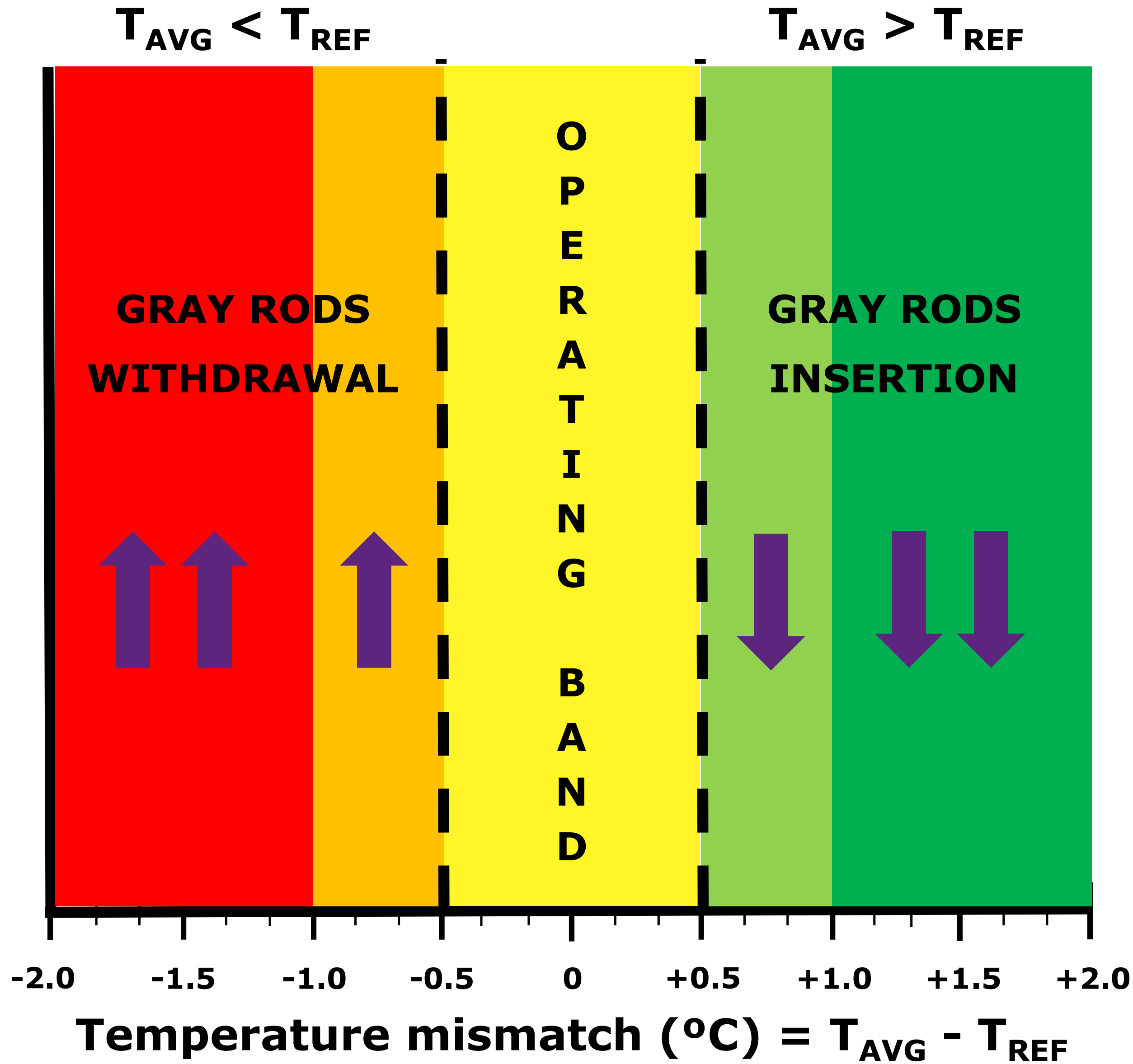


Programmed Temperature - T_{REF}

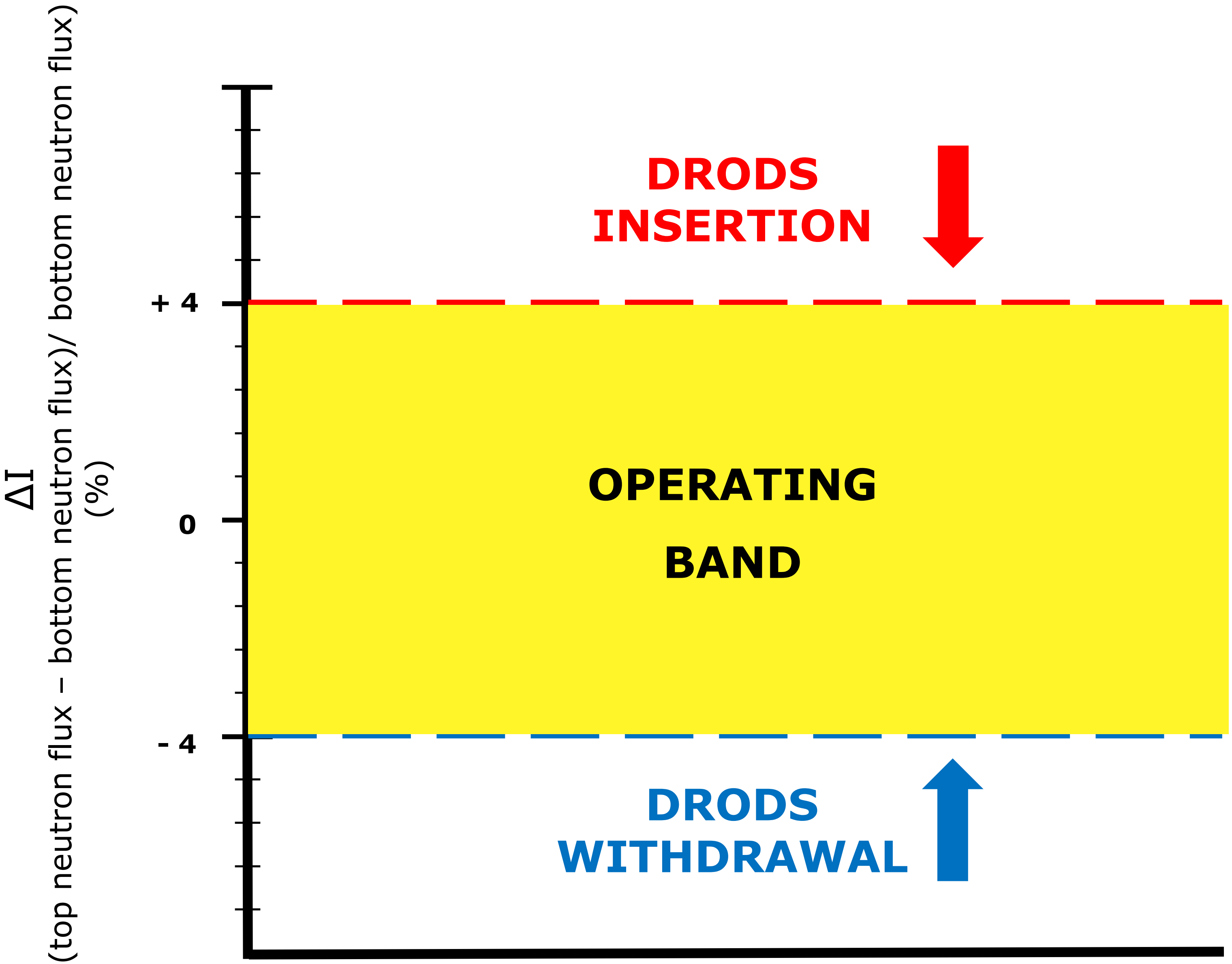
ADVANTAGES	DISADVANTAGES
• Higher T_{steam} & p_{steam} ✓ Higher Secondary Cycle Efficiency	• Higher Coolant Temperatures: ✓ Higher PZR volume changes ✓ Higher rods movements ✓ Lower margin for DNB ✓ Higher Corrosion



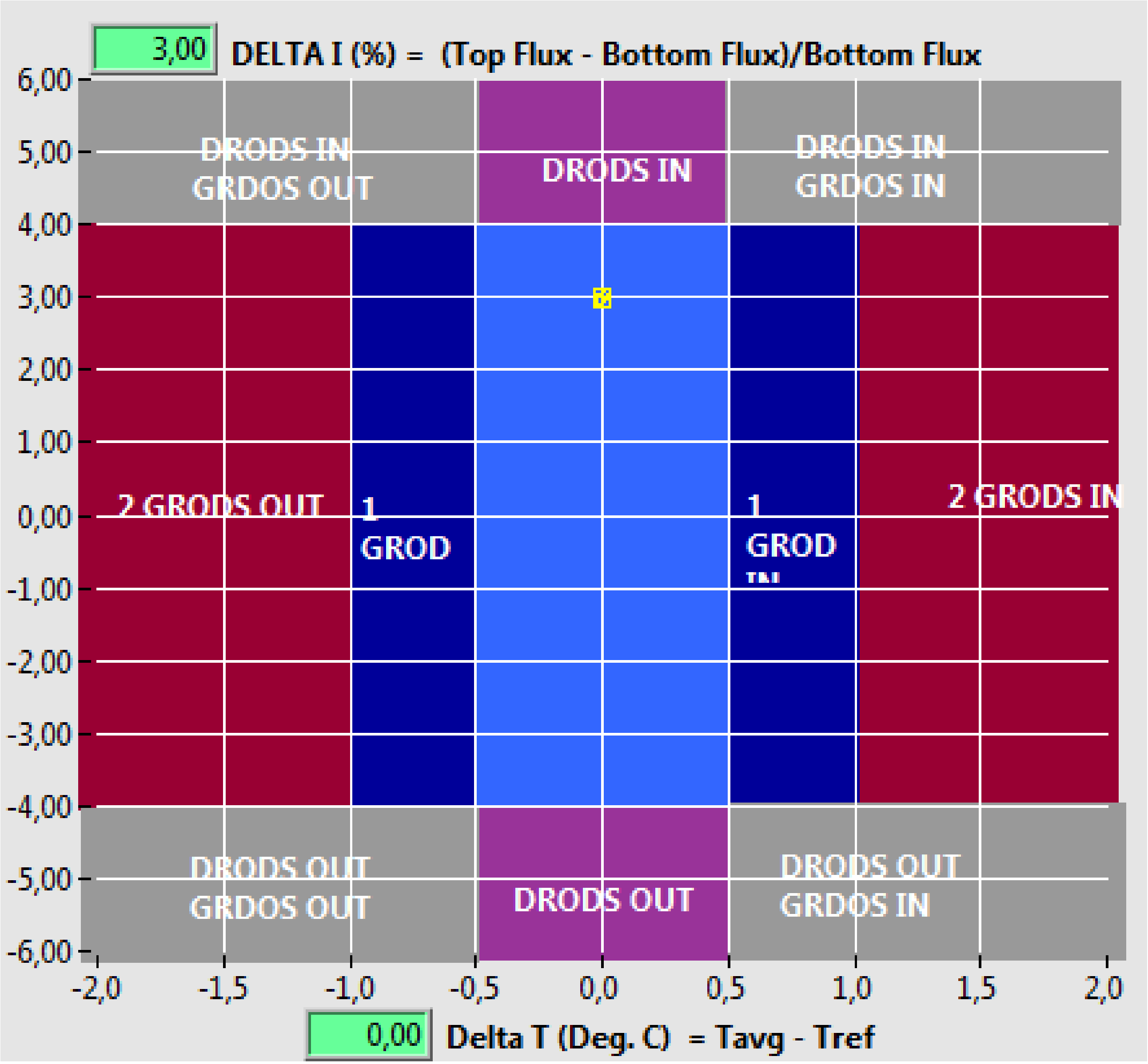
T_{AVG} Control



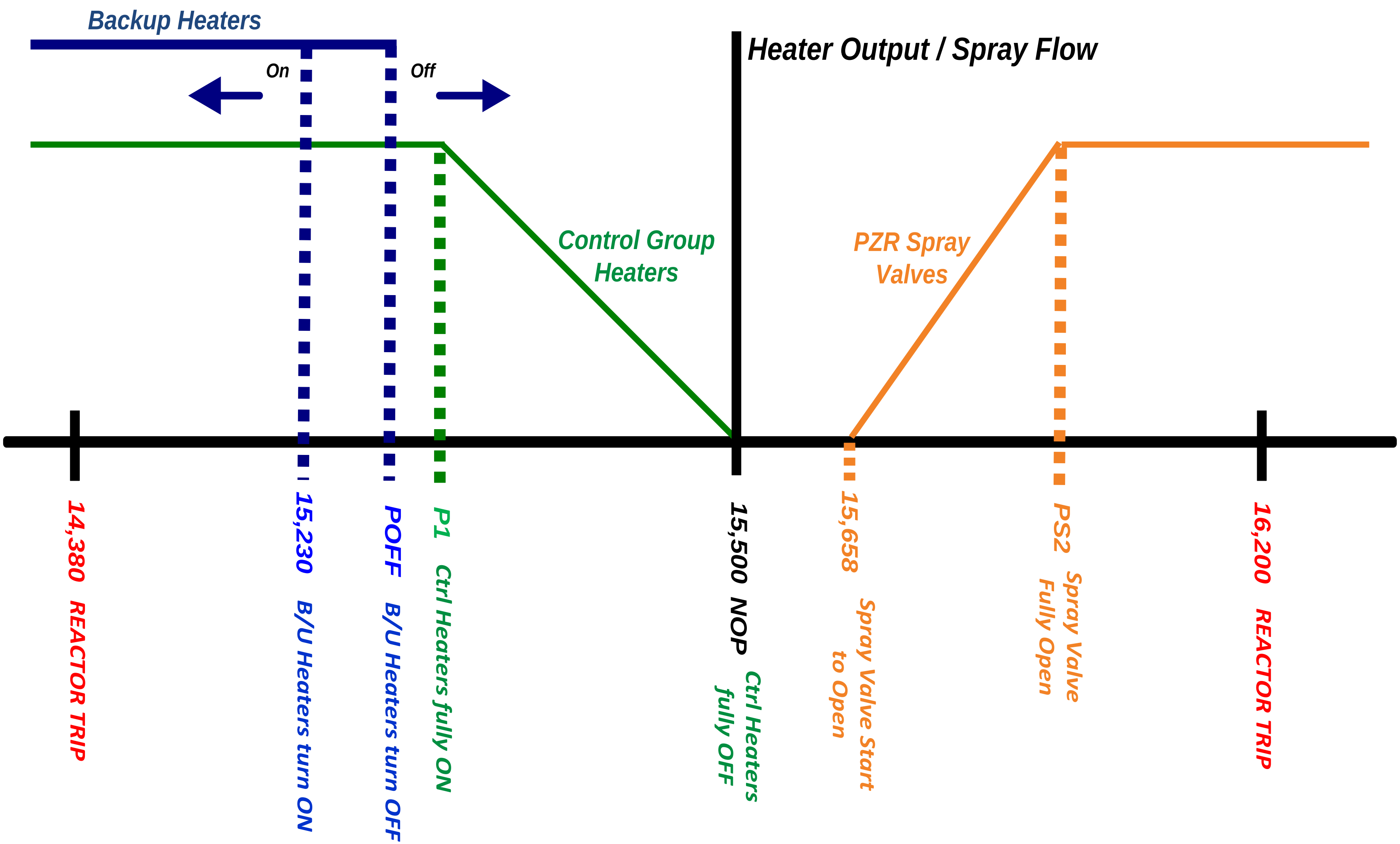
Axial Power Control



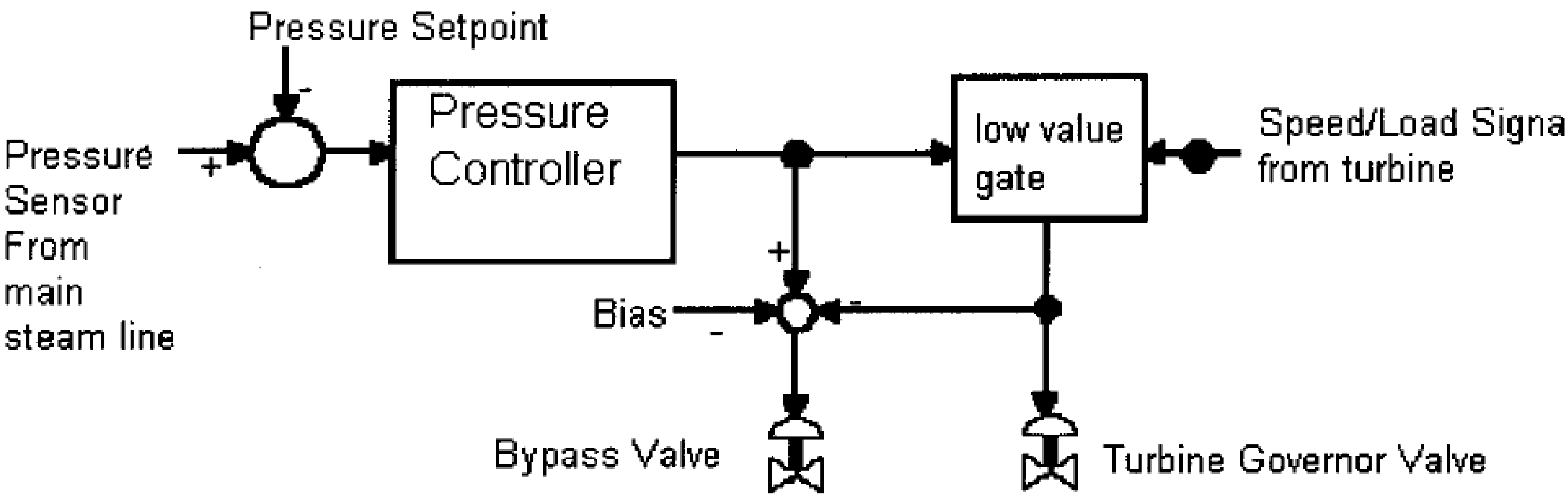
Control Rods Program



Primary Coolant Pressure Control



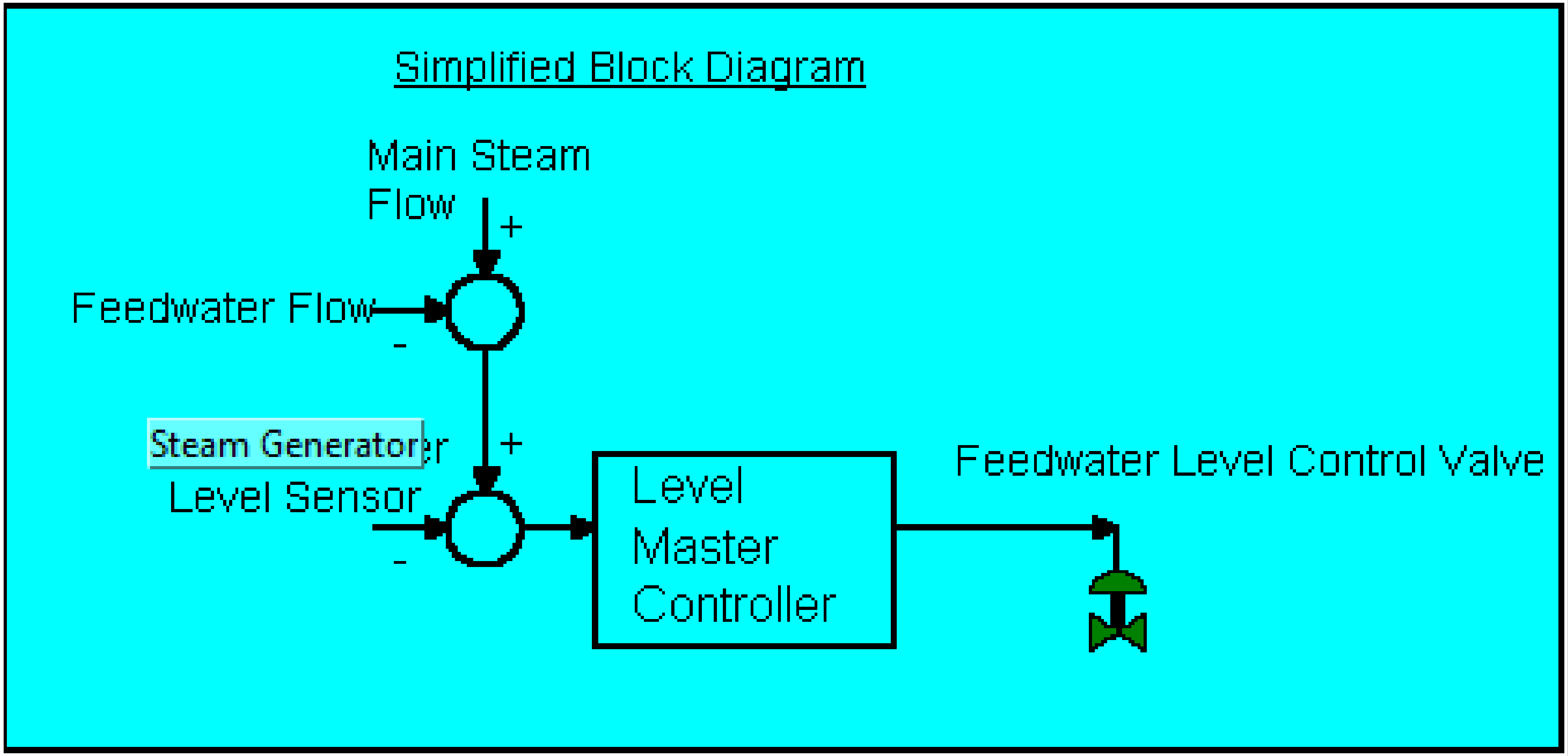
Steam Pressure Control



Main Steam Pressure Setpoint = 5,740 kPa

for any load level

Steam Generators Level Control

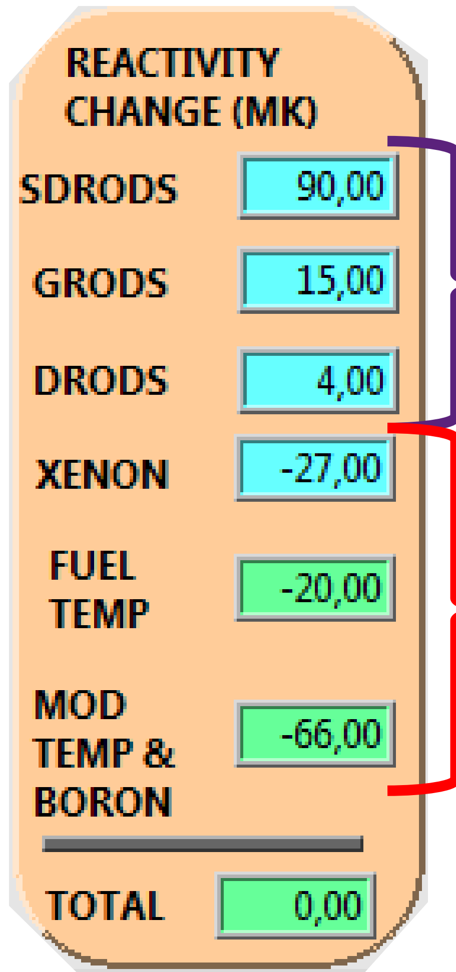


SG Level setpoint proportional to Power Level

100% → 13.51 m

0% → 11.67 m

Reactivity Balance Program



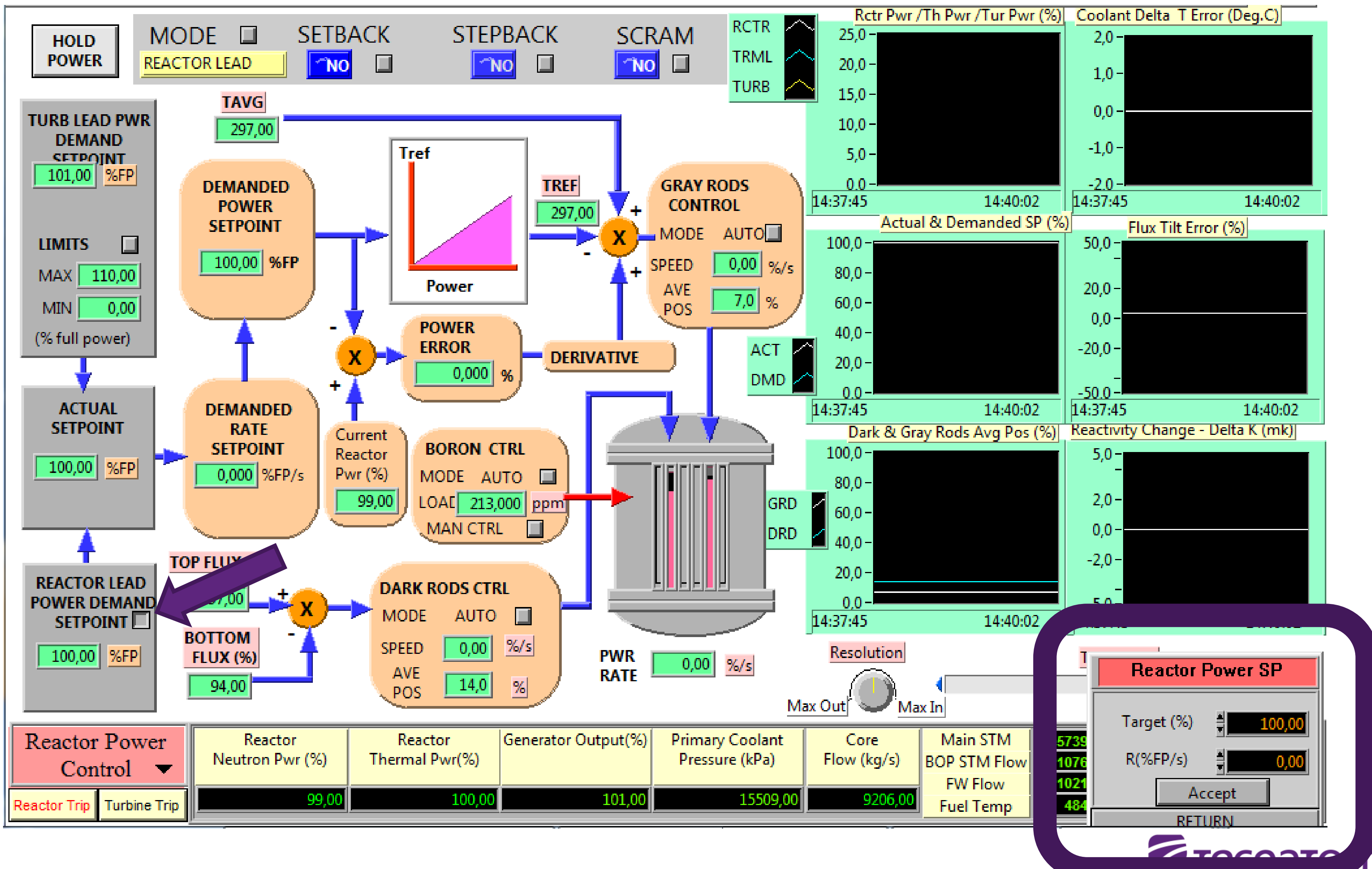
Positive Reactivity inserted into the core

Negative Reactivity inserted into the core

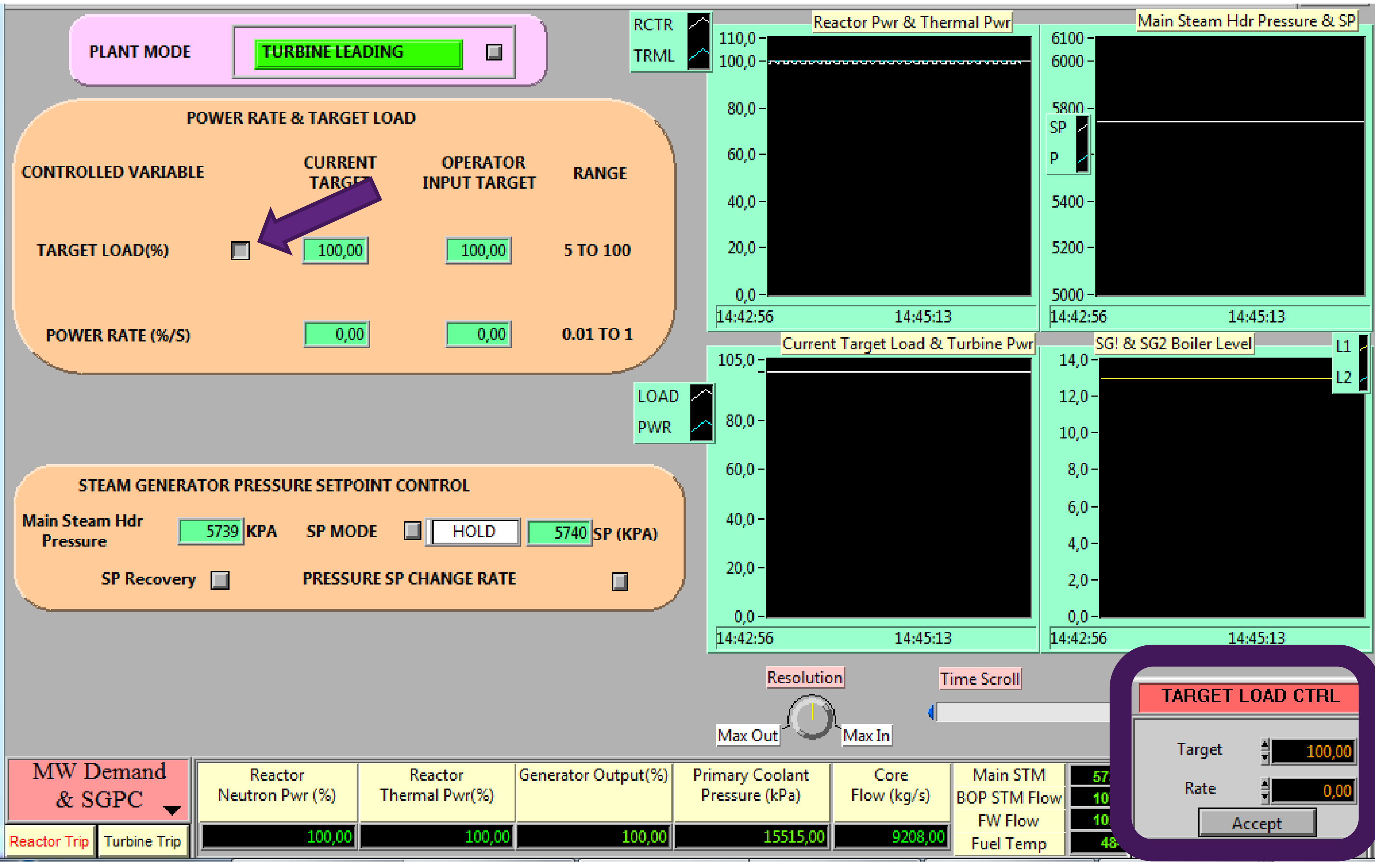
Power Control Modes

- **REACTOR LEAD → Turbine offline**
  - Used when Turbine-Generator is disconnected from the grid*.
  - GRODs are inserted/withdrawn to get selected Reactor power*.
- **TURBINE LEAD → Turbine online**
  - “Reactor follows the Turbine”.
  - GRODs are inserted/withdrawn to match Tavg to Tref.

