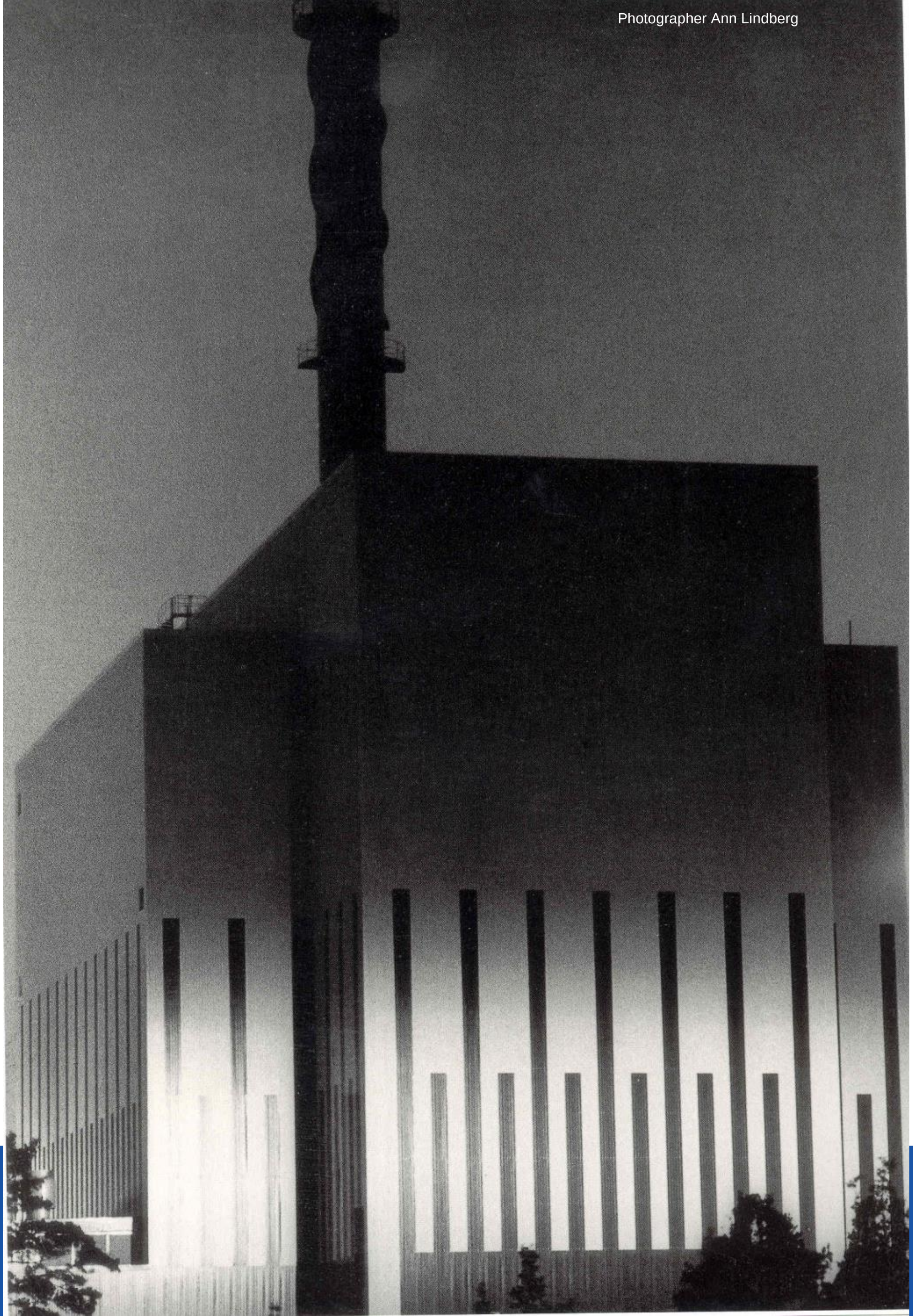
OSKARSHAMN-3, Feb.8 1998 stability event