REACTOR LEAD



TURBINE LEAD



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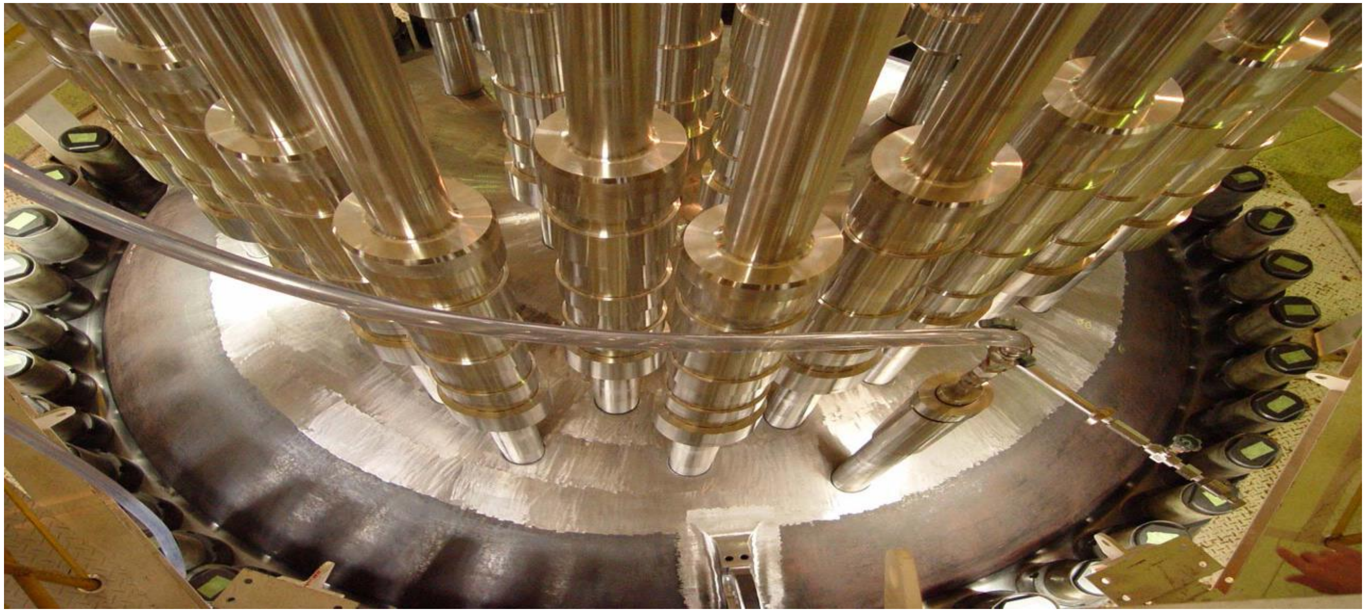
SIMULATOR PROTECTION SIGNALS



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REACTOR TRIPS (1/2)

- Low RCS Pressure < 14,380 kPa → *DNB Protection*
- Low SG level < 11.94 m → *Loss of Heat Sink*
- High RCS Pressure > 16,200 kPa → *RCS Integrity Protection*
- High neutron flux > 120 % FP → *Overpower Protection*
- High log rate > 8 % FP/s → *Overpower Protection*
- Low coolant flow < 2,000 kg/s → *DNB Protection*
- Low PZR level < 2.7 m → LOCA, inadvertent Safety Valve opening/PRHR actuation…

REACTOR TRIPS (2/2)

- Low FW disch header pressure < 5200 kPa→ Loss of Heat Sink Protection
- High Steam Flow (SG1 or SG2) > 644 kg/sec → Overcooling Protection

  OR

  Total steam flow >1289 kg/s
- Average heat flux in the core > 464 kW/m2 → *DNB Protection* (DNB Trip)
- Containment High Pressure > 105 kPa → LOCA, SLB IRC
- Manual trip

REACTOR STEPBACK

- Reduction of reactor power in a large step, in response to certain process parameters exceeding alarm limits, as a measure in support of reactor safety:
  - High RCS pressure >16051 kPa (target 2 % FP)
  - Loss of one RCP (target 60 % FP)
  - Loss of two RCPs (target 2 % FP)
  - High log rate > 7 %/s; (target 2 % FP)
  - Hi zone flux > 115 % of nominal zone flux at full power
  - Manual stepback (initiated by operator; target set by operator)

REACTOR SETBACK

- Ramping down of reactor power at fixed rate, to setback target, in response to certain process parameters exceeding alarm limits, as a measure in support of reactor safety:
  - Main steam header pressure High > 6150 kPa
  - High pressurizer level > 12 m
  - Manual setback in progress
  - Low SG level < 12 m
  - Low deaerator level < 2 m
  - High flux tilt > 20 %
  - High zonal flux > 110 %

OTHER PROTECTIVE ACTUATIONS

- **Safety Passive Core Cooling System Actuation** → Safety Injection and Emergency Core Cooling
  - Low-low PZR Level < 2 m → LOCA
  - Manual
- **Feedwater Isolation**
  - Safety Passive Core Cooling System Actuation → Prevent Overcooling (PRHR Act.)
  - High-high SG level > 15 m → Prevent Water Carry-over to MSLs/Turbine
  - Manual
- **Turbine trip**
  - Low Turbine forward power @ 0% Generator Output → Total Loss of Load
  - High-high SG level > 15 m → Prevent Water Carry-over to MSLs/Turbine
  - Manual
- **Reactor Coolant Pump trip**
  - Low-low PZR Level < 2 m **following Reactor trip** → Prevent interfere with CMTs
  - Manual

SIMULATOR FUNDAMENTALS

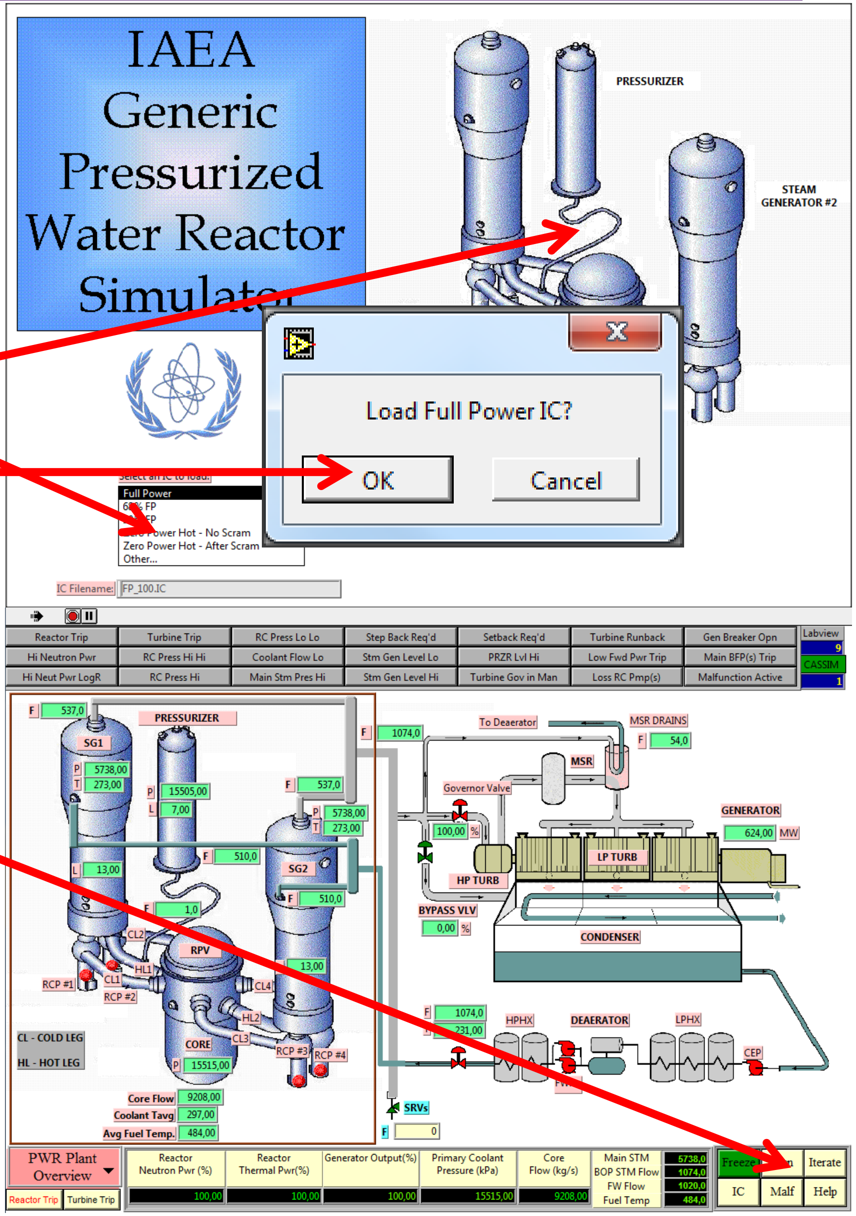
VERY IMPORTANT!!!!

- Make sure you got your computer set with "." for decimals (instead of ",").
- If not, the accuracy of your simulation will be reduced to one unit.

(Pannello di controllo → Orologio e opzioni internazionali→ Area geografica → Cambia data, ora o formato dei numeri → Impostazioni aggiuntive→ Separatore decimale)

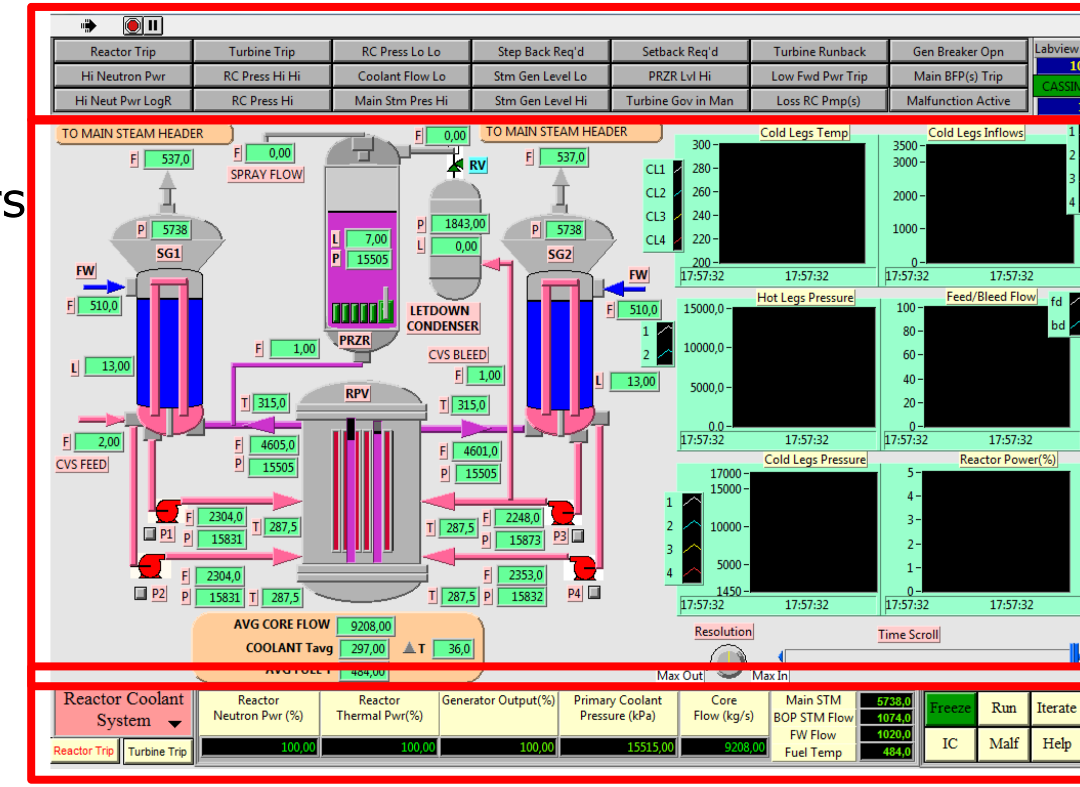
Simulator Fundamentals

- Simulator Startup
  1) Select IC
  2) Click on RCS Drawing
  3) Click on Ok
  4) Run



Simulator Fundamentals

- Displays Structure
  - Top:
    - Resume/Stop/Pause
    - Alarms Panel
    - Labview/CASSIM counters
  - Mid: Main Display
    - Controls & Displays
  - Bottom:
    - Navigation drop-down menu
    - Rx Trip and Tx Trip
    - Main plant parameters
    - Simulation Controls

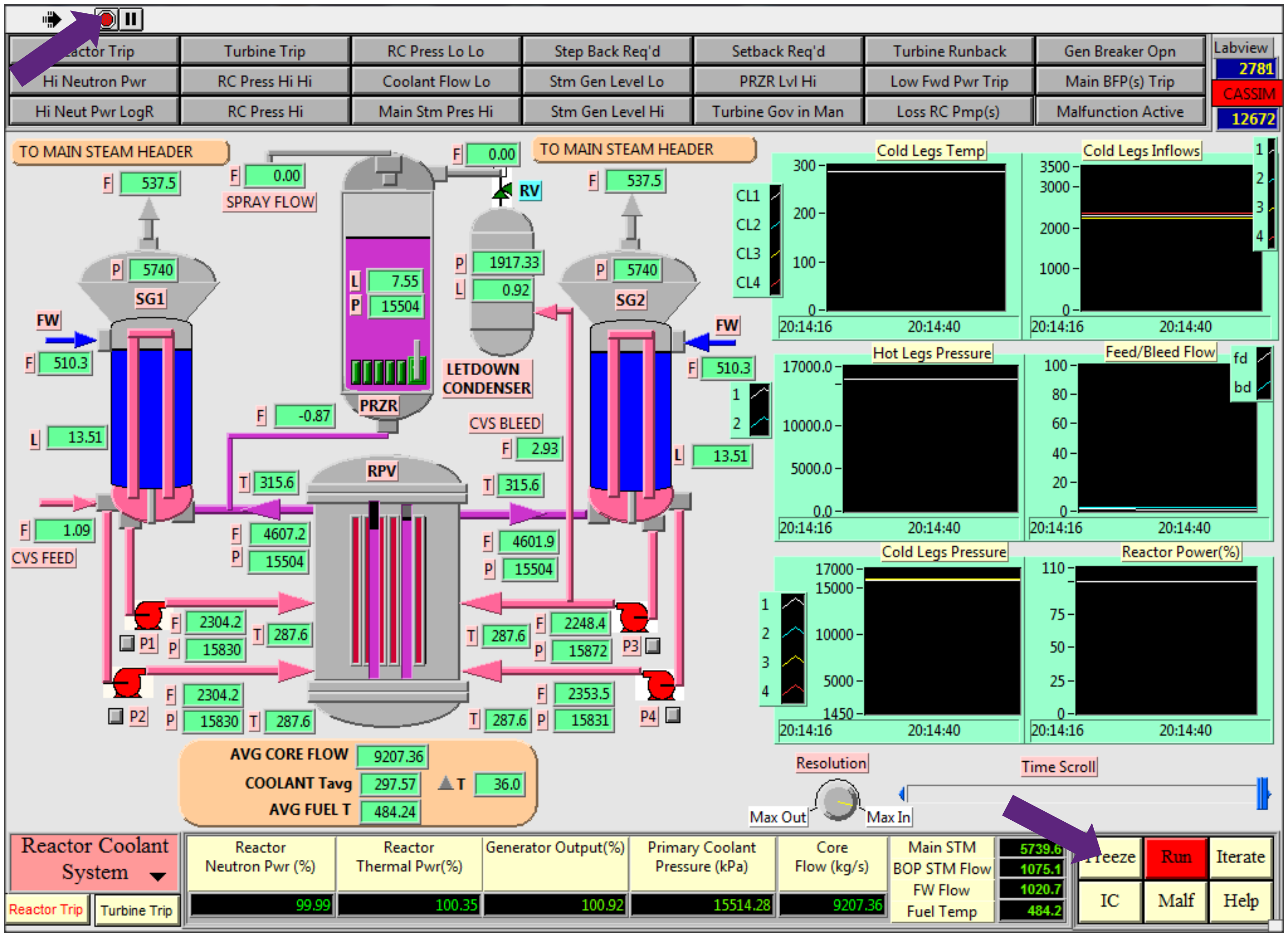


Simulator Fundamentals

- Displays Features:
  - Color Code:
    - **GREEN**: Valve closed, pump stopped, heater off.
    - **RED**: Valve open, pump started, heater on.
  - Units:
    - Temperature: ºC
    - Pressure: kPa
    - Flow: kg/s
    - Level: m
    - Reactivity: mk
  - Pop-up controls:
    - Click on **Return** to continue.

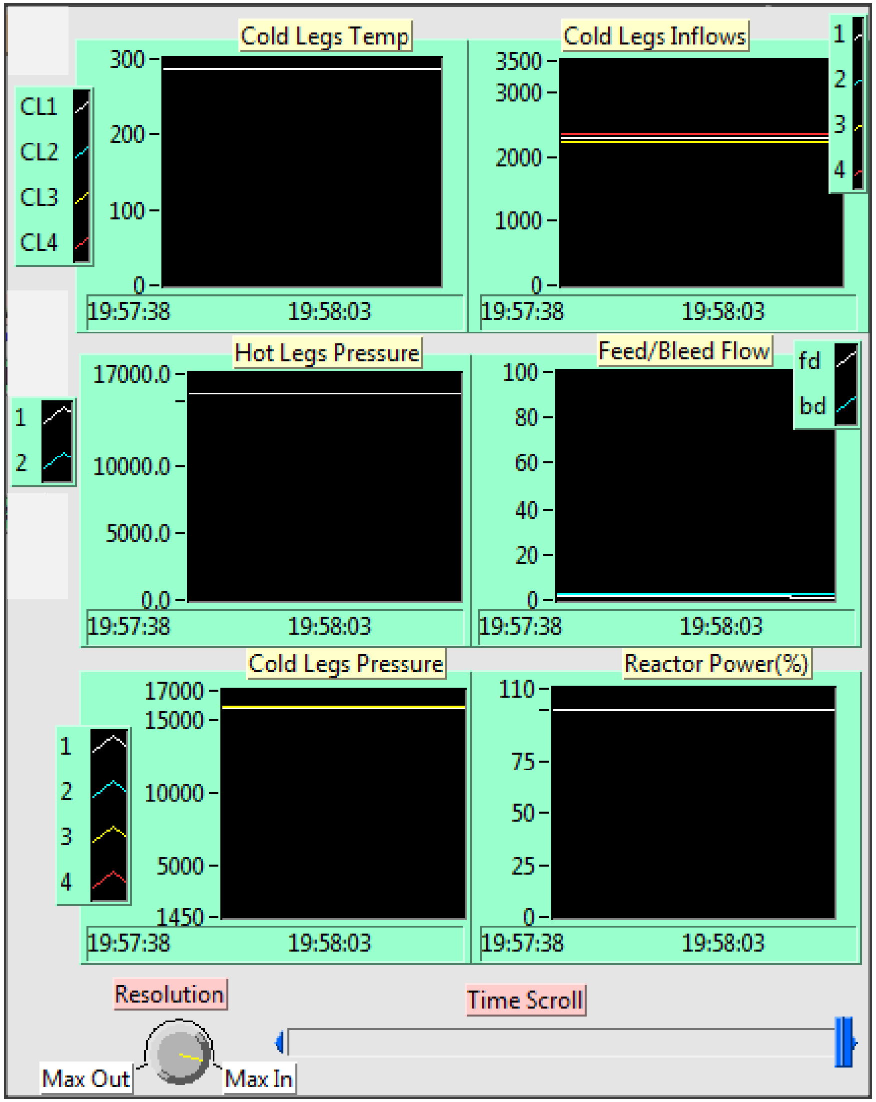
Simulator Fundamentals

- Stop/Run vs Freeze/Run



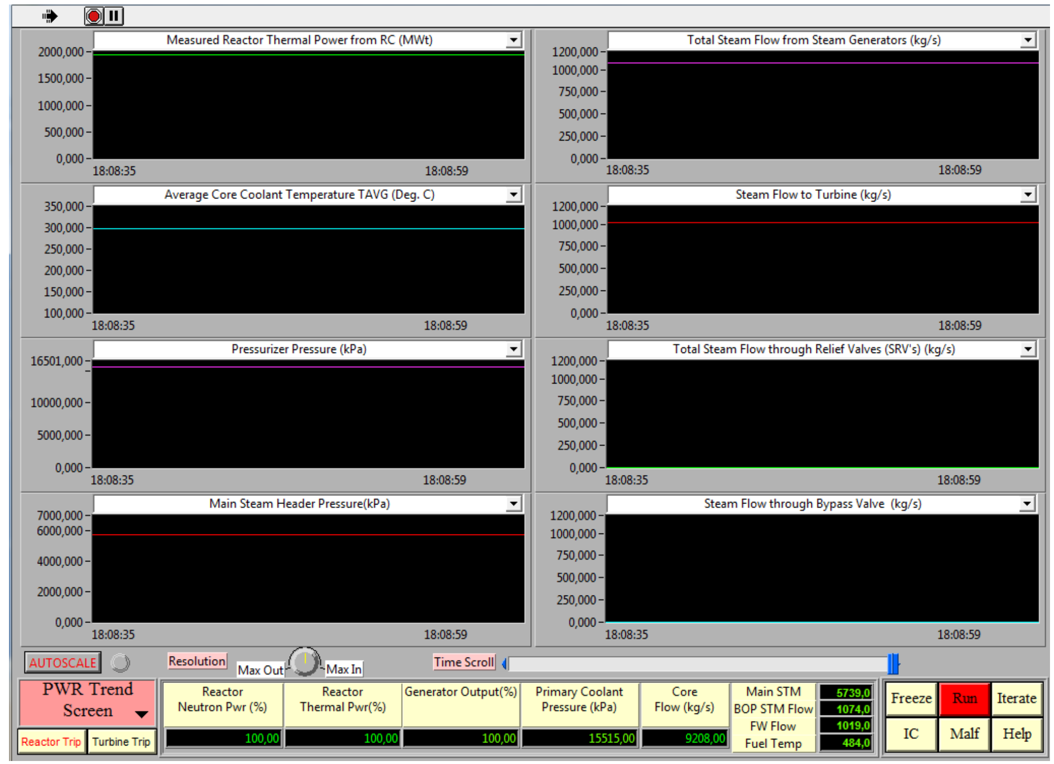
Simulator Fundamentals

- Default Trend
  - Screen-Specific
  - Modify Bands
  - Time Scroll Feature
  - Resolution



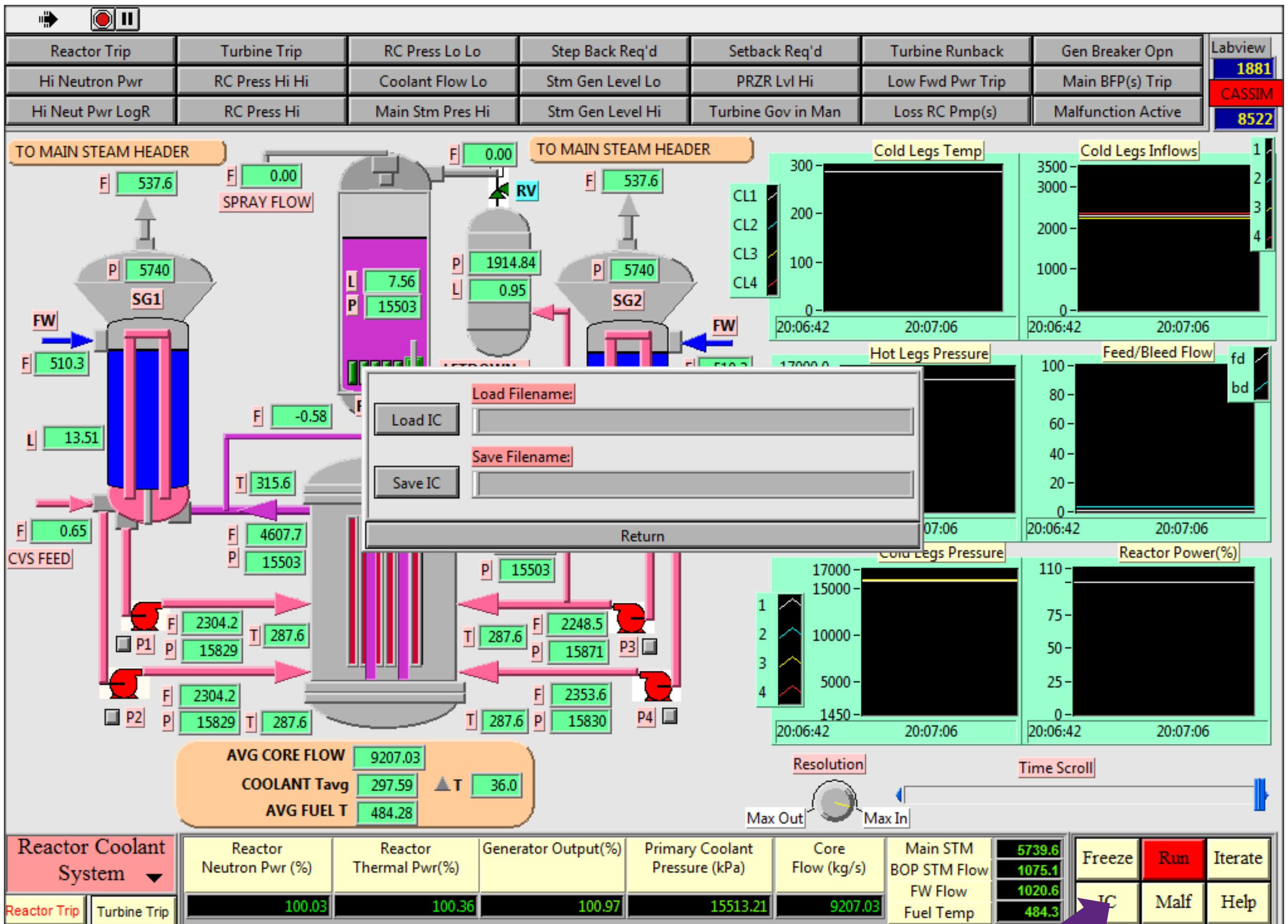
Simulator Fundamentals

- Create New Trends
  - PWR Trend Screen
  - Modify Bands - AUTOSCALE
  - Time Scroll Feature
  - Resolution



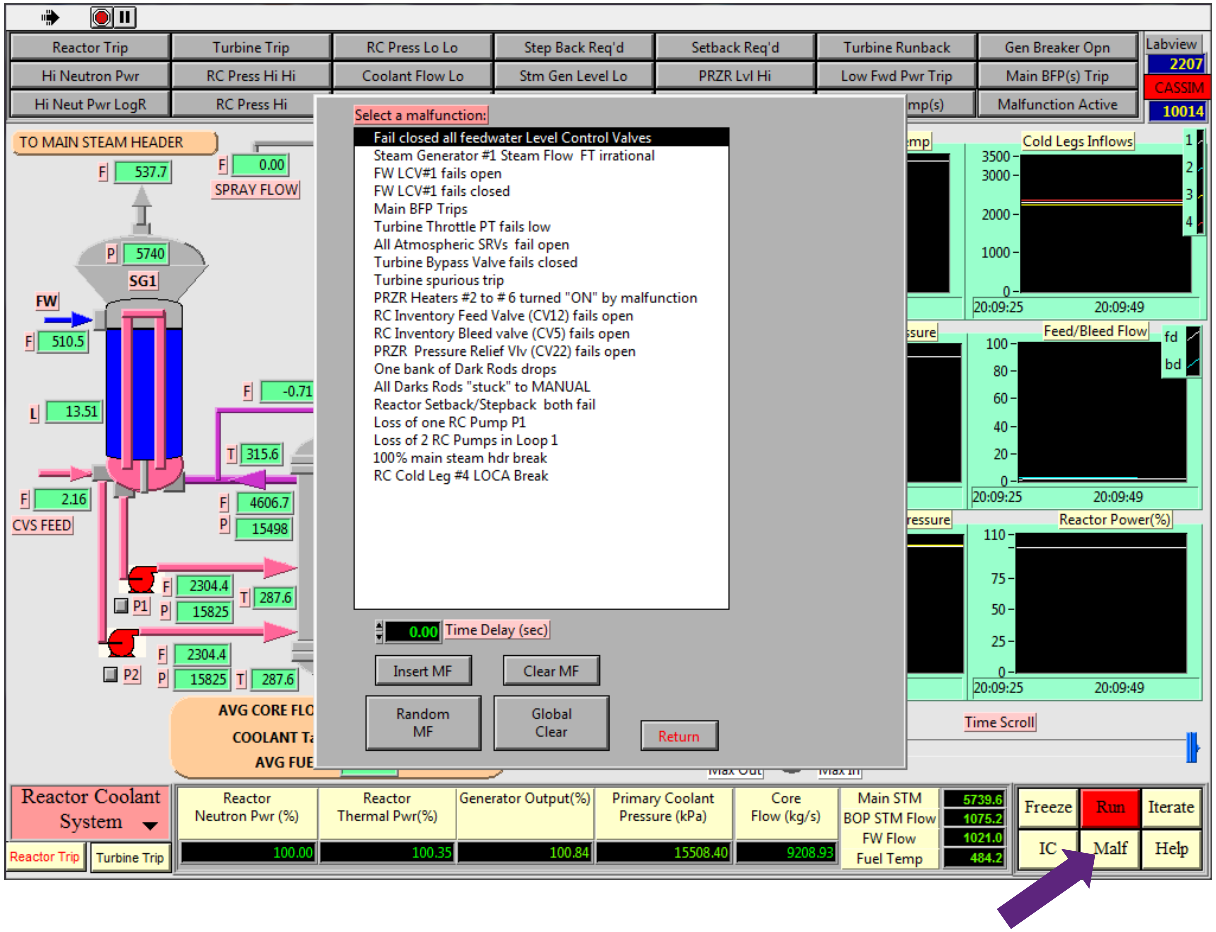
Simulator Fundamentals

- Create/Load an IC

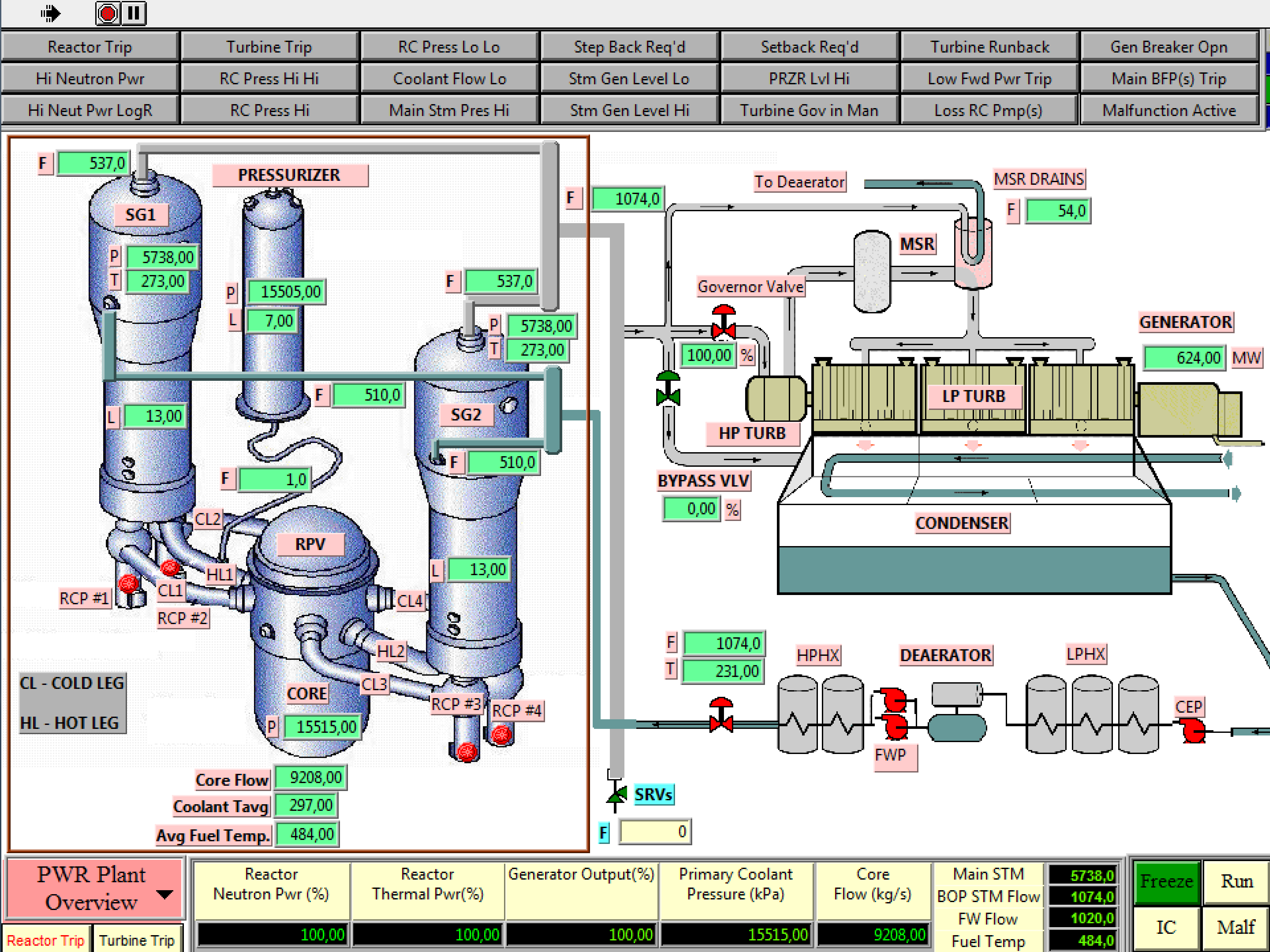


Simulator Fundamentals

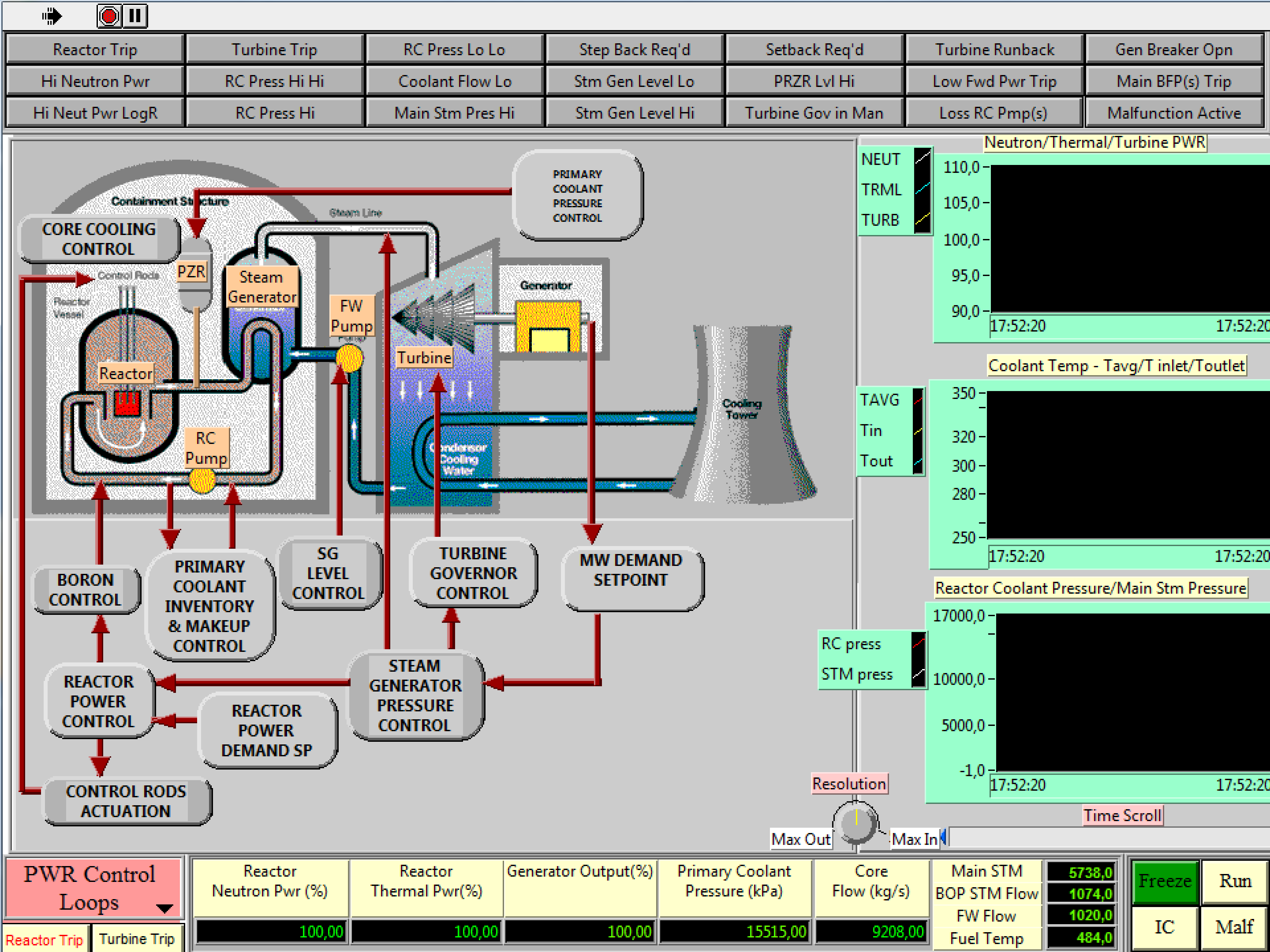
- Insert a Malfunction
  - Time delay
  - Clear/ Global Clear feature
  - Random MF



DISPLAYS



Reactor Trip
Turbine Trip
RC Press Lo Lo
Step Back Req'd
Setback Req'd
Turbine Runback
Gen Breaker Opn
Hi Neutron Pwr
RC Press Hi Hi
Coolant Flow Lo
Stm Gen Level Lo
PRZR Lvl Hi
Low Fwd Pwr Trip
Main BFP(s) Trip
Hi Neut Pwr LogR
RC Press Hi
Main Stm Pres Hi
Stm Gen Level Hi
Turbine Gov in Man
Loss RC Pmp(s)
Malfunction Active
F 537,0
PRESSURIZER
SG1
P 5738,00
T 273,00
P 15505,00
L 7,00
F 537,0
P 5738,00
T 273,00
F 510,0
SG2
L 13,00
F 510,0
F 1,0
CL2
RPV
HL1
CL1
RCP #1
RCP #2
CL4
L 13,00
HL2
CL3
CORE
RCP #3
RCP #4
P 15515,00
CL - COLD LEG
HL - HOT LEG
Core Flow 9208,00
Coolant Tavg 297,00
Avg Fuel Temp. 484,00
F 1074,0
To Deaerator
MSR DRAINS
F 54,0
MSR
Governor Valve
100,00 %
GENERATOR
624,00 MW
LP TURB
HP TURB
BYPASS VLV
0,00 %
CONDENSER
F 1074,0
T 231,00
HPHX
DEAERATOR
LPHX
CEP
FWP
SRVs
F 0
PWR Plant Overview
Reactor Trip
Turbine Trip
Reactor Neutron Pwr (%) 100,00
Reactor Thermal Pwr(%) 100,00
Generator Output(%) 100,00
Primary Coolant Pressure (kPa) 15515,00
Core Flow (kg/s) 9208,00
Main STM 5738,0
BOP STM Flow 1074,0
FW Flow 1020,0
Fuel Temp 484,0
Freeze
Run
IC
Malf



Reactor Trip
Turbine Trip
RC Press Lo Lo
Step Back Req'd
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RC Press Hi Hi
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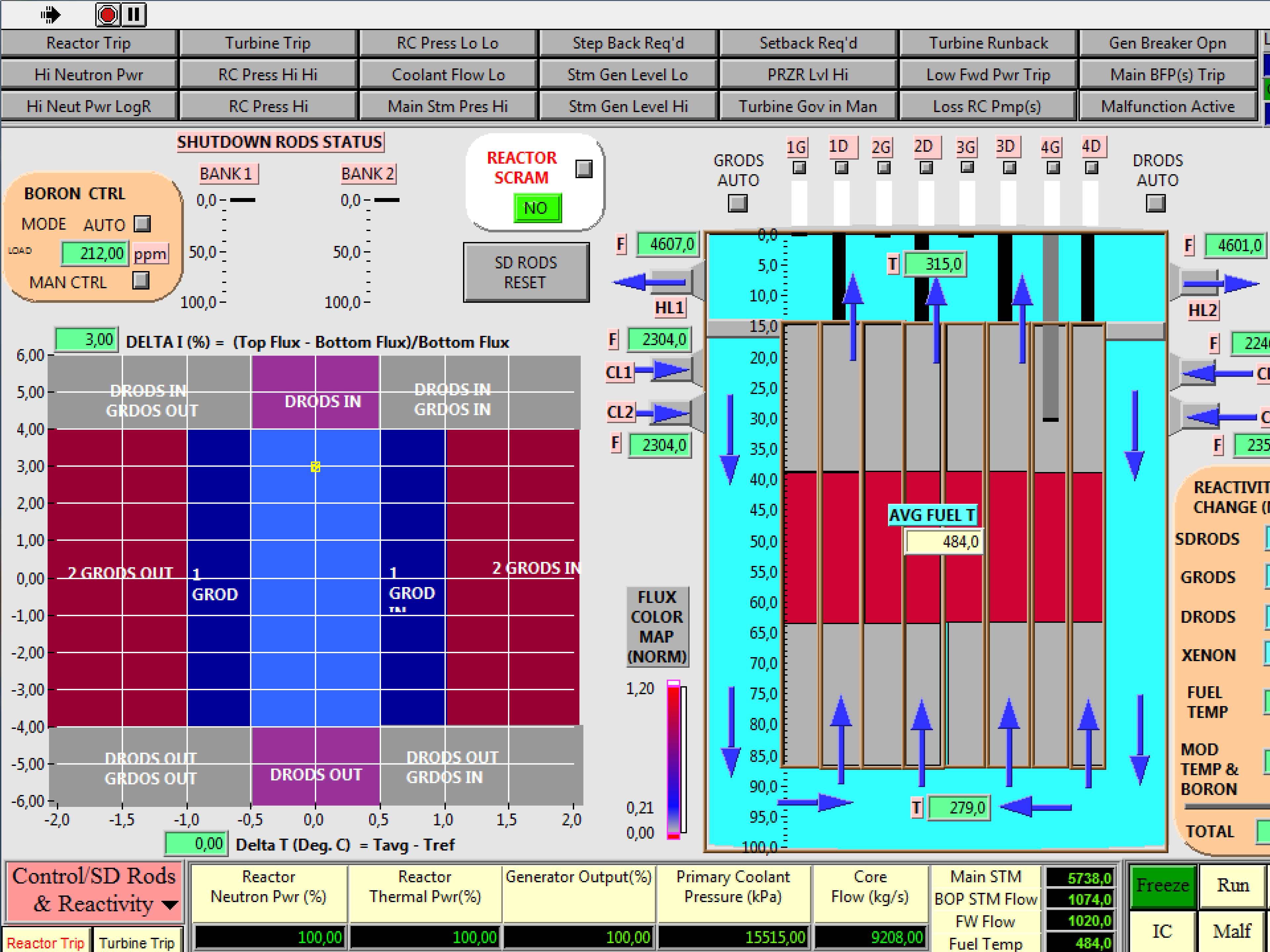
Stm Gen Level Lo
PRZR Lvl Hi
Low Fwd Pwr Trip
Main BFP(s) Trip
Hi Neut Pwr LogR
RC Press Hi
Main Stm Pres Hi
Stm Gen Level Hi
Turbine Gov in Man
Loss RC Pmp(s)
Malfunction Active
Containment Structure
CORE COOLING CONTROL
PZR
Steam Generator
Steam Line
PRIMARY COOLANT PRESSURE CONTROL
FW Pump
Turbine
Generator
Control Rods
Reactor Vessel
Reactor
RC Pump
Condensor Cooling Water
Cooling Tower
BORON CONTROL
PRIMARY COOLANT INVENTORY & MAKEUP CONTROL
SG LEVEL CONTROL
TURBINE GOVERNOR CONTROL
MW DEMAND SETPOINT
REACTOR POWER CONTROL
STEAM GENERATOR PRESSURE CONTROL
REACTOR POWER DEMAND SP
CONTROL RODS ACTUATION
Neutron/Thermal/Turbine PWR
NEUT
TRML
TURB
110,0
105,0
100,0
95,0
90,0
17:52:20
17:52:20
Coolant Temp - Tavg/T inlet/Toutlet
TAVG
Tin
Tout
350
320
300
280
250
17:52:20
17:52:20
Reactor Coolant Pressure/Main Stm Pressure
RC press
STM press
17000,0
10000,0
5000,0
-1,0
17:52:20
17:52:20
Resolution
Max Out
Max In
Time Scroll
PWR Control Loops
Reactor Trip
Turbine Trip
Reactor Neutron Pwr (%)
100,00
Reactor Thermal Pwr(%)
100,00
Generator Output(%)
100,00
Primary Coolant Pressure (kPa)
15515,00
Core Flow (kg/s)
9208,00
Main STM
5738,0
BOP STM Flow
1074,0
FW Flow
1020,0
Fuel Temp
484,0
Freeze
Run
IC
Malf



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Main BFP(s) Trip
Hi Neut Pwr LogR
RC Press Hi
Main Stm Pres Hi
Stm Gen Level Hi
Turbine Gov in Man
Loss RC Pmp(s)
Malfunction Active
SHUTDOWN RODS STATUS
BANK 1
BANK 2
BORON CTRL
MODE AUTO
LOAD
212,00 ppm
MAN CTRL
REACTOR SCRAM
NO
SD RODS RESET
GRODS AUTO
1G 1D 2G 2D 3G 3D 4G 4D
DRODS AUTO
F 4607,0
HL1
T 315,0
F 4601,0
HL2
F 2304,0
CL1
CL2
F 2304,0
3,00 DELTA I (%) = (Top Flux - Bottom Flux)/Bottom Flux
DRODS IN GRDOS OUT
DRODS IN
DRODS IN GRDOS IN
2 GRODS OUT
1 GROD
1 GROD
2 GRODS IN
DRODS OUT GRDOS OUT
DRODS OUT
DRODS OUT GRDOS IN
0,00 Delta T (Deg. C) = Tavg - Tref
FLUX COLOR MAP (NORM)
1,20
0,21
0,00
AVG FUEL T
484,0
T 279,0
REACTIVIT CHANGE
SDRODS
GRODS
DRODS
XENON
FUEL TEMP
MOD TEMP & BORON
TOTAL
Control/SD Rods & Reactivity
Reactor Trip
Turbine Trip
Reactor Neutron Pwr (%) 100,00
Reactor Thermal Pwr(%) 100,00
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Freeze
Run
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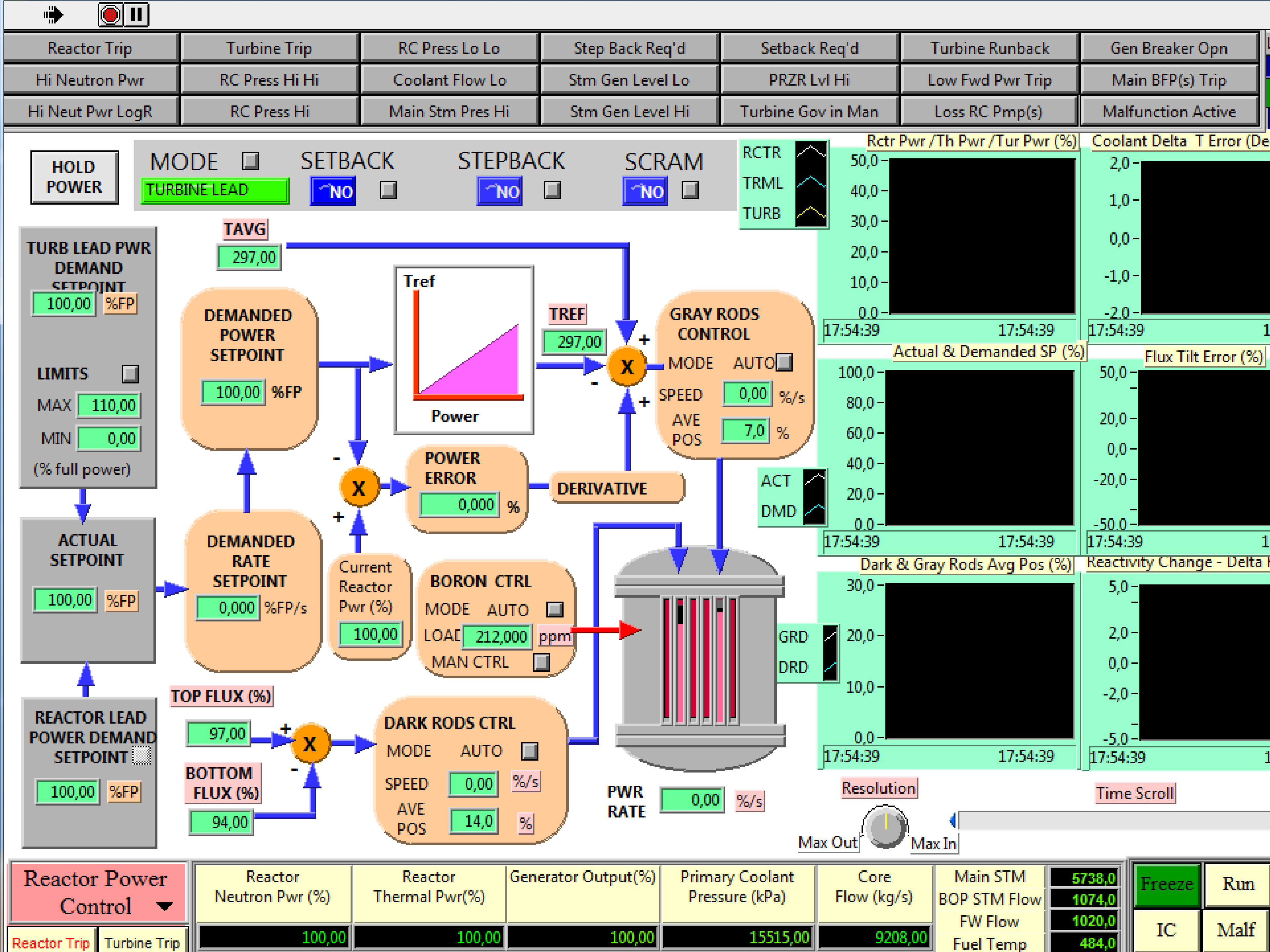

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RC Press Hi
Main Stm Pres Hi
Stm Gen Level Hi
Turbine Gov in Man
Loss RC Pmp(s)
Malfunction Active
HOLD POWER
MODE
TURBINE LEAD
SETBACK
NO
STEPBACK
NO
SCRAM
NO
RCTR
TRML
TURB
Rctr Pwr /Th Pwr /Tur Pwr (%)
Coolant Delta T Error
TAVG
297,00
TURB LEAD PWR DEMAND SETPOINT
100,00 %FP
LIMITS
MAX 110,00
MIN 0,00
(% full power)
DEMANDED POWER SETPOINT
100,00 %FP
Tref
Power
TREF
297,00
GRAY RODS CONTROL
MODE AUTO
SPEED 0,00 %/s
AVE POS 7,0 %
POWER ERROR
0,000 %
DERIVATIVE
ACTUAL SETPOINT
100,00 %FP
DEMANDED RATE SETPOINT
0,000 %FP/s
Current Reactor Pwr (%)
100,00
BORON CTRL
MODE AUTO
LOAD 212,000 ppm
MAN CTRL
ACT
DMD
Actual & Demanded SP (%)
Flux Tilt Error (%)
GRD
DRD
Dark & Gray Rods Avg Pos (%)
Reactivity Change - Delta
REACTOR LEAD POWER DEMAND SETPOINT
100,00 %FP
TOP FLUX (%)
97,00
BOTTOM FLUX (%)
94,00
DARK RODS CTRL
MODE AUTO
SPEED 0,00 %/s
AVE POS 14,0 %
PWR RATE 0,00 %/s
Resolution
Max Out
Max In
Time Scroll
17:54:39
Reactor Power Control
Reactor Trip
Turbine Trip
Reactor Neutron Pwr (%) 100,00
Reactor Thermal Pwr(%) 100,00
Generator Output(%) 100,00
Primary Coolant Pressure (kPa) 15515,00
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BOP STM Flow 1074,0
FW Flow 1020,0
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Freeze
Run
IC
Malf

Reactor Trip	Turbine Trip	RC Press Lo Lo	Step Back Req'd	Setback Req'd	Turbine Runback	Gen Breaker Opn
Hi Neutron Pwr	RC Press Hi Hi	Coolant Flow Lo	Stm Gen Level Lo	PRZR Lvl Hi	Low Fwd Pwr Trip	Main BFP(s) Trip
Hi Neut Pwr LogR	RC Press Hi	Main Stm Pres Hi	Stm Gen Level Hi	Turbine Gov in Man	Loss RC Pmp(s)	Malfunction Active

REACTOR TRIP PARAMETERS

FIRST OUT **SCRAM CAUSES**

- Low Coolant Pressure Trip
- Low Steam Generator Level Trip
- High Coolant Pressure Trip
- High Neutron Flux Trip
- High Log Rate Trip
- Low Coolant Flow Trip
- Low Pressurizer Level Trip
- Low Feedwater Discharge Header Pressure Trip
- High Steam Flow Trip
- Departure from Nucleate Boiling (DNB) Trip
- Containment High Pressure Trip
- Manual Trip

SDS Reactor Trip Setpoint For High Neutron Flux 120,0 %FP

REACTOR STEPBACK CAUSES

- Hi RC Pressure
- Loss of 1 RC Pump
- Loss of 2 RC Pumps
- Hi Log Rate
- Manual Stepback
- Hi Zone Flux