Sean Roshan

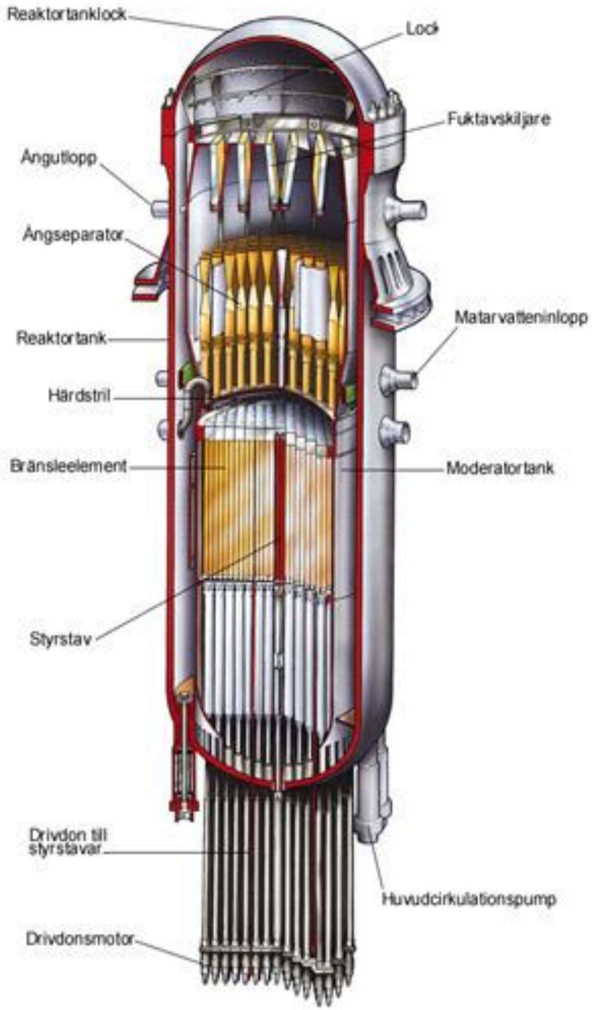
Stability events prior to 2000

Events with power oscillations

Date	Power Plant	Country	Status before event	Power/ Flow (%)	Root cause of event	Type of oscillation	P-P (%)	(P-P)/ A (%)	Scram at (%)
1979-??-??	TVO 1	Finland	Startup	-/-	Not reported ?	Regional ?			
1982-06-30	Caorso	Italy	Startup	54/38	Operation within unstable area	out-of-phase			120
1984-01-13	Caorso	Italy	Power op	-/-	Loss of one feedw preheater	out-of-phase			
1984-??-??	Vermont Yankee	USA	?	?/?	?	in-phase			
1987-02-23	TVO 1	Finland	Startup	62/40	Loss of one feedw preheater train	in-phase	12	20	90
1988-03-09	LaSalle 2	USA	Power op	84/76	Loss of one feedw preheater train	in-phase	25-50	30-60	118
1989-01-15	Forsmark 1	Sweden	Startup	63/42	Operation within unstable area	in-phase	50	80	
1989-10-26	Ringhals 1	Sweden	Startup	73/50	Operation within unstable area	out-of-phase	16	22	118
1990-01-08	Oskarshamn 2	Sweden	Power op	69/52	Operation within unstable area	in-phase	20	29	
1990-??-??	Leibstadt	Germany	?	?/?					
1991-01-29	Cofrentes	Spain	Startup	41/31	Low feedwater temperature	out-of-phase	13	32	
1991-07-03	Isar 1	Germany	Power op	50/30	Trip of four pumps	in-phase	30	60	
1991-??-??	TVO 1	Finland	Startup	?/?	Non-seated assemblies	local			
1992-08-15	WNP 2	USA	Startup	36/30	Skewed radial & axial power distr	in-phase	25	70	
1994-??-??	Wurgassen	Germany	?	?/?	Not reported	in-phase	?	?	?
1995-01-??	Laguna Verde 1	Mexico	Startup	35/38	Operation within unstable area	in-phase	10	29	
199?-??-??	Cofrentes	Spain	Power op	?/?	Recirc. flow control valve malfunc		15	15	
1996-??-??	Forsmark 1	Sweden	Startup	?/?	Non-seated assemblies	local			
1997-01-31	Oskarshamn 3	Sweden	Power op	?/?	?	?			
1998-02-08	Oskarshamn 3	Sweden	Startup	60/32	Operation within unstable area	in-phase	45	75	96
1999-01-25	Oskarshamn 3	Sweden	Power op	50/22	?	in-phase			
1999-02-25	Oskarshamn 2	Sweden	Power op	?/?	Loss of two preheater trains	in-phase	??	??	132
2000-01-27	Oskarshamn 3	Sweden	Power op	?/?	?	?			