Press to clear

REACTOR SETPBACK CAUSES

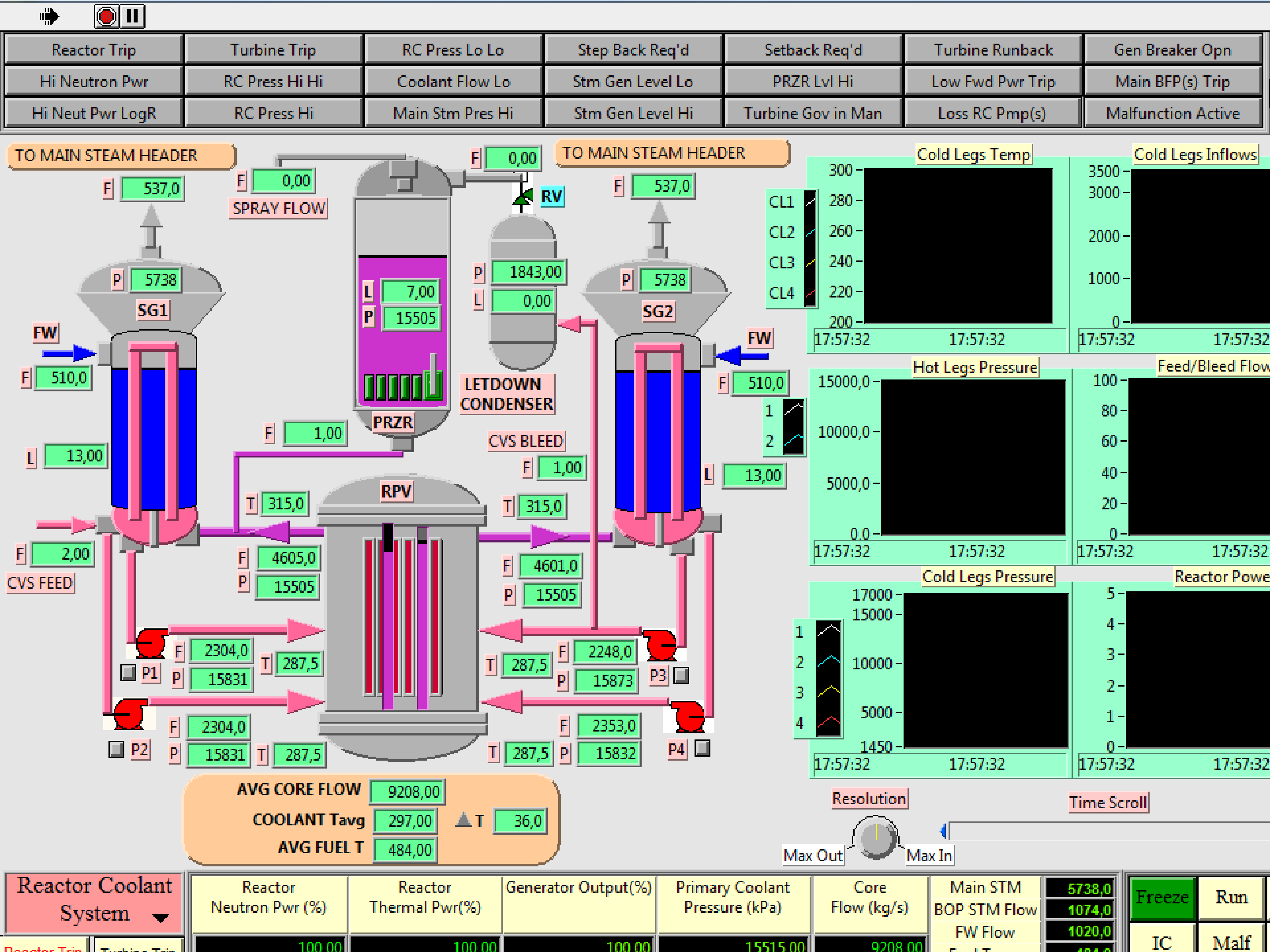
- Main Steam Header Press H
- Hi Pressurizer Level
- Manual Setback in progress
- Lo Steam Generator Level
- Lo Deaerator Level
- Hi Flux Tilt
- Hi Zonal Flux

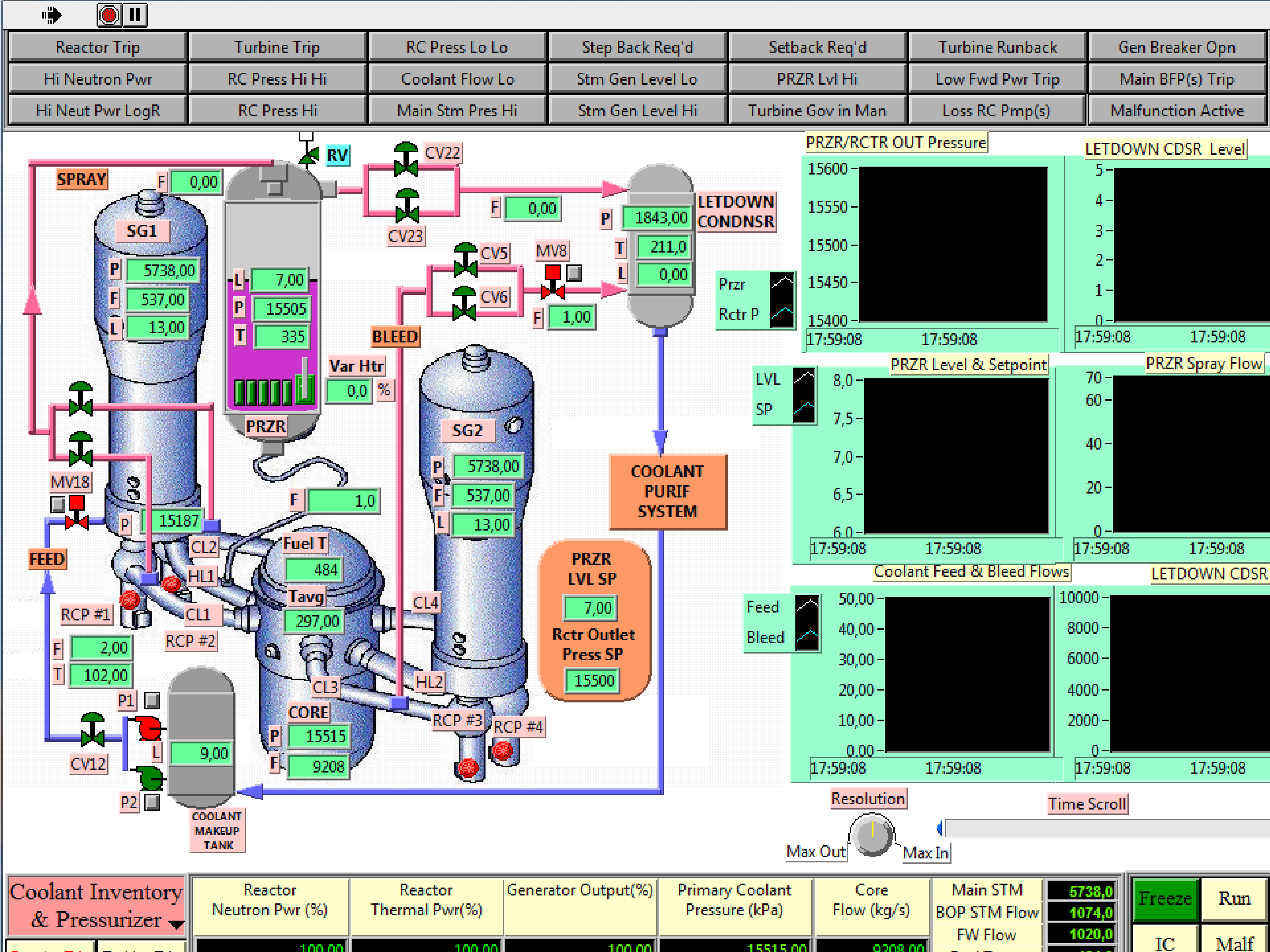
Press to clear

Trip Parameters

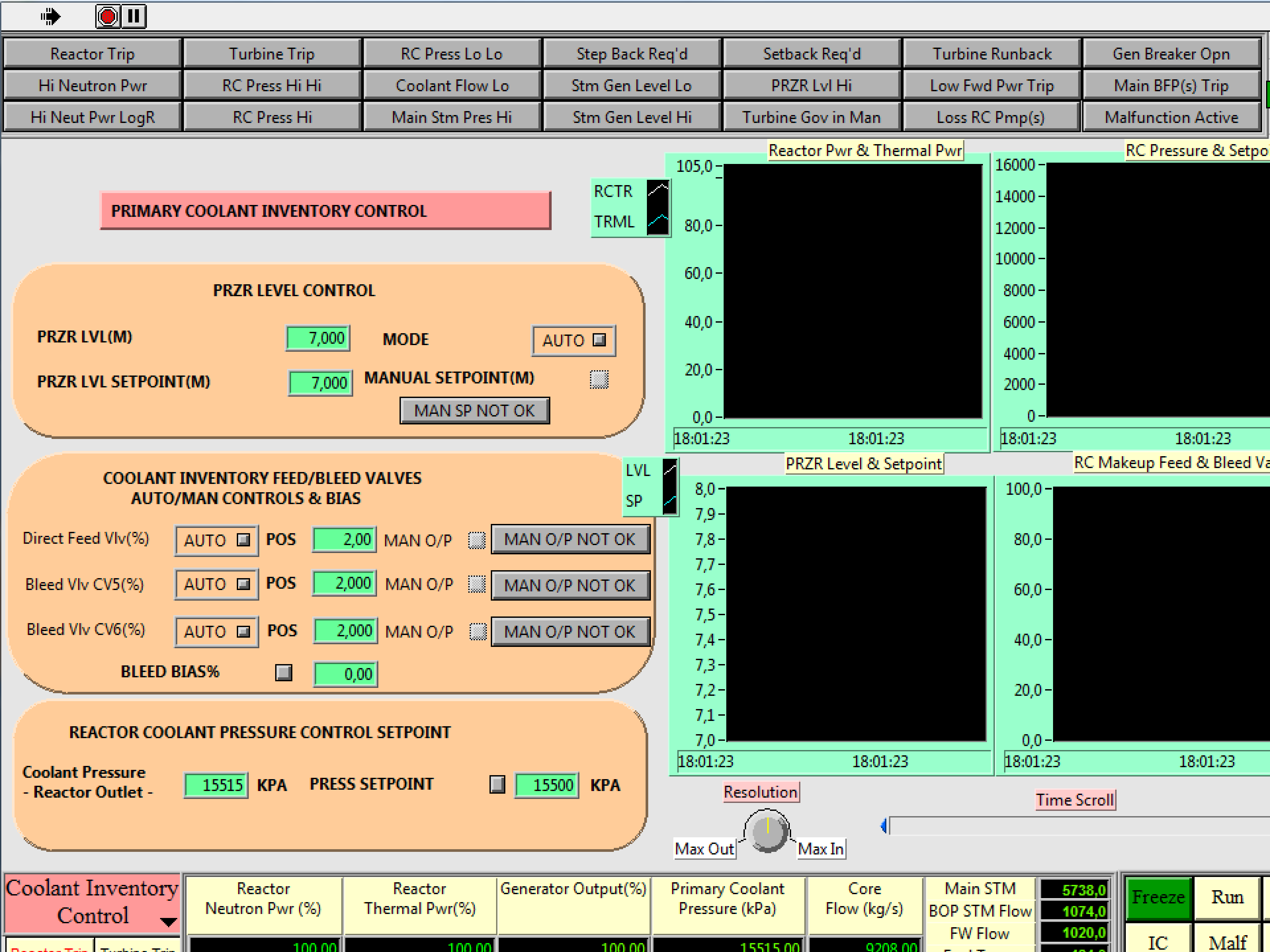
Reactor Neutron Pwr (%)	Reactor Thermal Pwr(%)	Generator Output(%)	Primary Coolant Pressure (kPa)	Core Flow (kg/s)	Main STM / BOP STM Flow / FW Flow
100,00	100,00	100,00	15515,00	9208,00	5738,0 / 1074,0 / 1020,0

Freeze Run IC Malf

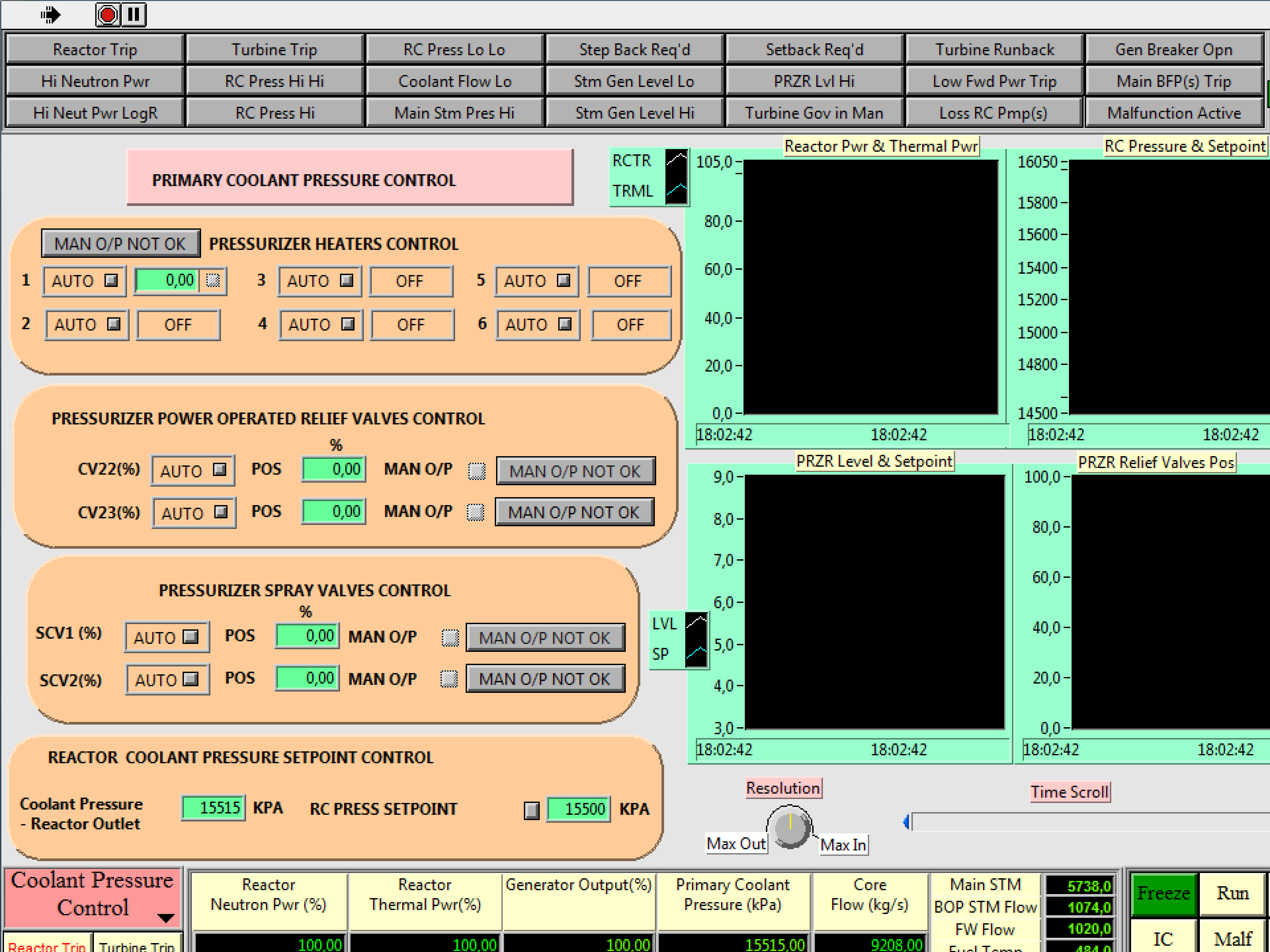

Reactor Trip
Turbine Trip
RC Press Lo Lo
Step Back Req'd
Setback Req'd
Turbine Runback
Gen Breaker Opn
Hi Neutron Pwr
RC Press Hi Hi
Coolant Flow Lo
Stm Gen Level Lo
PRZR Lvl Hi
Low Fwd Pwr Trip
Main BFP(s) Trip
Hi Neut Pwr LogR
RC Press Hi
Main Stm Pres Hi
Stm Gen Level Hi
Turbine Gov in Man
Loss RC Pmp(s)
Malfunction Active
TO MAIN STEAM HEADER
F 537,0
F 0,00
SPRAY FLOW
F 0,00
RV
TO MAIN STEAM HEADER
F 537,0
P 5738
SG1
L 7,00
P 15505
P 1843,00
L 0,00
P 5738
SG2
FW
F 510,0
PRZR
LETDOWN CONDENSER
FW
F 510,0
L 13,00
F 1,00
CVS BLEED
F 1,00
L 13,00
RPV
T 315,0
T 315,0
F 2,00
CVS FEED
F 4605,0
P 15505
F 4601,0
P 15505
F 2304,0
P1
P 15831
T 287,5
T 287,5
F 2248,0
P 15873
P3
F 2304,0
P2
P 15831
T 287,5
T 287,5
F 2353,0
P 15832
P4
AVG CORE FLOW 9208,00
COOLANT Tavg 297,00
ΔT 36,0
AVG FUEL T 484,00
Cold Legs Temp
CL1
CL2
CL3
CL4
300
280
260
240
220
200
17:57:32
17:57:32
Cold Legs Inflows
3500
3000
2000
1000
0
17:57:32
17:57:32
Hot Legs Pressure
15000,0
10000,0
5000,0
0,0
1
2
17:57:32
17:57:32
Feed/Bleed Flow
100
80
60
40
20
0
17:57:32
17:57:32
Cold Legs Pressure
17000
15000
10000
5000
1450
1
2
3
4
17:57:32
17:57:32
Reactor Powe
5
4
3
2
1
0
17:57:32
17:57:32
Resolution
Max Out
Max In
Time Scroll
Reactor Coolant System
Reactor Neutron Pwr (%)
Reactor Thermal Pwr(%)
Generator Output(%)
Primary Coolant Pressure (kPa)
Core Flow (kg/s)
Main STM
BOP STM Flow
FW Flow
5738,0
1074,0
1020,0
Freeze
Run
IC
Malf
100,00
100,00
100,00
15515,00
9208,00



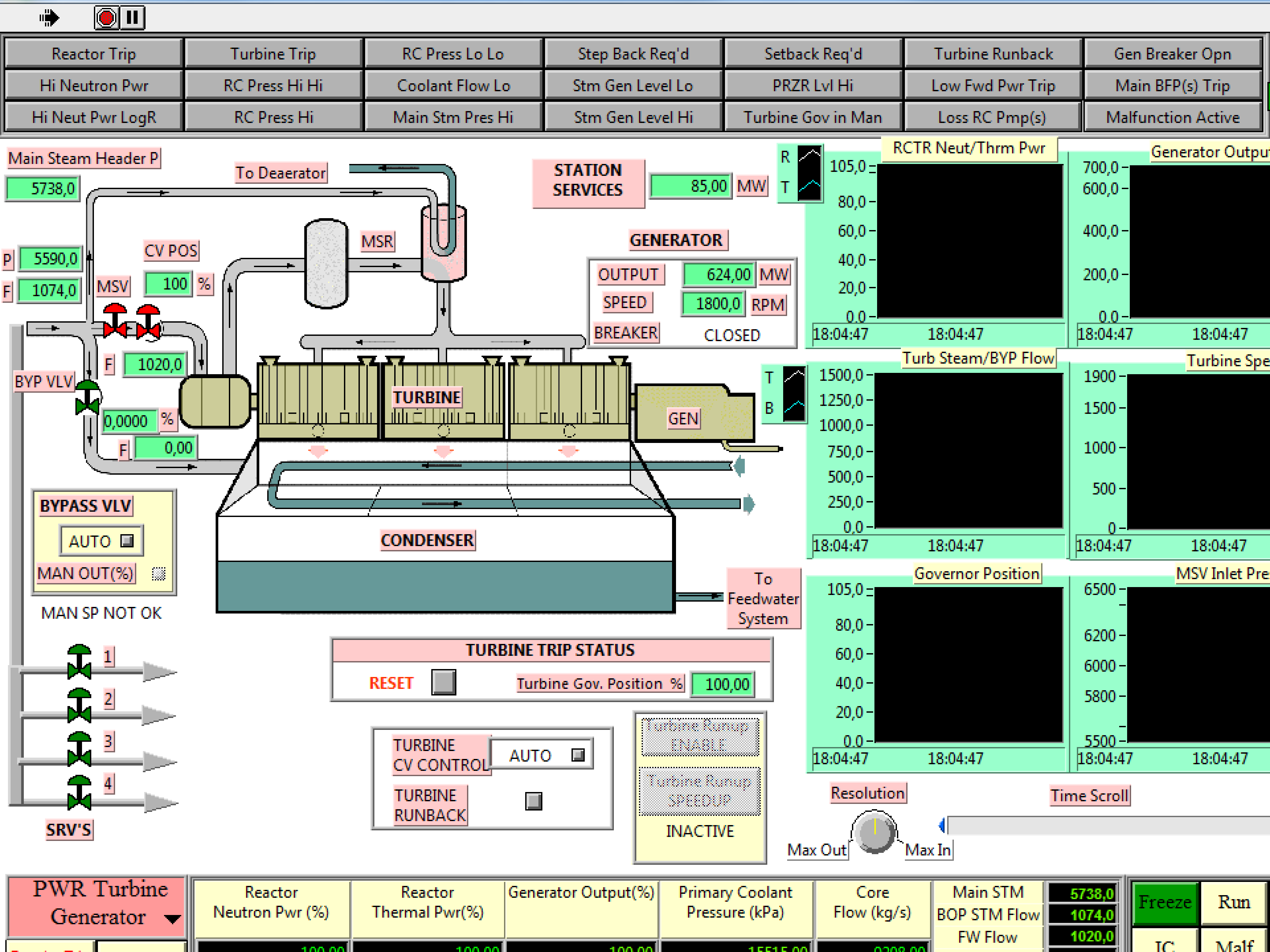
Reactor Trip
Turbine Trip
RC Press Lo Lo
Step Back Req'd
Setback Req'd
Turbine Runback
Gen Breaker Opn
Hi Neutron Pwr
RC Press Hi Hi
Coolant Flow Lo
Stm Gen Level Lo
PRZR Lvl Hi
Low Fwd Pwr Trip
Main BFP(s) Trip
Hi Neut Pwr LogR
RC Press Hi
Main Stm Pres Hi
Stm Gen Level Hi
Turbine Gov in Man
Loss RC Pmp(s)
Malfunction Active
RV
CV22
SPRAY
F 0,00
F 0,00
CV23
LETDOWN CONDNSR
P 1843,00
T 211,0
L 0,00
SG1
P 5738,00
F 537,00
L 13,00
L 7,00
P 15505
T 335
CV5
CV6
MV8
F 1,00
BLEED
Var Htr
0,0 %
PRZR
SG2
P 5738,00
F 537,00
L 13,00
MV18
P 15187
F 1,0
CL2
Fuel T
484
HL1
Tavg
297,00
CL1
CL4
FEED
RCP #1
RCP #2
F 2,00
T 102,00
P1
CV12
P2
L 9,00
CL3
HL2
CORE
P 15515
F 9208
RCP #3
RCP #4
COOLANT PURIF SYSTEM
PRZR LVL SP
7,00
Rctr Outlet Press SP
15500
COOLANT MAKEUP TANK
PRZR/RCTR OUT Pressure
15600
15550
15500
15450
15400
17:59:08
Przr
Rctr P
LETDOWN CDSR Level
5
4
3
2
1
0
PRZR Level & Setpoint
LVL
SP
8,0
7,5
7,0
6,5
6,0
PRZR Spray Flow
70
60
40
20
0
Coolant Feed & Bleed Flows
Feed
Bleed
50,00
40,00
30,00
20,00
10,00
0,00
LETDOWN CDSR
10000
8000
6000
4000
2000
0
Resolution
Max Out
Max In
Time Scroll
Coolant Inventory & Pressurizer
Reactor Neutron Pwr (%)
100,00
Reactor Thermal Pwr(%)
100,00
Generator Output(%)
100,00
Primary Coolant Pressure (kPa)
15515,00
Core Flow (kg/s)
9208,00
Main STM
BOP STM Flow
FW Flow
5738,0
1074,0
1020,0
Freeze
Run
IC
Malf



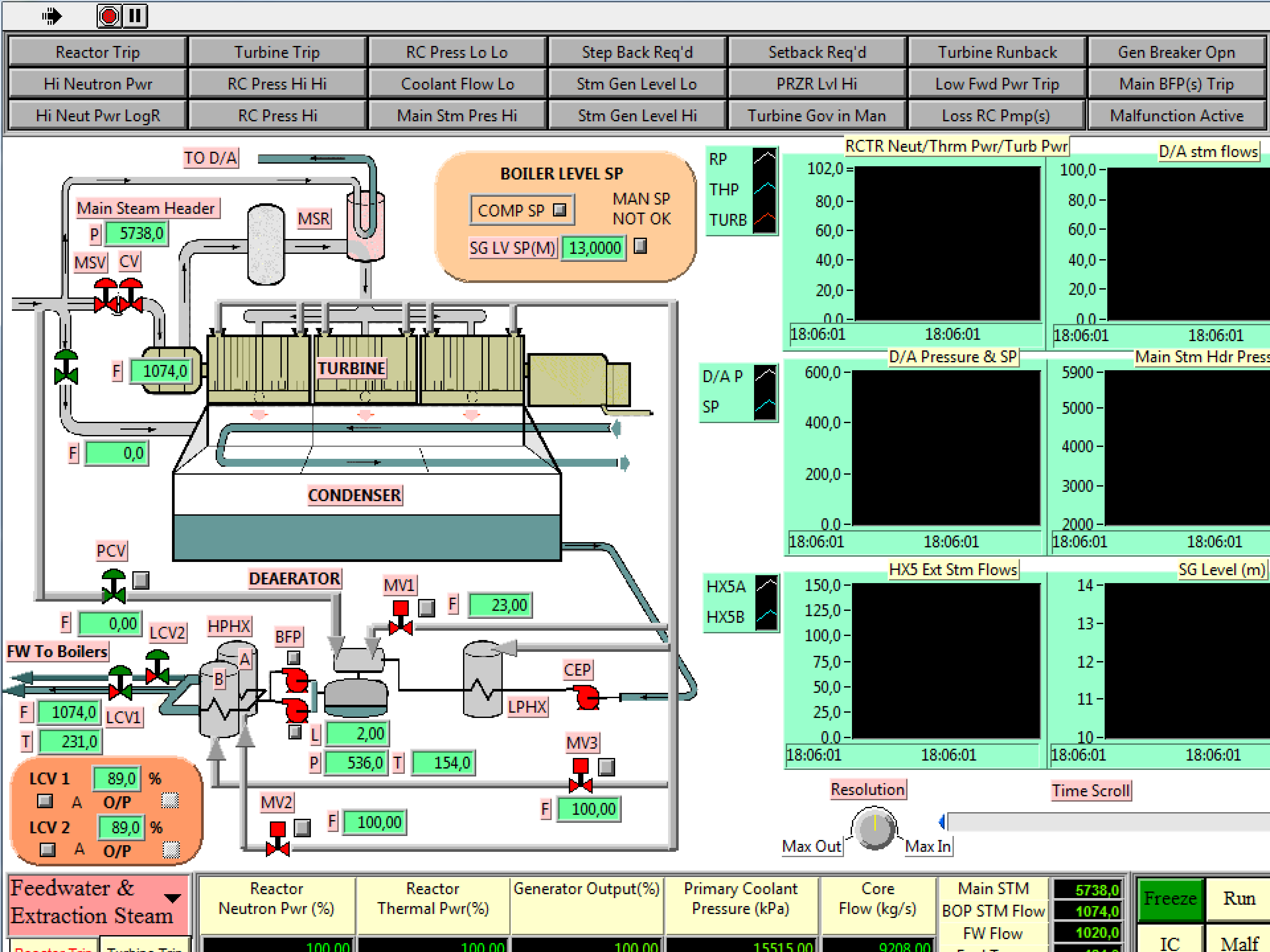
Reactor Trip
Turbine Trip
RC Press Lo Lo
Step Back Req'd
Setback Req'd
Turbine Runback
Gen Breaker Opn
Hi Neutron Pwr
RC Press Hi Hi
Coolant Flow Lo
Stm Gen Level Lo
PRZR Lvl Hi
Low Fwd Pwr Trip
Main BFP(s) Trip
Hi Neut Pwr LogR
RC Press Hi
Main Stm Pres Hi
Stm Gen Level Hi
Turbine Gov in Man
Loss RC Pmp(s)
Malfunction Active
PRIMARY COOLANT INVENTORY CONTROL
PRZR LEVEL CONTROL
PRZR LVL(M) 7,000
MODE AUTO
PRZR LVL SETPOINT(M) 7,000
MANUAL SETPOINT(M)
MAN SP NOT OK
COOLANT INVENTORY FEED/BLEED VALVES
AUTO/MAN CONTROLS & BIAS
Direct Feed Vlv(%) AUTO POS 2,00 MAN O/P MAN O/P NOT OK
Bleed Vlv CV5(%) AUTO POS 2,000 MAN O/P MAN O/P NOT OK
Bleed Vlv CV6(%) AUTO POS 2,000 MAN O/P MAN O/P NOT OK
BLEED BIAS% 0,00
REACTOR COOLANT PRESSURE CONTROL SETPOINT
Coolant Pressure
- Reactor Outlet - 15515 KPA
PRESS SETPOINT 15500 KPA
Reactor Pwr & Thermal Pwr
RCTR
TRML
105,0
80,0
60,0
40,0
20,0
0,0
18:01:23
18:01:23
RC Pressure & Setpo
16000
14000
12000
10000
8000
6000
4000
2000
0
18:01:23
18:01:23
PRZR Level & Setpoint
LVL
SP
8,0
7,9
7,8
7,7
7,6
7,5
7,4
7,3
7,2
7,1
7,0
18:01:23
18:01:23
RC Makeup Feed & Bleed Va
100,0
80,0
60,0
40,0
20,0
0,0
18:01:23
18:01:23
Resolution
Max Out
Max In
Time Scroll
Coolant Inventory Control
Reactor Neutron Pwr (%)
Reactor Thermal Pwr(%)
Generator Output(%)
Primary Coolant Pressure (kPa)
Core Flow (kg/s)
Main STM
BOP STM Flow
FW Flow
5738,0
1074,0
1020,0
Freeze
Run
IC
Malf



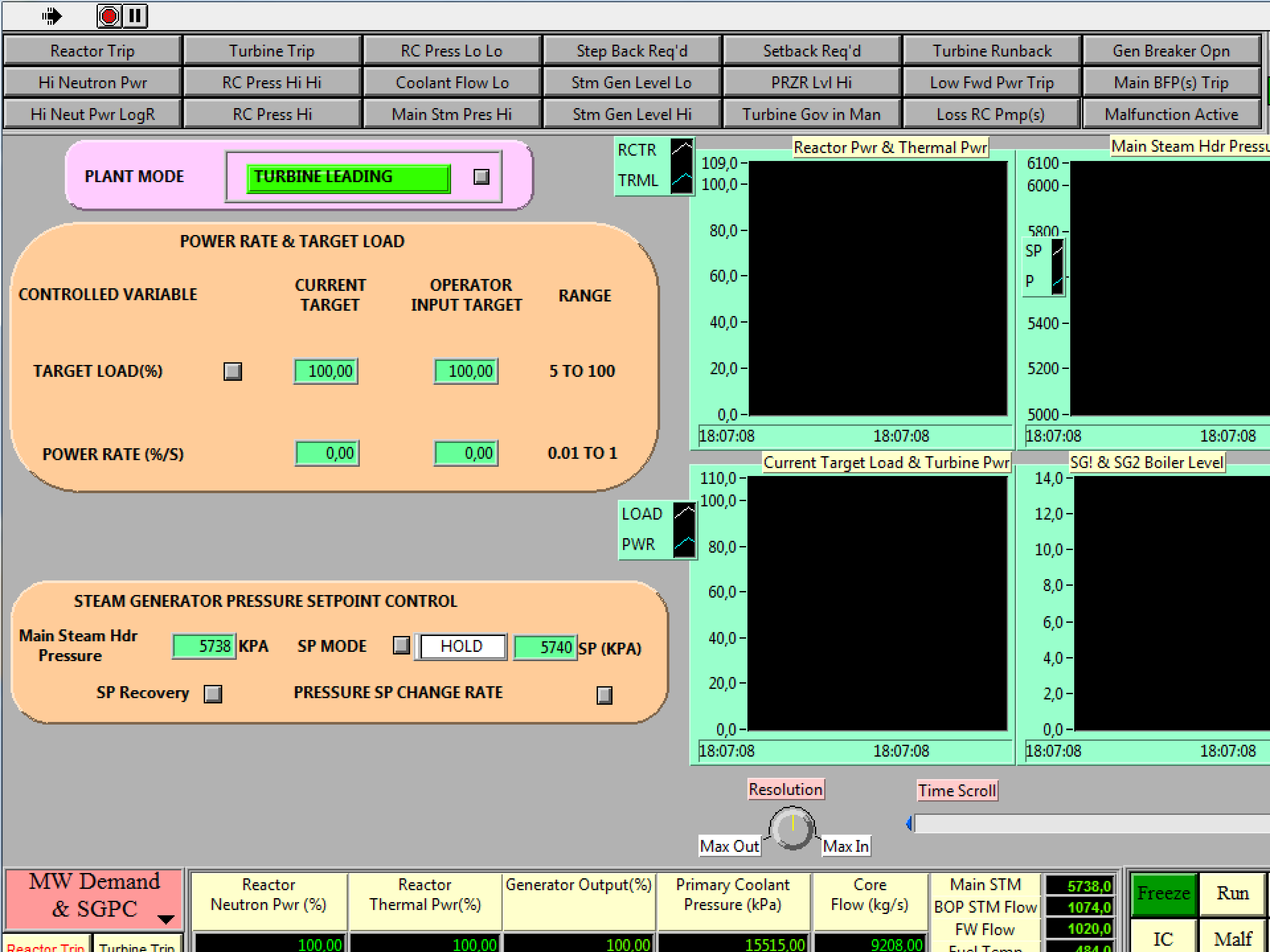
Reactor Trip
Turbine Trip
RC Press Lo Lo
Step Back Req'd
Setback Req'd
Turbine Runback
Gen Breaker Opn
Hi Neutron Pwr
RC Press Hi Hi
Coolant Flow Lo
Stm Gen Level Lo
PRZR Lvl Hi
Low Fwd Pwr Trip
Main BFP(s) Trip
Hi Neut Pwr LogR
RC Press Hi
Main Stm Pres Hi
Stm Gen Level Hi
Turbine Gov in Man
Loss RC Pmp(s)
Malfunction Active
PRIMARY COOLANT PRESSURE CONTROL
MAN O/P NOT OK
PRESSURIZER HEATERS CONTROL
1 AUTO 0,00
2 AUTO OFF
3 AUTO OFF
4 AUTO OFF
5 AUTO OFF
6 AUTO OFF
PRESSURIZER POWER OPERATED RELIEF VALVES CONTROL
%
CV22(%) AUTO POS 0,00 MAN O/P MAN O/P NOT OK
CV23(%) AUTO POS 0,00 MAN O/P MAN O/P NOT OK
PRESSURIZER SPRAY VALVES CONTROL
%
SCV1 (%) AUTO POS 0,00 MAN O/P MAN O/P NOT OK
SCV2(%) AUTO POS 0,00 MAN O/P MAN O/P NOT OK
REACTOR COOLANT PRESSURE SETPOINT CONTROL
Coolant Pressure - Reactor Outlet 15515 KPA
RC PRESS SETPOINT 15500 KPA
RCTR
TRML
Reactor Pwr & Thermal Pwr
105,0
80,0
60,0
40,0
20,0
0,0
18:02:42
18:02:42
RC Pressure & Setpoint
16050
15800
15600
15400
15200
15000
14800
14500
18:02:42
18:02:42
PRZR Level & Setpoint
9,0
8,0
7,0
6,0
5,0
4,0
3,0
LVL
SP
18:02:42
18:02:42
PRZR Relief Valves Pos
100,0
80,0
60,0
40,0
20,0
0,0
18:02:42
18:02:42
Resolution
Max Out
Max In
Time Scroll
Coolant Pressure Control
Reactor Trip
Turbine Trip
Reactor Neutron Pwr (%)
100,00
Reactor Thermal Pwr(%)
100,00
Generator Output(%)
100,00
Primary Coolant Pressure (kPa)
15515,00
Core Flow (kg/s)
9208,00
Main STM
5738,0
BOP STM Flow
1074,0
FW Flow
1020,0
Freeze
Run
IC
Malf

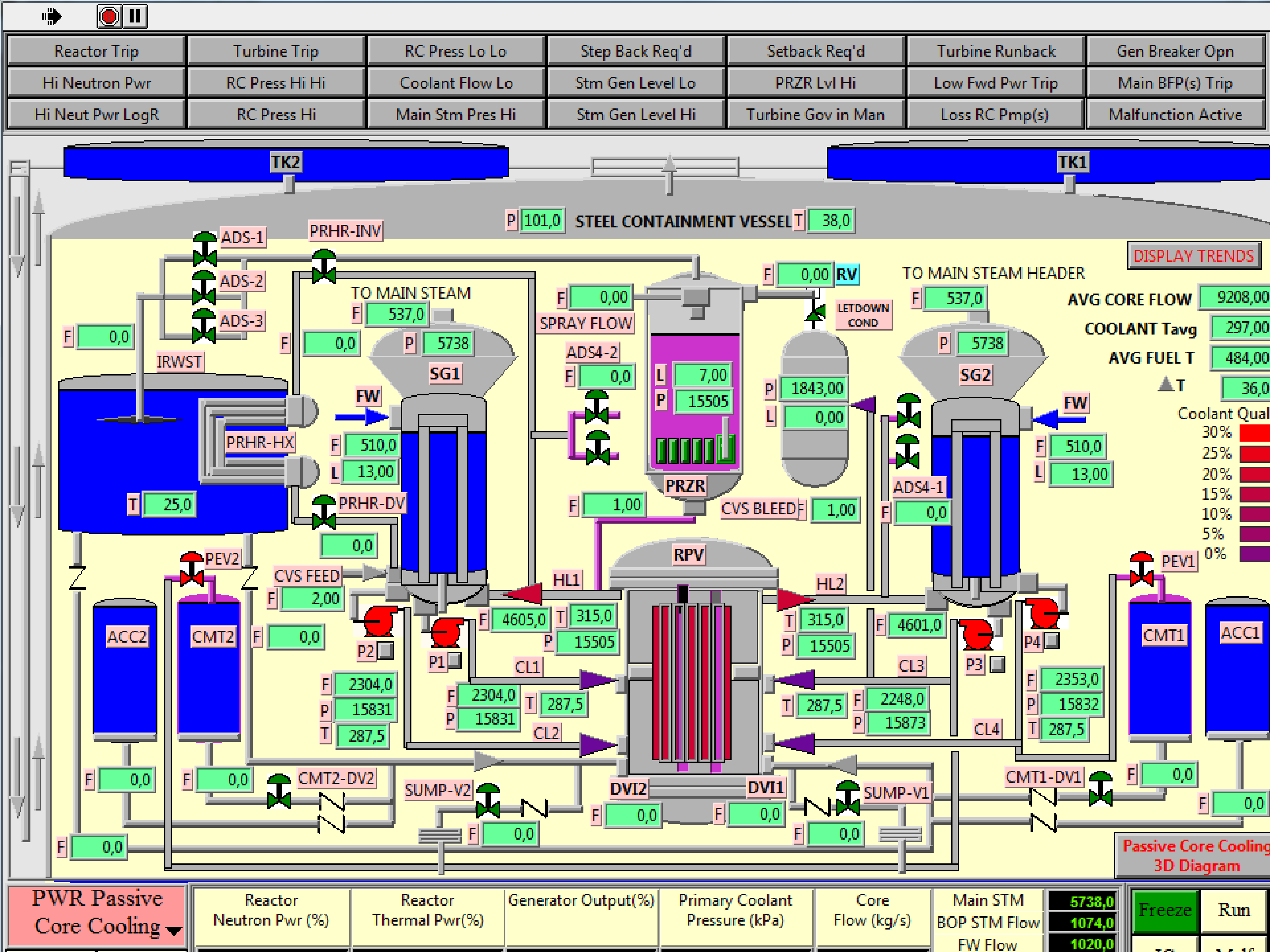


Reactor Trip
Turbine Trip
RC Press Lo Lo
Step Back Req'd
Setback Req'd
Turbine Runback
Gen Breaker Opn
Hi Neutron Pwr
RC Press Hi Hi
Coolant Flow Lo
Stm Gen Level Lo
PRZR Lvl Hi
Low Fwd Pwr Trip
Main BFP(s) Trip
Hi Neut Pwr LogR
RC Press Hi
Main Stm Pres Hi
Stm Gen Level Hi
Turbine Gov in Man
Loss RC Pmp(s)
Malfunction Active
Main Steam Header P
5738,0
To Deaerator
STATION SERVICES
85,00 MW
P 5590,0
F 1074,0
CV POS
100 %
MSV
MSR
GENERATOR
OUTPUT 624,00 MW
SPEED 1800,0 RPM
BREAKER CLOSED
F 1020,0
BYP VLV
0,0000 %
F 0,00
TURBINE
GEN
CONDENSER
BYPASS VLV
AUTO
MAN OUT(%)
MAN SP NOT OK
To Feedwater System
TURBINE TRIP STATUS
RESET
Turbine Gov. Position %
100,00
1
2
3
4
SRV'S
TURBINE CV CONTROL
AUTO
TURBINE RUNBACK
Turbine Runup ENABLE
Turbine Runup SPEEDUP
INACTIVE
RCTR Neut/Thrm Pwr
R
T
Generator Output
Turb Steam/BYP Flow
B
Turbine Spe
Governor Position
MSV Inlet Pre
18:04:47
Resolution
Time Scroll
Max Out
Max In
PWR Turbine Generator
Reactor Neutron Pwr (%)
Reactor Thermal Pwr(%)
Generator Output(%)
Primary Coolant Pressure (kPa)
Core Flow (kg/s)
Main STM
BOP STM Flow
FW Flow
5738,0
1074,0
1020,0
Freeze
Run
IC
Malf

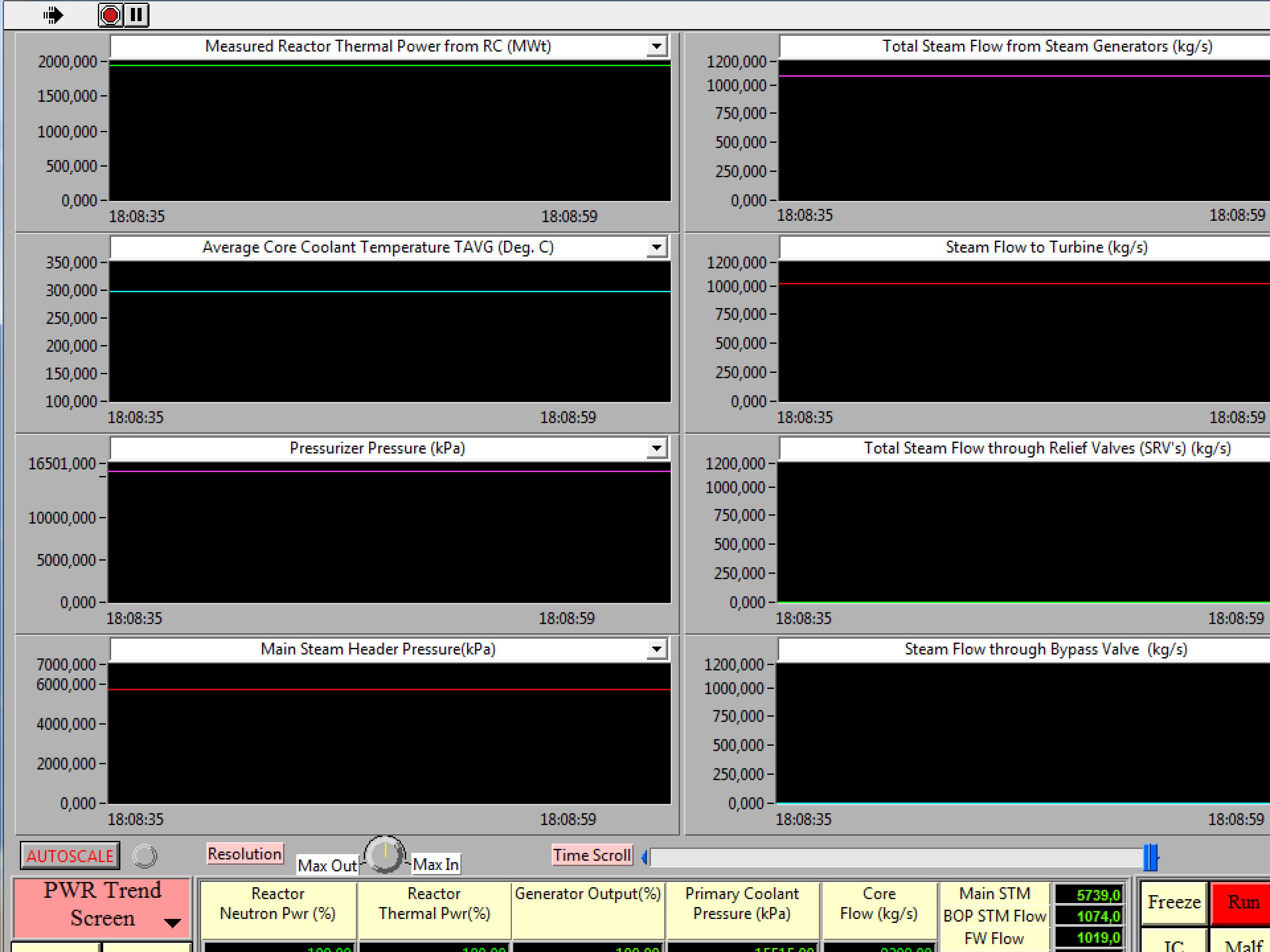


Reactor Trip
Turbine Trip
RC Press Lo Lo
Step Back Req'd
Setback Req'd
Turbine Runback
Gen Breaker Opn
Hi Neutron Pwr
RC Press Hi Hi
Coolant Flow Lo
Stm Gen Level Lo
PRZR Lvl Hi
Low Fwd Pwr Trip
Main BFP(s) Trip
Hi Neut Pwr LogR
RC Press Hi
Main Stm Pres Hi
Stm Gen Level Hi
Turbine Gov in Man
Loss RC Pmp(s)
Malfunction Active
TO D/A
Main Steam Header
P 5738,0
MSR
MSV
CV
F 1074,0
TURBINE
F 0,0
CONDENSER
BOILER LEVEL SP
COMP SP
MAN SP
NOT OK
SG LV SP(M) 13,0000
PCV
DEAERATOR
MV1
F 23,00
F 0,00
LCV2
HPHX
BFP
FW To Boilers
A
B
CEP
LPHX
F 1074,0
LCV1
T 231,0
L 2,00
P 536,0
T 154,0
MV3
LCV 1 89,0 %
A O/P
LCV 2 89,0 %
A O/P
MV2
F 100,00
F 100,00
RP
THP
TURB
RCTR Neut/Thrm Pwr/Turb Pwr
D/A stm flows
D/A P
SP
D/A Pressure & SP
Main Stm Hdr Press
HX5A
HX5B
HX5 Ext Stm Flows
SG Level (m)
18:06:01
Resolution
Time Scroll
Max Out
Max In
Feedwater & Extraction Steam
Reactor Neutron Pwr (%)
Reactor Thermal Pwr(%)
Generator Output(%)
Primary Coolant Pressure (kPa)
Core Flow (kg/s)
Main STM
BOP STM Flow
FW Flow
5738,0
1074,0
1020,0
Freeze
Run
IC
Malf


Reactor Trip
Turbine Trip
RC Press Lo Lo
Step Back Req'd
Setback Req'd
Turbine Runback
Gen Breaker Opn
Hi Neutron Pwr
RC Press Hi Hi
Coolant Flow Lo
Stm Gen Level Lo
PRZR Lvl Hi
Low Fwd Pwr Trip
Main BFP(s) Trip
Hi Neut Pwr LogR
RC Press Hi
Main Stm Pres Hi
Stm Gen Level Hi
Turbine Gov in Man
Loss RC Pmp(s)
Malfunction Active
PLANT MODE
TURBINE LEADING
POWER RATE & TARGET LOAD
CONTROLLED VARIABLE
CURRENT TARGET
OPERATOR INPUT TARGET
RANGE
TARGET LOAD(%)
100,00
100,00
5 TO 100
POWER RATE (%/S)
0,00
0,00
0.01 TO 1
STEAM GENERATOR PRESSURE SETPOINT CONTROL
Main Steam Hdr Pressure
5738
KPA
SP MODE
HOLD
5740
SP (KPA)
SP Recovery
PRESSURE SP CHANGE RATE
RCTR
TRML
Reactor Pwr & Thermal Pwr
109,0
100,0
80,0
60,0
40,0
20,0
0,0
18:07:08
18:07:08
Main Steam Hdr Pressu
6100
6000
5800
SP
P
5400
5200
5000
18:07:08
18:07:08
Current Target Load & Turbine Pwr
LOAD
PWR
110,0
100,0
80,0
60,0
40,0
20,0
0,0
18:07:08
18:07:08
SG! & SG2 Boiler Level
14,0
12,0
10,0
8,0
6,0
4,0
2,0
0,0
18:07:08
18:07:08
Resolution
Time Scroll
Max Out
Max In
MW Demand & SGPC
Reactor Trip
Turbine Trip
Reactor Neutron Pwr (%)
100,00
Reactor Thermal Pwr(%)
100,00
Generator Output(%)
100,00
Primary Coolant Pressure (kPa)
15515,00
Core Flow (kg/s)
9208,00
Main STM
5738,0
BOP STM Flow
1074,0
FW Flow
1020,0
Fuel Temp
484,0
Freeze
Run
IC
Malf



Reactor Trip
Turbine Trip
RC Press Lo Lo
Step Back Req'd
Setback Req'd
Turbine Runback
Gen Breaker Opn
Hi Neutron Pwr
RC Press Hi Hi
Coolant Flow Lo
Stm Gen Level Lo
PRZR Lvl Hi
Low Fwd Pwr Trip
Main BFP(s) Trip
Hi Neut Pwr LogR
RC Press Hi
Main Stm Pres Hi
Stm Gen Level Hi
Turbine Gov in Man
Loss RC Pmp(s)
Malfunction Active
TK2
TK1
P 101,0
STEEL CONTAINMENT VESSEL
T 38,0
DISPLAY TRENDS
ADS-1
ADS-2
ADS-3
PRHR-INV
TO MAIN STEAM
F 537,0
F 0,0
F 0,0
P 5738
SG1
IRWST
PRHR-HX
T 25,0
FW
F 510,0
L 13,00
PRHR-DV
0,0
F 0,00
SPRAY FLOW
ADS4-2
F 0,0
L 7,00
P 15505
PRZR
F 0,00
RV
LETDOWN COND
P 1843,00
L 0,00
TO MAIN STEAM HEADER
F 537,0
P 5738
SG2
FW
F 510,0
L 13,00
ADS4-1
F 0,0
AVG CORE FLOW 9208,00
COOLANT Tavg 297,00
AVG FUEL T 484,00
ΔT 36,0
Coolant Qual
30%
25%
20%
15%
10%
5%
0%
F 1,00
CVS BLEED
F 1,00
RPV
HL1
HL2
CVS FEED
F 2,00
F 0,0
PEV2
PEV1
ACC2
CMT2
CMT1
ACC1
F 4605,0
T 315,0
P 15505
T 315,0
P 15505
F 4601,0
P1
P2
P3
P4
CL1
CL2
CL3
CL4
F 2304,0
P 15831
T 287,5
F 2304,0
P 15831
T 287,5
T 287,5
F 2248,0
P 15873
F 2353,0
P 15832
T 287,5
F 0,0
F 0,0
CMT2-DV2
SUMP-V2
DVI2
DVI1
SUMP-V1
CMT1-DV1
F 0,0
F 0,0
F 0,0
F 0,0
F 0,0
F 0,0
F 0,0
F 0,0
Passive Core Cooling 3D Diagram
PWR Passive Core Cooling
Reactor Neutron Pwr (%)
Reactor Thermal Pwr(%)
Generator Output(%)
Primary Coolant Pressure (kPa)
Core Flow (kg/s)
Main STM
BOP STM Flow
FW Flow
5738,0
1074,0
1020,0
Freeze
Run



Measured Reactor Thermal Power from RC (MWt)
2000,000
1500,000
1000,000
500,000
0,000
18:08:35
18:08:59
Total Steam Flow from Steam Generators (kg/s)
1200,000
1000,000
750,000
500,000
250,000
0,000
18:08:35
18:08:59
Average Core Coolant Temperature TAVG (Deg. C)
350,000
300,000
250,000
200,000
150,000
100,000
18:08:35
18:08:59
Steam Flow to Turbine (kg/s)
1200,000
1000,000
750,000
500,000
250,000
0,000
18:08:35
18:08:59
Pressurizer Pressure (kPa)
16501,000
10000,000
5000,000
0,000
18:08:35
18:08:59
Total Steam Flow through Relief Valves (SRV's) (kg/s)
1200,000
1000,000
750,000
500,000
250,000
0,000
18:08:35
18:08:59
Main Steam Header Pressure(kPa)
7000,000
6000,000
4000,000
2000,000
0,000
18:08:35
18:08:59
Steam Flow through Bypass Valve (kg/s)
1200,000
1000,000
750,000
500,000
250,000
0,000
18:08:35
18:08:59
AUTOSCALE
Resolution
Max Out
Max In
Time Scroll
PWR Trend Screen
Reactor Neutron Pwr (%)
Reactor Thermal Pwr(%)
Generator Output(%)
Primary Coolant Pressure (kPa)
Core Flow (kg/s)
Main STM
BOP STM Flow
FW Flow
5739,0
1074,0
1019,0
Freeze
Run
IC
Malf

EXERCISES

PWR Operation

- Normal Operation:
  - Plant heatup and startup, operation at power, load following, plant shutdown, plant cooldown, refueling,…
- Abnormal Operation:
  - Loss of instrument air, feedwater system malfunction, uncontrolled cooldown, turbine trip…
- Emergency Operation:
  - Design Basis Accidents (SLB, LOCA, SGTR, FLB…)
  - Beyond Design Basis Accidents (includ. severe accidents)

Normal Operation
Exercise 1 (Power Reduction)

- **Plant is stable at full power conditions with the "TURBINE LEAD" mode.**

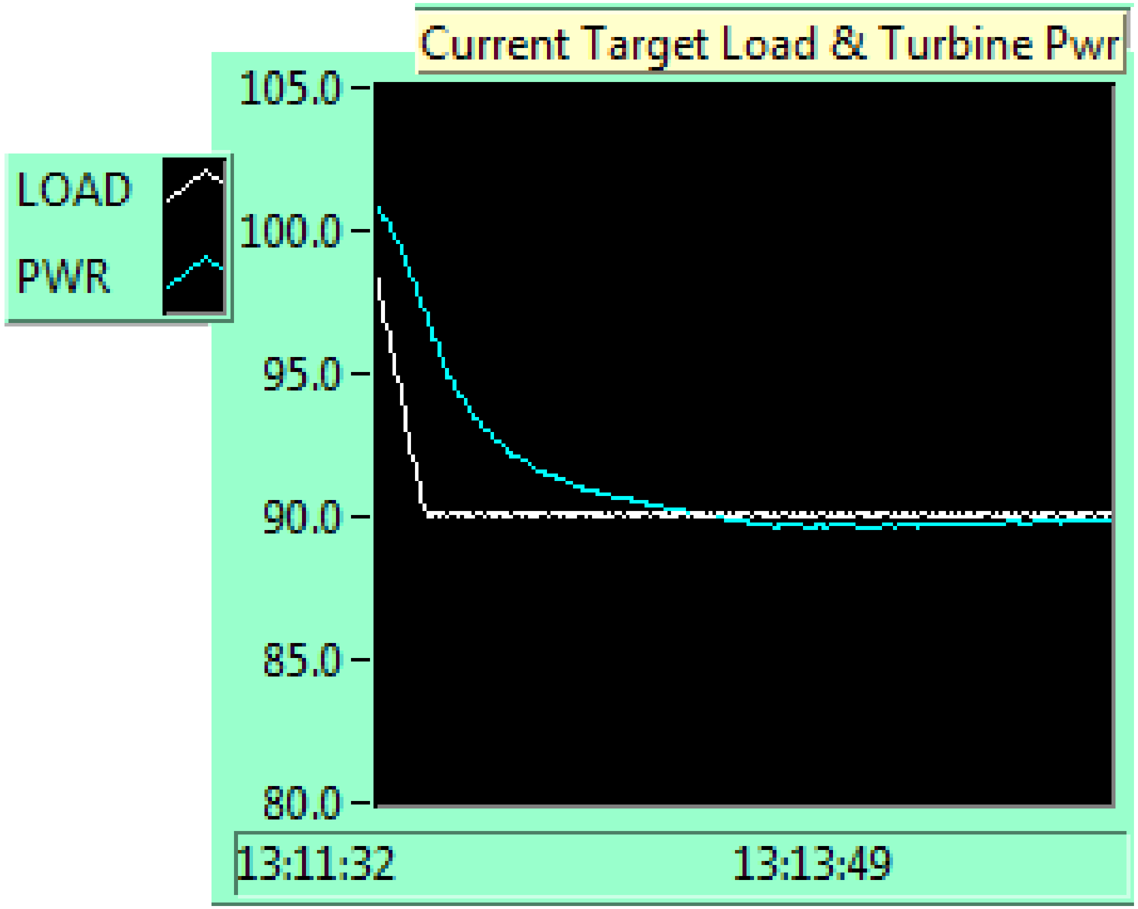
- **Load Dispatcher requests a 10% load reduction due to a big consumer disconnecting from the grid.**

Normal Operation Exercise 1 (Power Reduction)

- **Reduce the Turbine Load to 90% FP at a rate of <0.8%/sec by using the TURBINE LEAD mode.**
- **Describe the evolution of the following parameters:**
  - **Turbine Power**
  - **Reactor Neutron Power**
  - **Average Coolant Temperature**
  - **Pressurizer Pressure**
  - **Pressurizer Level**
  - **Gray Rods Average**
  - **Dark Rods Average**
  - **Boron Concentration**
  - **Main Steam Header Pressure**
  - **SG1&2 Boiler Levels**

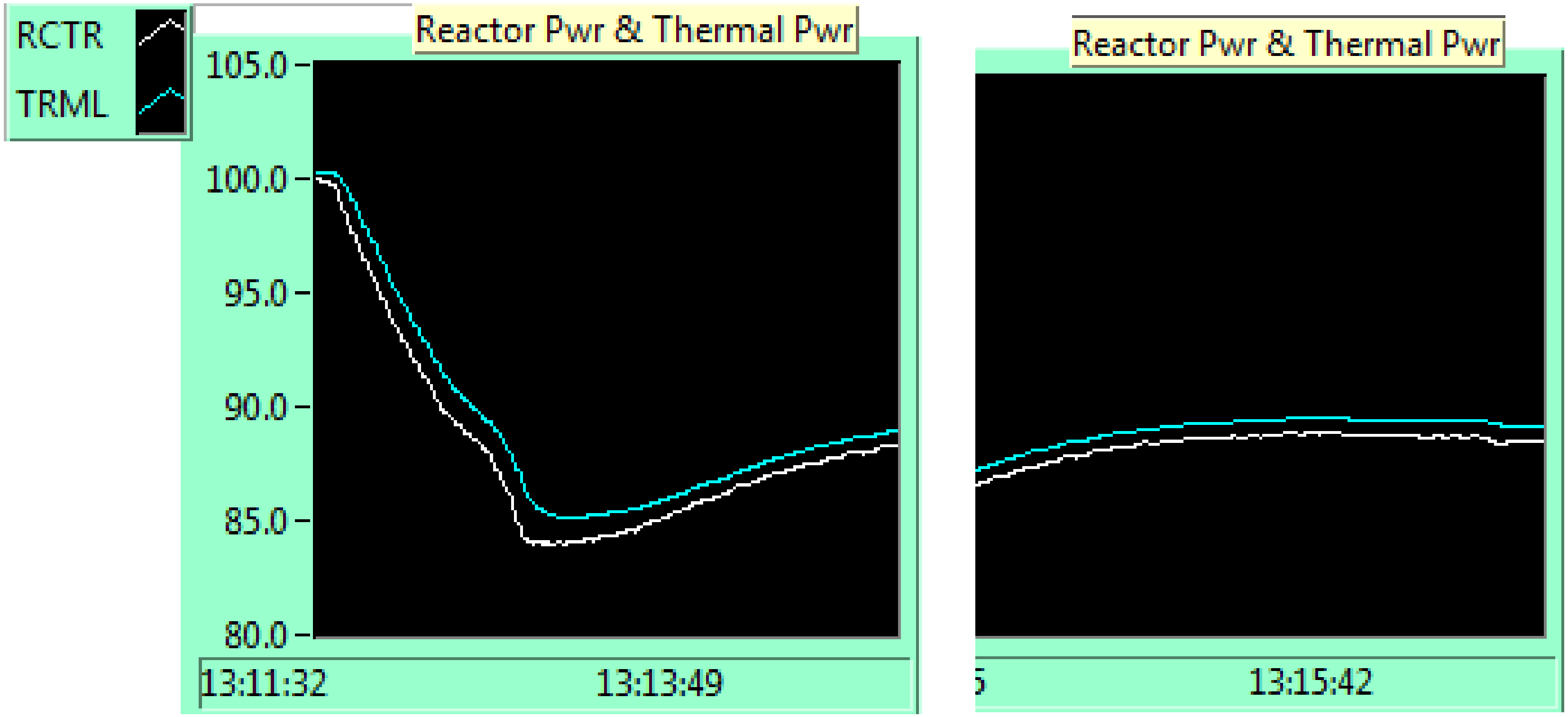
Normal Operation
Exercise 1 (Power Reduction)

- Turbine Power



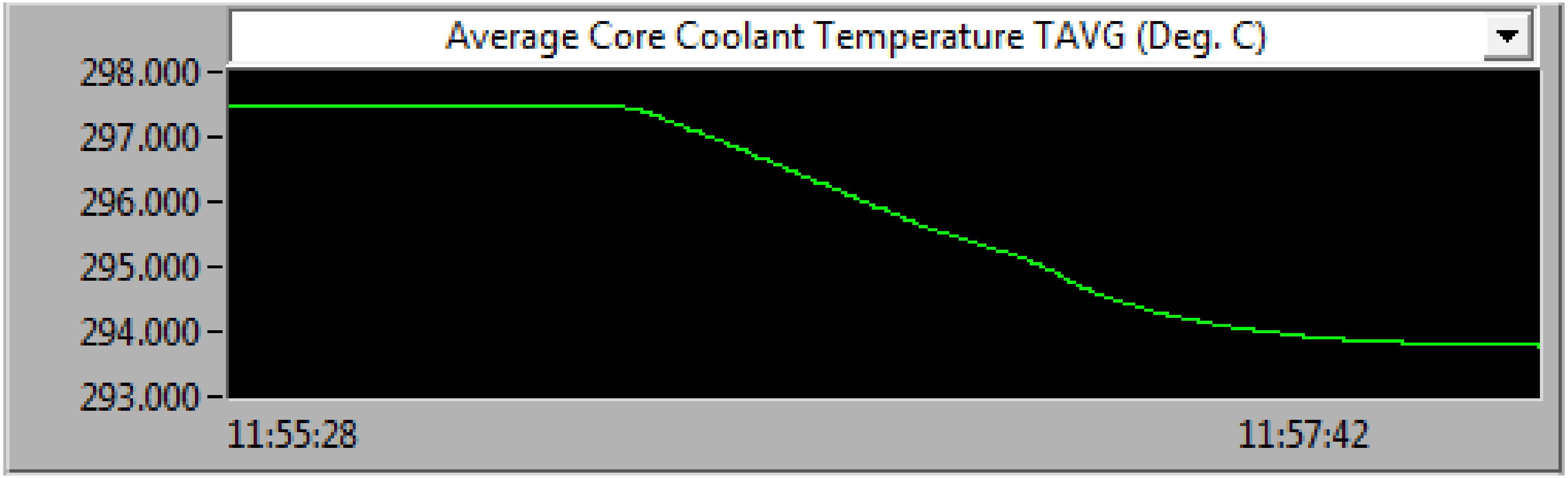
Normal Operation
Exercise 1 (Power Reduction)

- Reactor Neutron Power



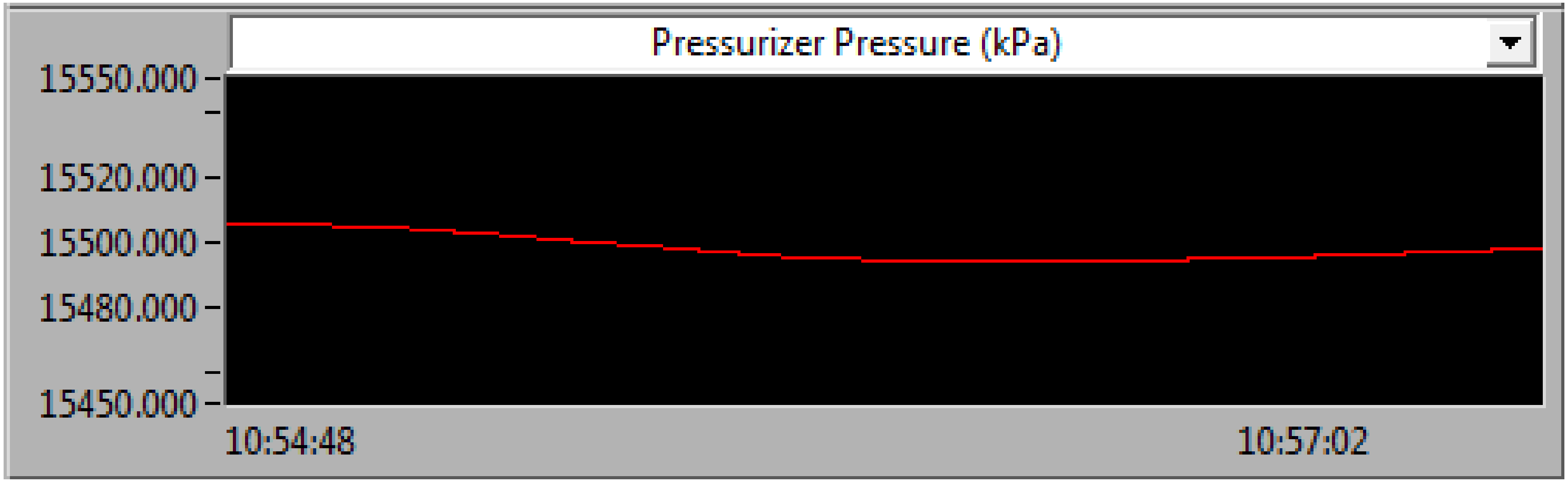
Normal Operation
Exercise 1 (Power Reduction)

- Average Coolant Temperature



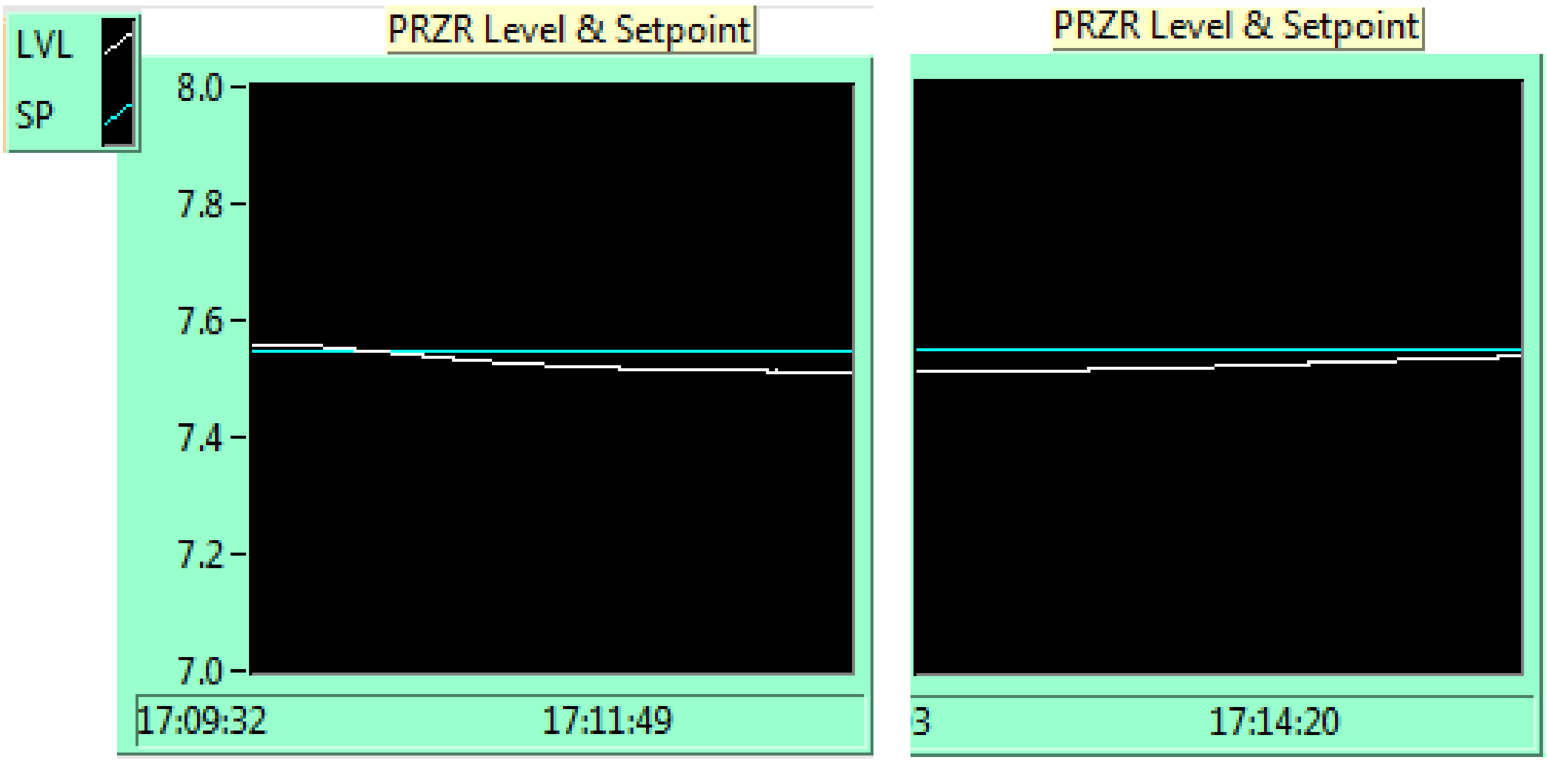
Normal Operation
Exercise 1 (Power Reduction)

- Pressurizer Pressure



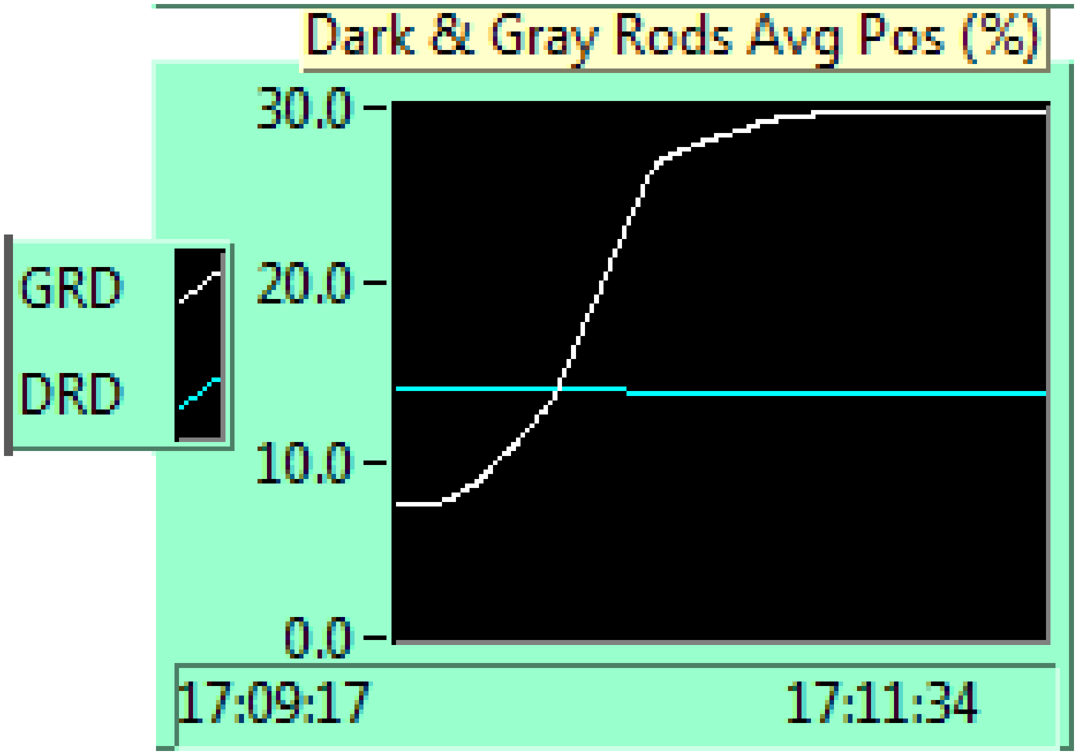
Normal Operation
Exercise 1 (Power Reduction)

- Pressurizer Level



Normal Operation
Exercise 1 (Power Reduction)

- Gray Rods Average & Dark Rods Average



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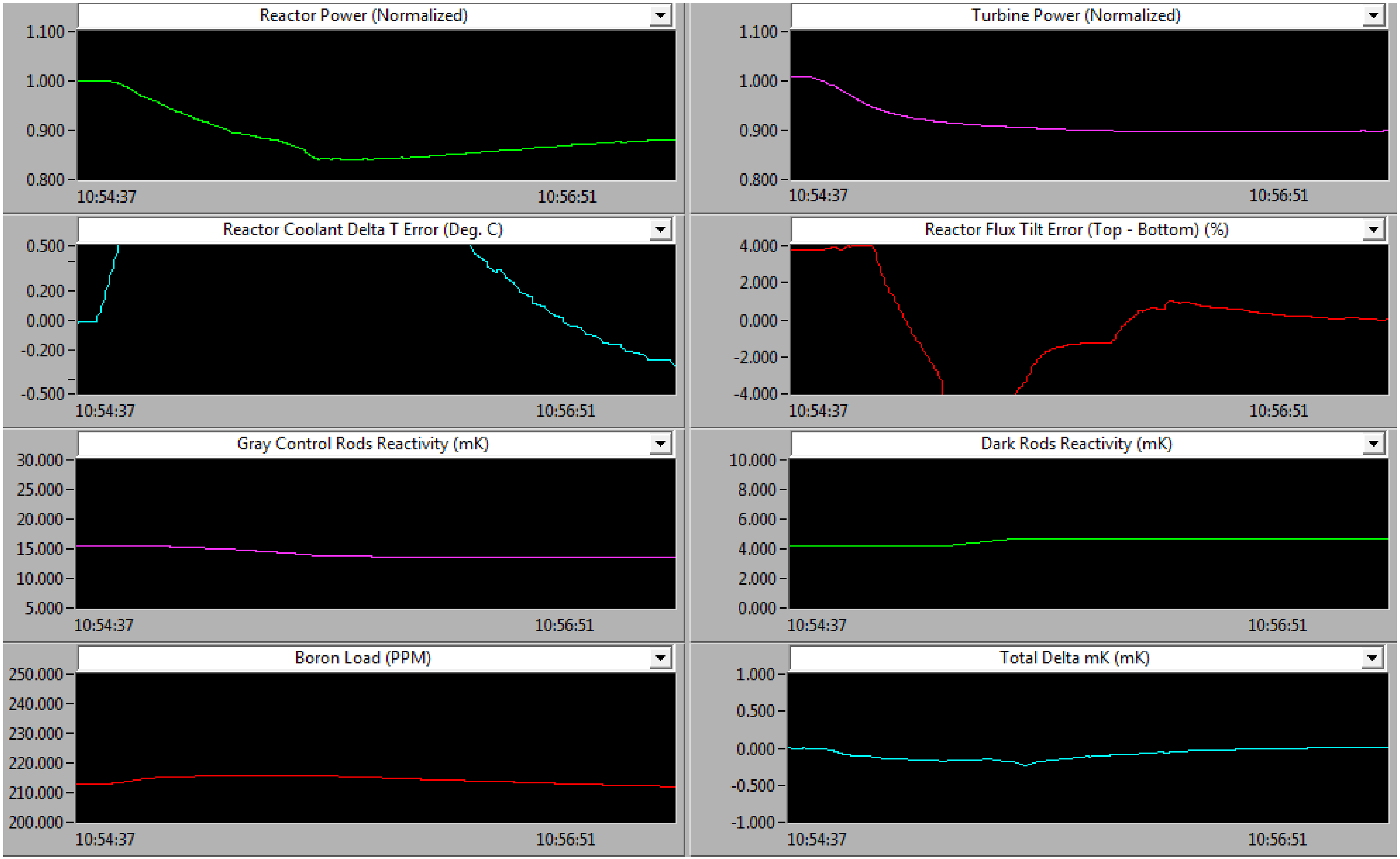
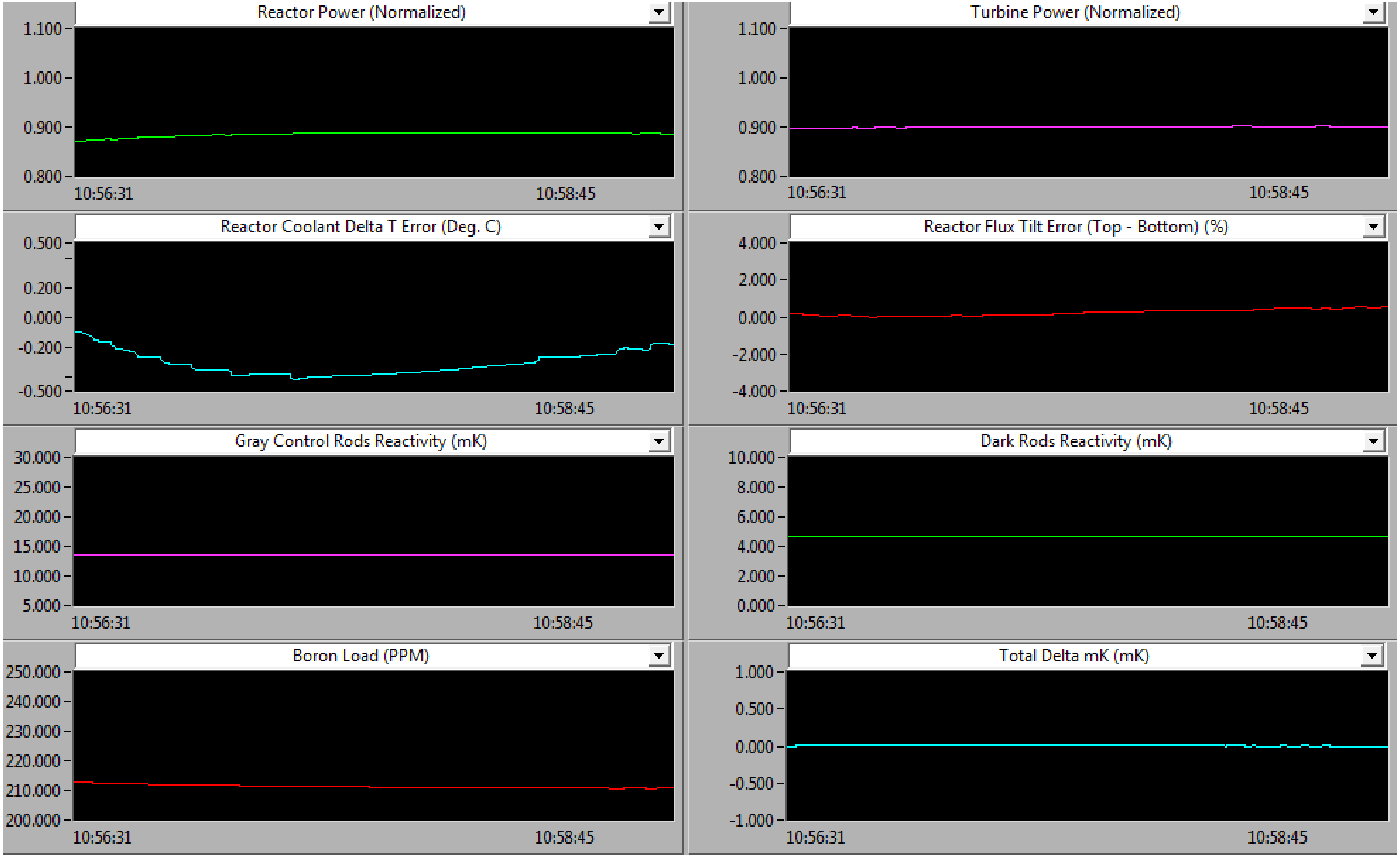
Normal Operation
Exercise 1 (Power Reduction)

- Sequence of reactivity changes



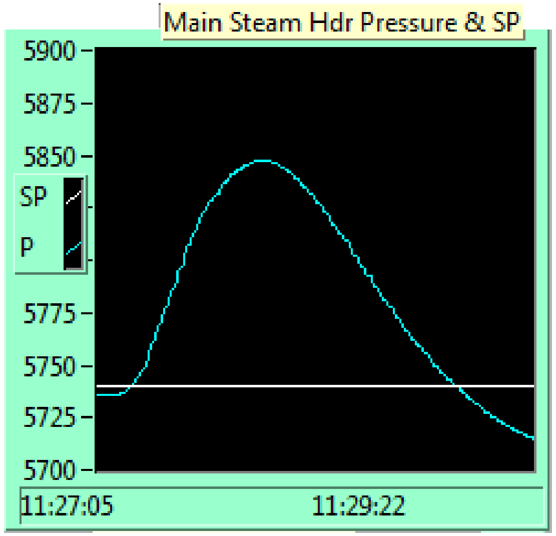
Normal Operation
Exercise 1 (Power Reduction)

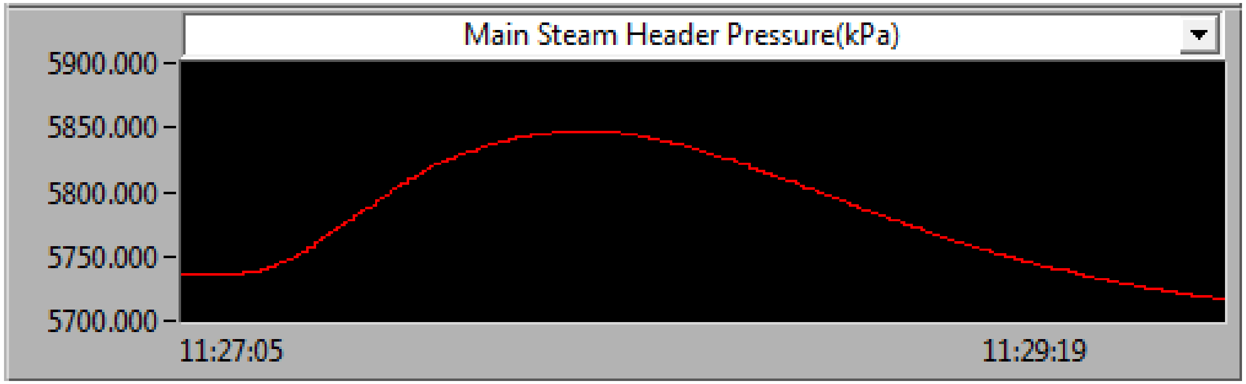
- Sequence of reactivity changes (cont.)



Normal Operation
Exercise 1 (Power Reduction)

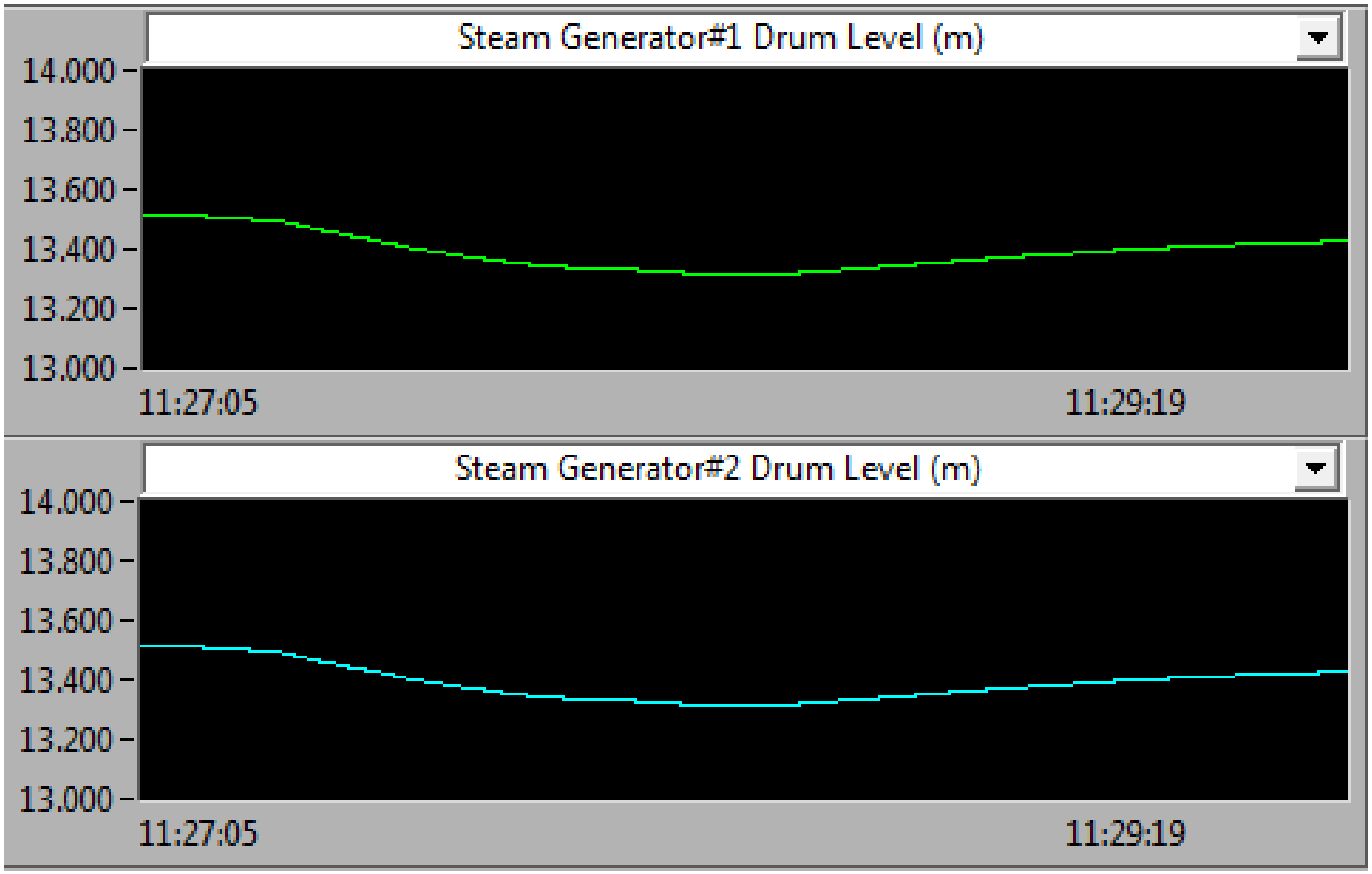
- Main Steam Header Pressure





Normal Operation
Exercise 1 (Power Reduction)

- SG1&2 Boiler Levels



Normal Operation
Exercise 2 (Plant Startup)

- **Reactor power is stable at 5% FP with the REACTOR LEAD mode.**
- **Turbine is tripped and engaged on the turning gear.**
- **Describe the main actions to carry out for a plant startup up to full power.**

Normal Operation
Exercise 2 (Plant Startup)

1) Raise Reactor Power to 25% at a rate of ≤ 0.8%/sec

2) Reset the Turbine Trip Control → Alarm clears

3) Enable Turbine Runup and immediately place the Turbine CV Control in Manual:

   a) Turbine speeds up to synchronous speed (1800 rpm)

   b) Generator Circuit breaker closes

   c) Load is accepted and raise continuously.

   Stop before Generator Output reaches 25 % (≈ 155 MW)

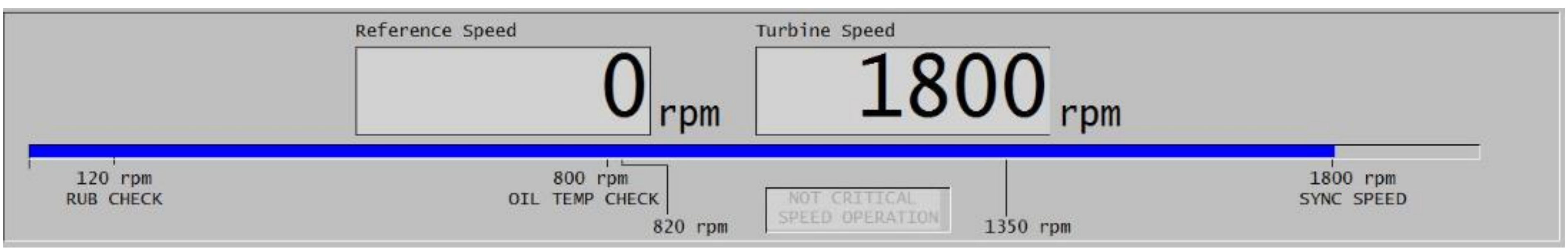
Normal Operation
Exercise 2 (Plant Startup)

4) Once Reactor and Turbine power at 25% approximately:
   a) Select TURBINE LEAD mode.
   b) Set Turbine Load demand at current Turbine Load
   c) Place Turbine CV position in AUTO
   d) Set Turbine Load demand slightly higher than current Reactor Power (~30%)
5) Raise Turbine load up to 85% at ≤ 0.8%/sec in several stages.
6) Perform smaller load rises when approaching to Full Power (above 85%) → 90% - 94% - 97% - 98% - 99% - 99.7%

Normal Operation
Exercise 2 (Plant Startup)

Some differences respect to a real Plant Startup:

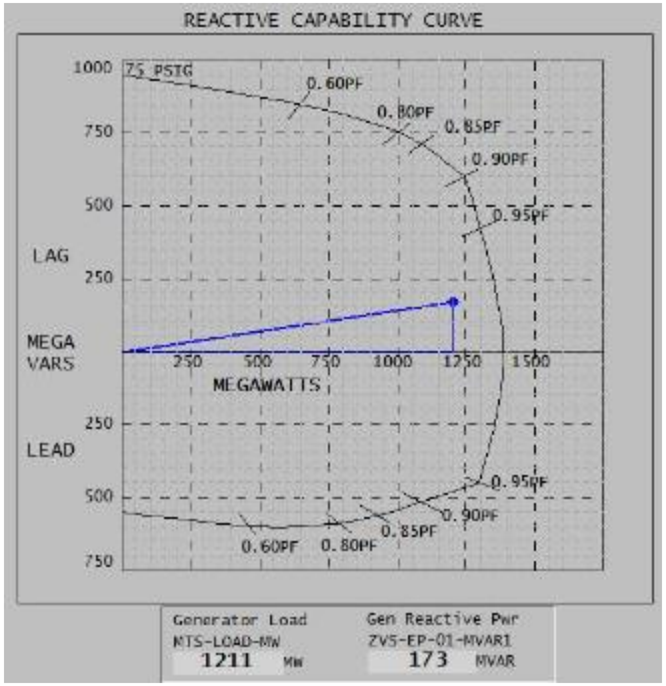
- Turbine rolled up to synch speed much slower.
- Stops @120 rpm for rub check & @800 rpm for oil temp check
- Turbine accelerated when approaching to critical speeds (820 rpm and 1350 rpm)



Normal Operation
Exercise 2 (Plant Startup)

Some differences respect to a real Plant Startup:

- Once at synch speed, Generator is synchronized with grid.
- After this, Generator circuit breaker is closed providing a minimum load of ≈ 6% of the total load.
- Reactive Power (MVARs) is adjusted according to grid demand.
- Load is raised at a max rate of 1%/min (~12MW/min)



- Feedwater and Condensate pumps started when approaching to the maximum capability of the running ones.

Normal Operation
Exercise 2 (Plant Startup)

- **The generator is designed to accept a minimum initial load when is synchronized with the grid.**
- **Is there any concern about synchronizing the main generator at very low loads?**

Normal Operation
Exercise 2 (Plant Startup)

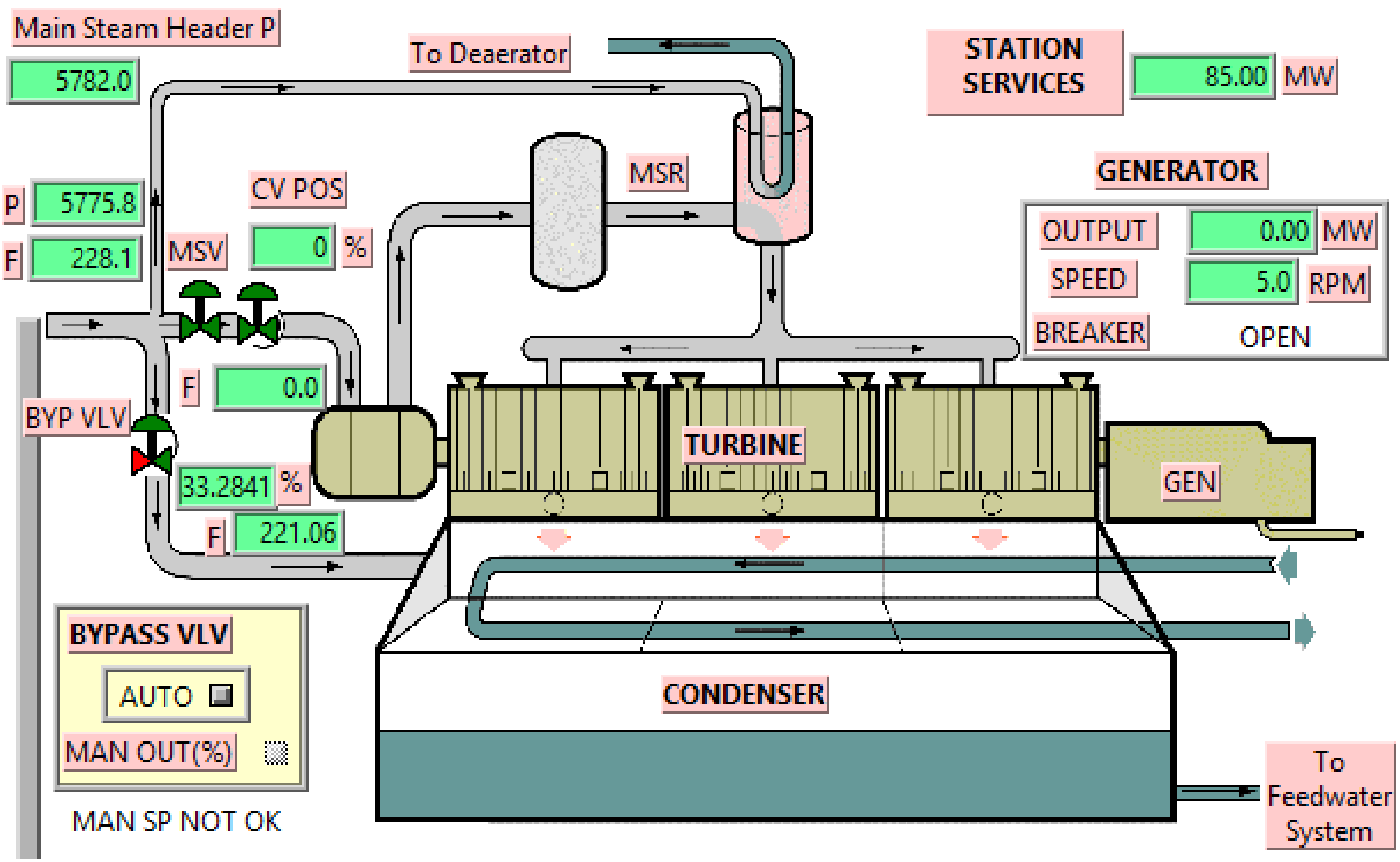
- There is a risk of "Generator motorization", that is, Generator consuming power from the grid instead of producing it, if Generator accepts a low below ≈ 6%.

Normal Operation
Exercise 2 (Plant Startup)

- **Describe how the steam delivery changes during the Turbine-Generator synchronization.**

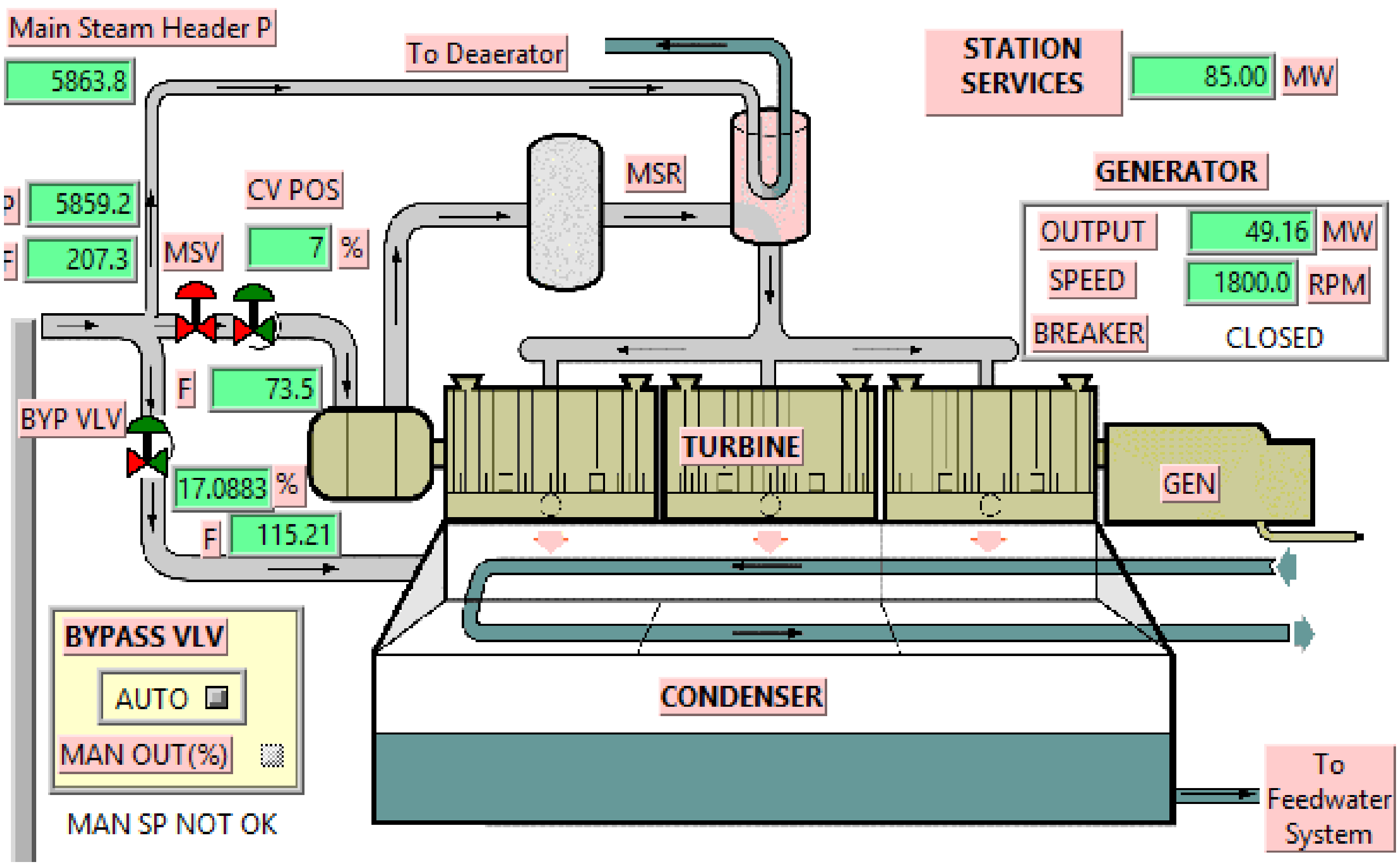
Normal Operation
Exercise 2 (Plant Startup)

- Initially all steam produced by the Reactor is diverted through the bypass.



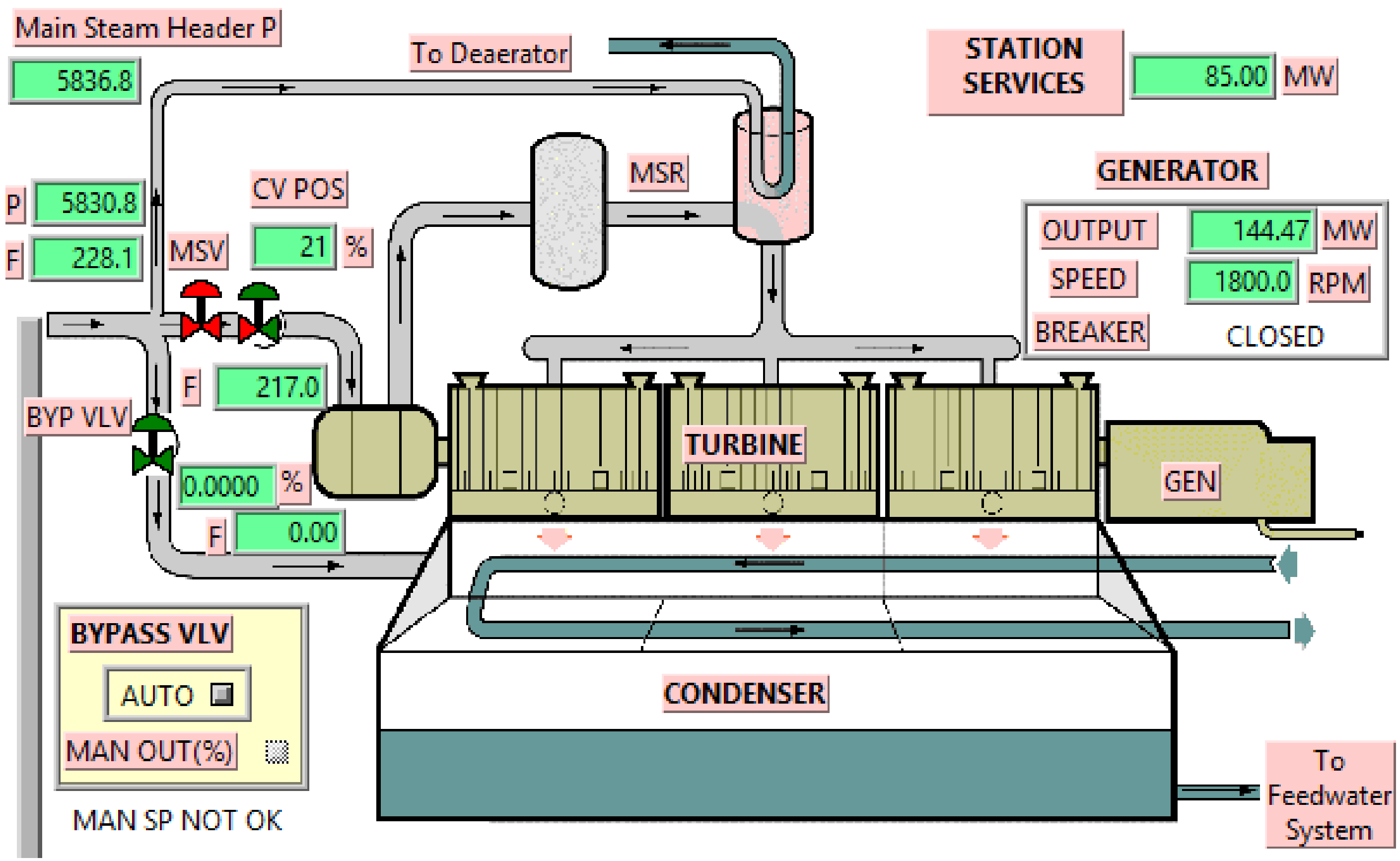
Normal Operation
Exercise 2 (Plant Startup)

- As turbine load raises, the proportional part is sent through the Turbine while flow through the bypass is reduced.



Normal Operation Exercise 2 (Plant Startup)

- Once Turbine reaches 25% of load, turbine bypass valves fully close, and all the steam is sent to the Turbine for electricity generation.



Normal Operation
Exercise 2 (Plant Startup)

- **If the simulator nuclear power plant was installed in Italy, would Turbine-Generator speed be the same? Reason the answer.**

Normal Operation
Exercise 2 (Plant Startup)

- It depends on national grid frequency, according to the following formula:

$$n = \frac{60 * f}{P}$$

Where,

n – Turbine-Generator speed (rpm).

f – Grid frequency (Hz).

P – Pair of poles in Generator.

50 Hz → 1500 rpm (most of Europe, Asia, all Arab Atomic Energy Agency countries)

60 Hz → 1800 rpm (USA, Canada, Japan, Mexico…)

Abnormal Operation Exercise 3 (Turbine trip)

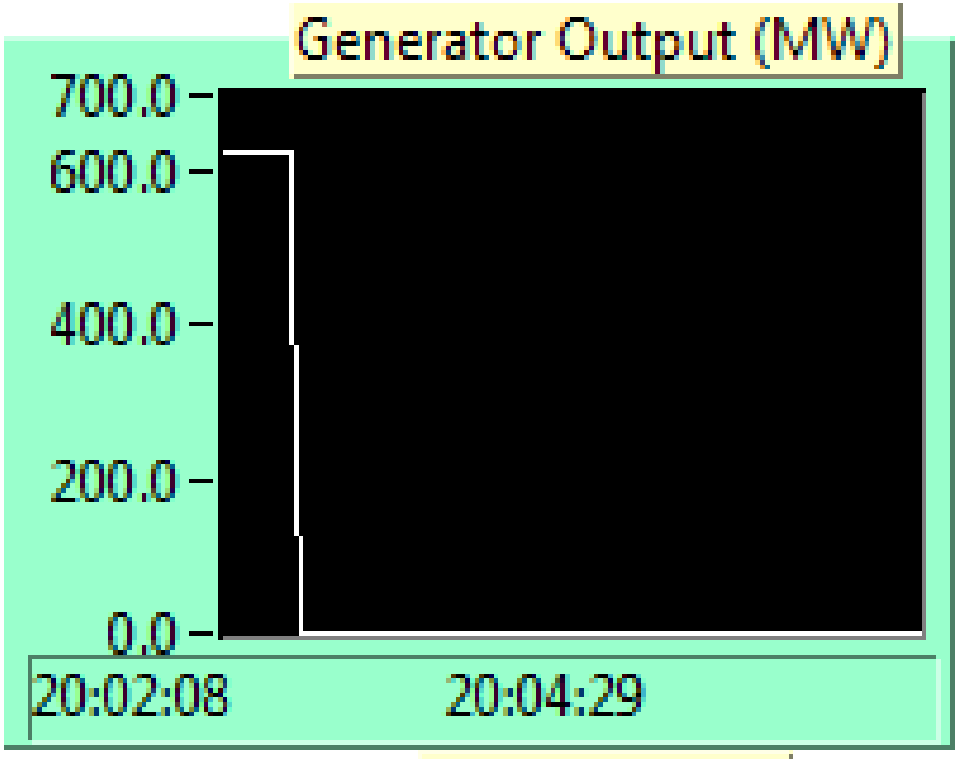
- **Plant is stable at full power.**
- **Suddenly, vibrations on the turbine shaft require a Turbine trip.**
- **Perform a manual turbine trip and analyze the transient.**

Abnormal Operation Exercise 3 (Turbine trip)

- **Pay special attention to the following parameters:**
  - **MW power produced**
  - **Reactor power**
  - **Temperature mismatch (Tavg-Tref)**
  - **Steam Header pressure**
  - **Steam Generator Boilers safety relief valves**
  - **Steam Bypass flow**

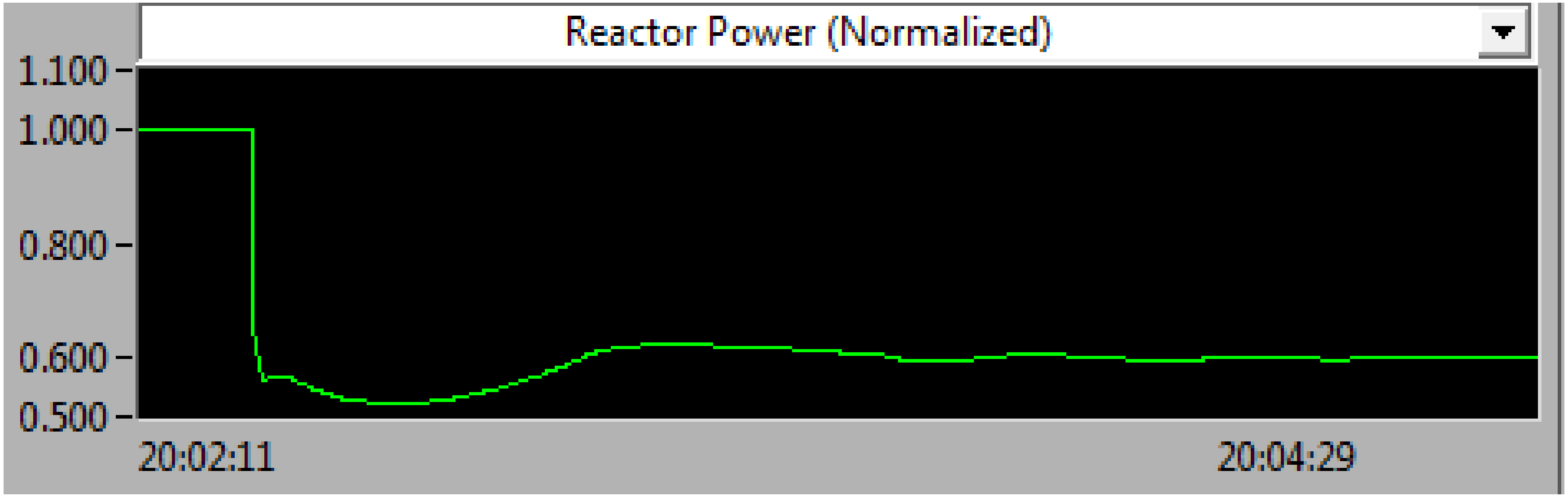
Abnormal Operation Exercise 3 (Turbine trip)

- MW power produced



Abnormal Operation Exercise 3 (Turbine trip)

- Reactor power

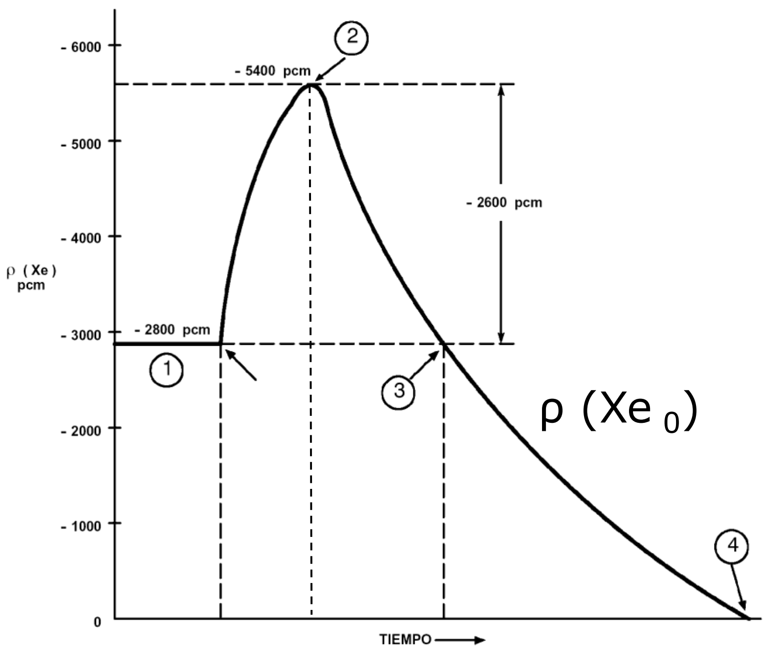


Abnormal Operation
Exercise 3 (Turbine trip)

- **What is the reason of this power stepback?**
- **Why the stepback is set at 60%?**

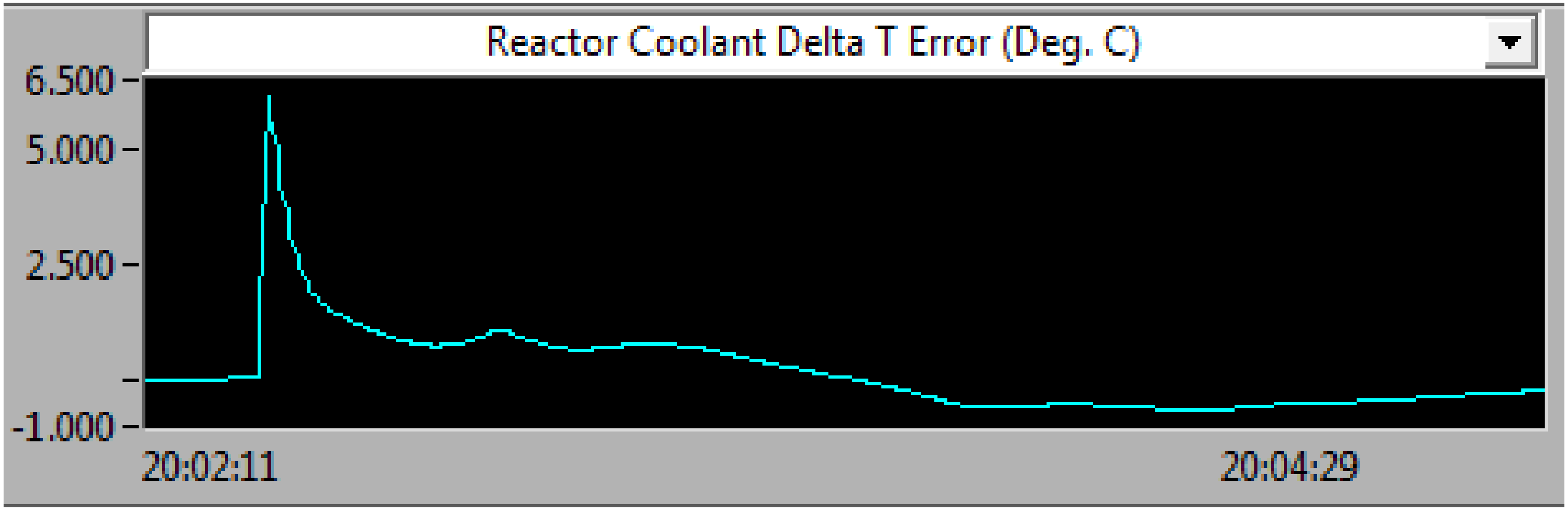
Abnormal Operation Exercise 3 (Turbine trip)

- Reactor power stepbacks to 60% by a rapid insertion of control rods.
- Sufficient power reduction to avoid SG Safety Valves opening while avoiding excessive Xe buildup exceeds the positive reactivity available.



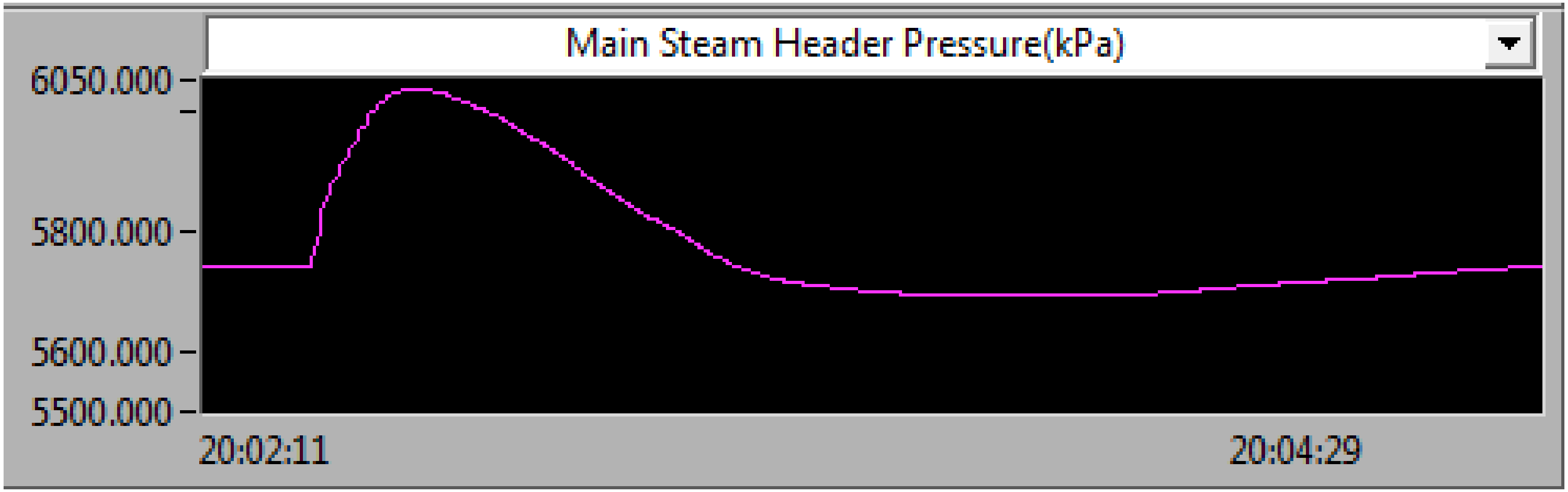
Abnormal Operation Exercise 3 (Turbine trip)

- Temperature mismatch (Tavg-Tref)



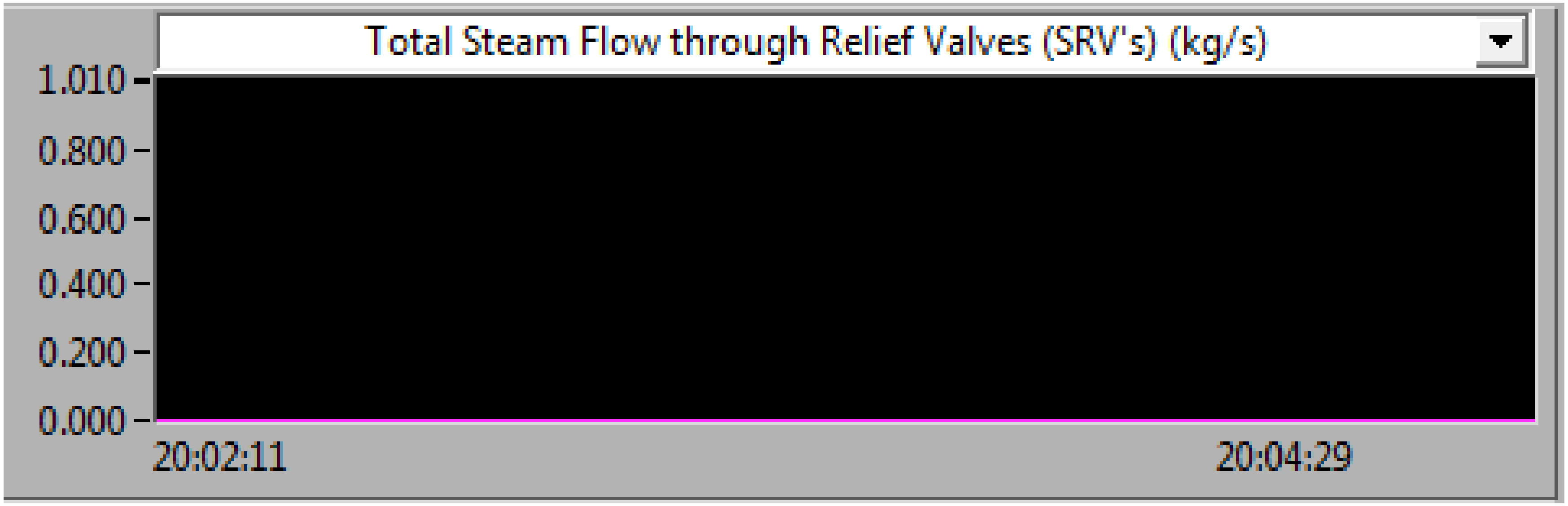
Abnormal Operation Exercise 3 (Turbine trip)

- Steam Header pressure



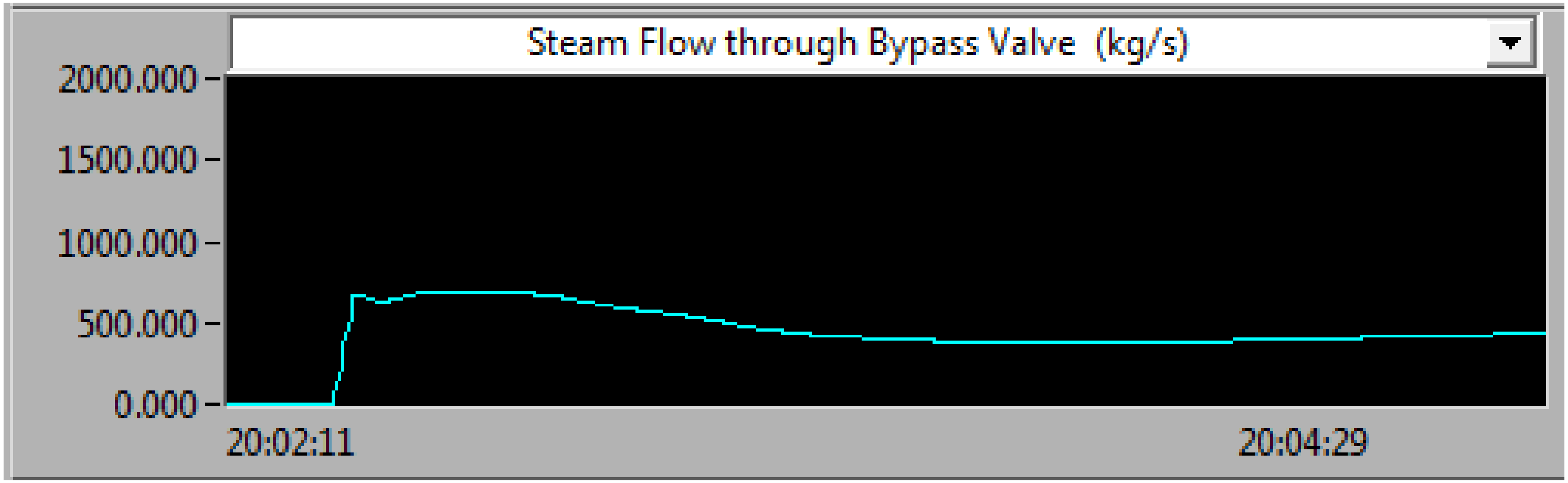
Abnormal Operation
Exercise 3 (Turbine trip)

- Steam Generator Boilers safety relief valves



Abnormal Operation Exercise 3 (Turbine trip)

- Steam Bypass flow



Abnormal Operation Exercise 3 (Turbine trip)

- **Shouldn’t the Turbine fully stop rolling after the trip? Reason the answer.**

Abnormal Operation Exercise 3 (Turbine trip)

- No, it is coupled on the turning gear in order to roll at very low speed during several hours before fully stop.
- The intent is to homogenize the cooldown within the inner parts of the turbine in order to avoid deformations on the shaft due to differential expansion.

Emergency Operation
Exercise 4 (Manual Reactor trip)

- **Plant is operating at full power while a loss of Reactor Coolant Pumps (RCPs) cooling is detected.**
- **What major actions are immediately required?**
- **What is the sequence for these actions? Reason the answer.**

Emergency Operation
Exercise 4 (Manual Reactor trip)

1) Manually trip the Reactor: Stop the fission heat

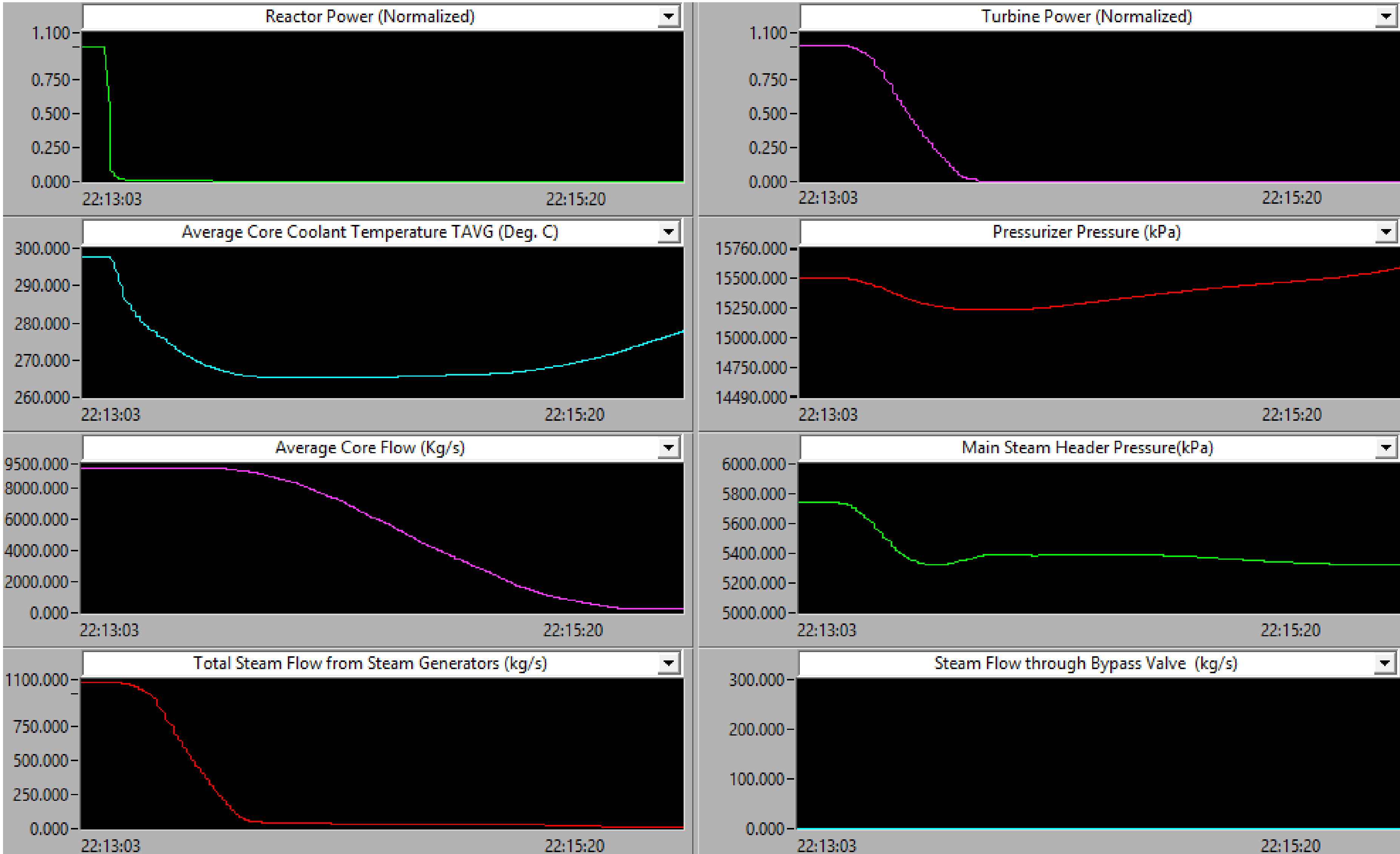
2) Check Reactor is tripped: Safeguards systems designed for decay heat only

3) Stop all RCPs: protect equipment from irreparable damage.

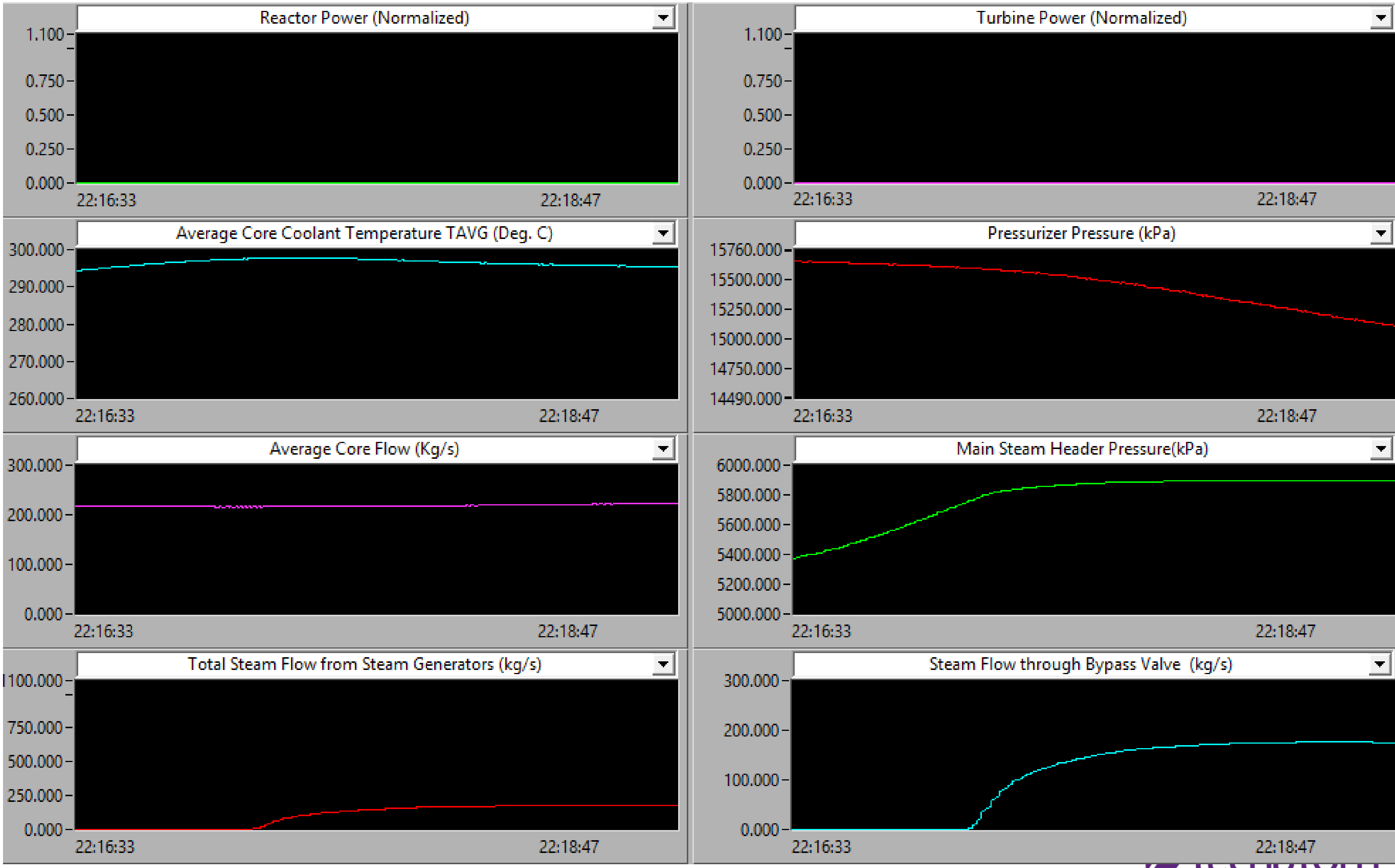
Emergency Operation
Exercise 4 (Manual Reactor trip)

- **Describe the response of the overall unit, paying special attention to:**
  - **Reactor Power**
  - **Average coolant temperature**
  - **Reactor coolant pressure**
  - **Reactor coolant flow**
  - **Steam flow**

Emergency Operation
Exercise 4 (Manual Reactor trip)



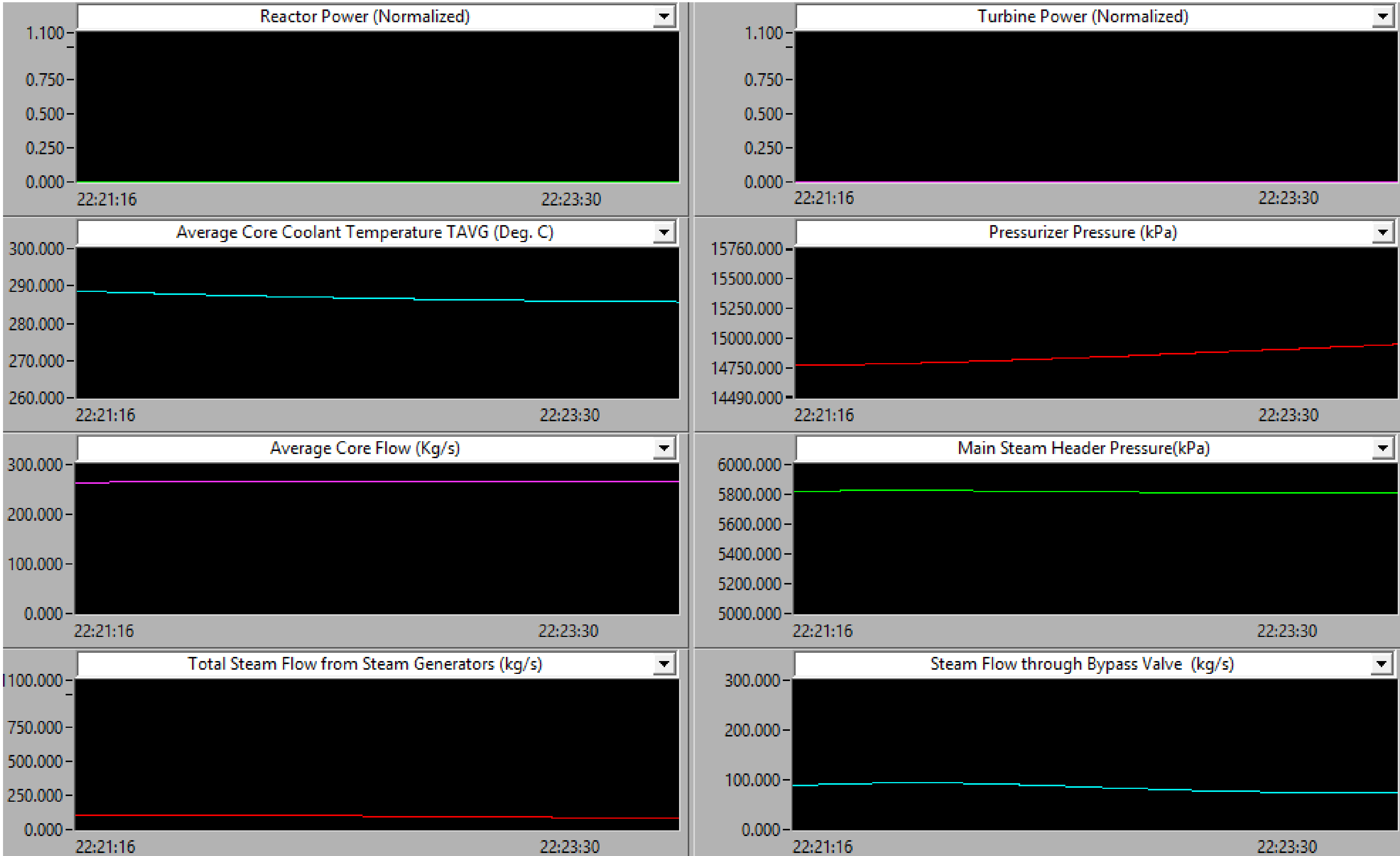
Emergency Operation
Exercise 4 (Manual Reactor trip)



Emergency Operation
Exercise 4 (Manual Reactor trip)

- Finally equilibrium is reached by primary coolant natural circulation and SGs/Steam bypass as heat sink:
  - $T_{avg} \approx 280^oC$
  - $p_{RCS} \approx 15650$ kPa→ $T_{SAT} \approx 345^oC$→ **Subcooling margin≈65ºC**
  - $flow_{RCS} \approx 260$ kg/s
  - $p_{steam} \approx 5786$kPa
  - $flow_{steam} \approx 59$kg/s

Emergency Operation
Exercise 4 (Manual Reactor trip)



Emergency Operation Exercise 5 (Steam Line Break)

- **Plant is operating at full load conditions.**
- **Suddenly, a double-ended main steam line break occurs.**
- **Describe the main consequences of this accident.**

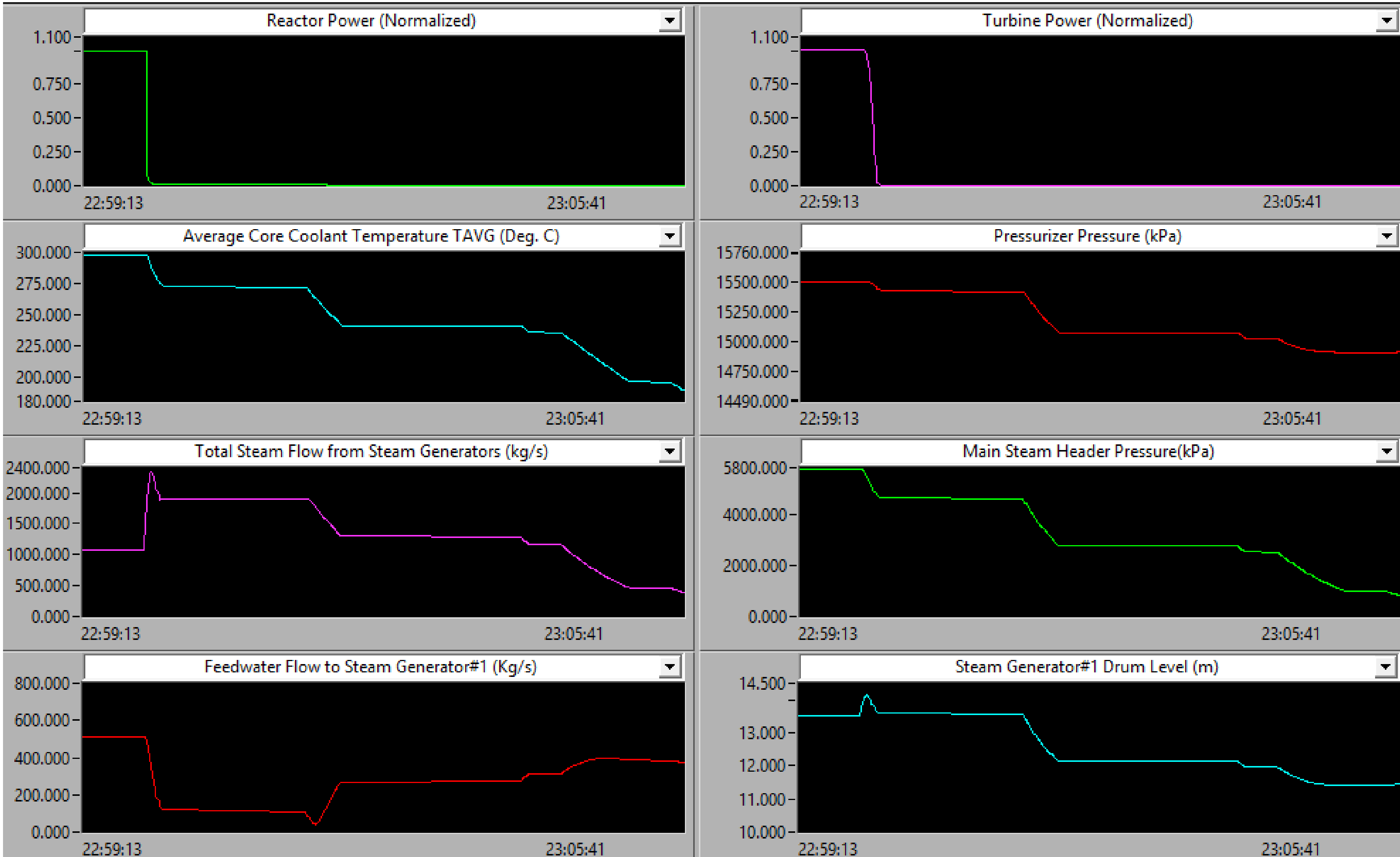
Emergency Operation
Exercise 5 (Steam Line Break)

- A **pipe break** upstream main steam line isolation valve.
- **Reactor trip** on high main steam flow (1072 kg/s).
- **Turbine** runbacks, and **trips** after a while on zero forward power.

Emergency Operation Exercise 5 (Steam Line Break)

- Rise in steam flow makes **SG boiler levels** to **lower**.
- **Feedwater** Control valves **fully open** to compensate the level drop.
- **Excessive primary cooling**.
- This overcooling will **drop** both coolant **temperature and pressure** significantly.

Emergency Operation Exercise 5 (Steam Line Break)



Emergency Operation Exercise 5 (Steam Line Break)

- **What is the big challenge of this particular accident?**

Emergency Operation Exercise 5 (Steam Line Break)

- The overcooling introduces a great amount of positive reactivity into the primary, that can lead to a power excursion.

Emergency Operation
Exercise 5 (Steam Line Break)

- **What would be the solution to counteract this event?**

Emergency Operation Exercise 5 (Steam Line Break)

- The counter measure is to inject highly borated makeup sources in the primary coolant to compensate the excess of positive reactivity.

Emergency Operation Exercise 5 (Steam Line Break)

- **Could you mention a different accident with a similar transient?**

Emergency Operation Exercise 5 (Steam Line Break)

- Steam Relief valves failed open.
- Turbine Bypass valve failed open.

Emergency Operation
Exercise 6 (Cold Leg LOCA)

- **While the plant is operating at full power conditions, a Loss of Coolant Accident (LOCA) occurs on cold leg 4.**
- **List the actions carried out by the protective passive systems.**

Emergency Operation Exercise 6 (Cold Leg LOCA)

- PZR level and pressure lower rapidly.
- **Reactor trip** on low coolant pressure (14,380 kPa)
- **Safety Passive Core Cooling** on low low PZR level (2 m):
  - **PRHR HX** actuation.
  - **CMTs** injection → RCPs trip.
- **ACCs** injection at ≈4000 kPa. CMTs injection rate is reduced.
- **PCS** actuation on high Containment pressure (114 kPa)
- **ADS Stage 1** actuation on low CMT level.
- 1 min and 30 sec later, **ADS Stage 2** actuation
- 1 min and 30 sec later **ADS Stage 3** actuation
- Right after ADS 3, ACCs injection finished while CMTs injecting alone.
- ≈ 7 min and 30 sec later, low-2 CMT level is reached, so **ADS Stage 4** actuation & **IRWST** injection occurs.
- Some time later, CMTs fully depleted while IRWST injecting.
- Several hours later, **Containment Recirculation** on low IRWST level. For actual injection flow, sufficient Containment floodup level required for proper driving force.

QUESTIONS?

IAEA
International Atomic Energy Agency
Atoms for Peace

ICTP The Abdus Salam International Centre for Theoretical Physics

THANKS FOR YOUR ATTENTION

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QUIZ

- 5 Questions.
- Single choice.
- 2 points each.
- 20 minutes.