Photographer Ann Lindberg

TECHNICAL INFORMATION



Type: BWR Contractor: ASEA-ATOM

Start of commercial operation: Aug. 1985

Vessel height	20.8 m	20.8 m
Vessel diameter:	6.4 m	6.4 m
Core height:	3.75 m	3.75 m
Core diameter:	4.62 m	4.62 m
Fuel bundles:	700	700
Control rods:	169	169
Circulation pumps:	8	8
Thermal Power:	3300 MW	3000 MW
Circulation flow:	13100 kg/s	11400 kg/s
Steam flow:	1780 kg/s	1620 kg/s
Generator rating:	1200 MW	1097 MW
Fuel:	SVEA 96/100	SVEA 8X8
Fuel rod outer diam.:	9.62 mm	12.25 mm

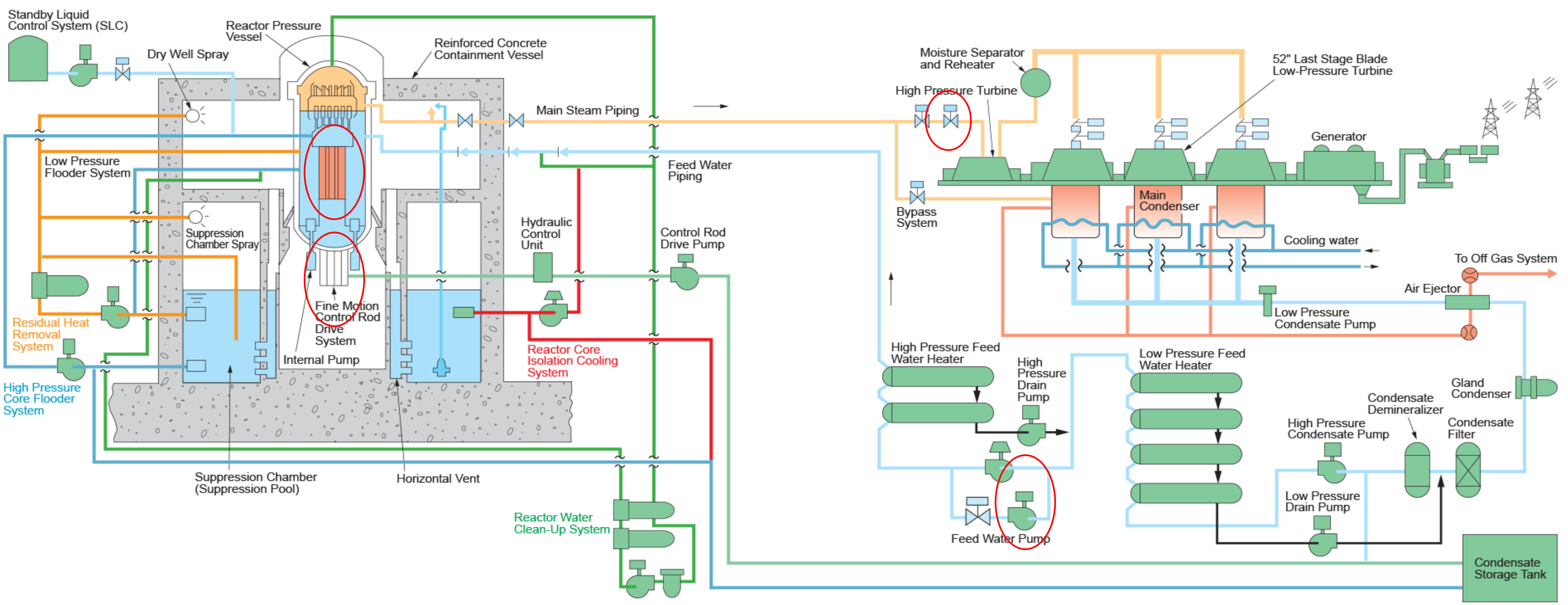
The Event

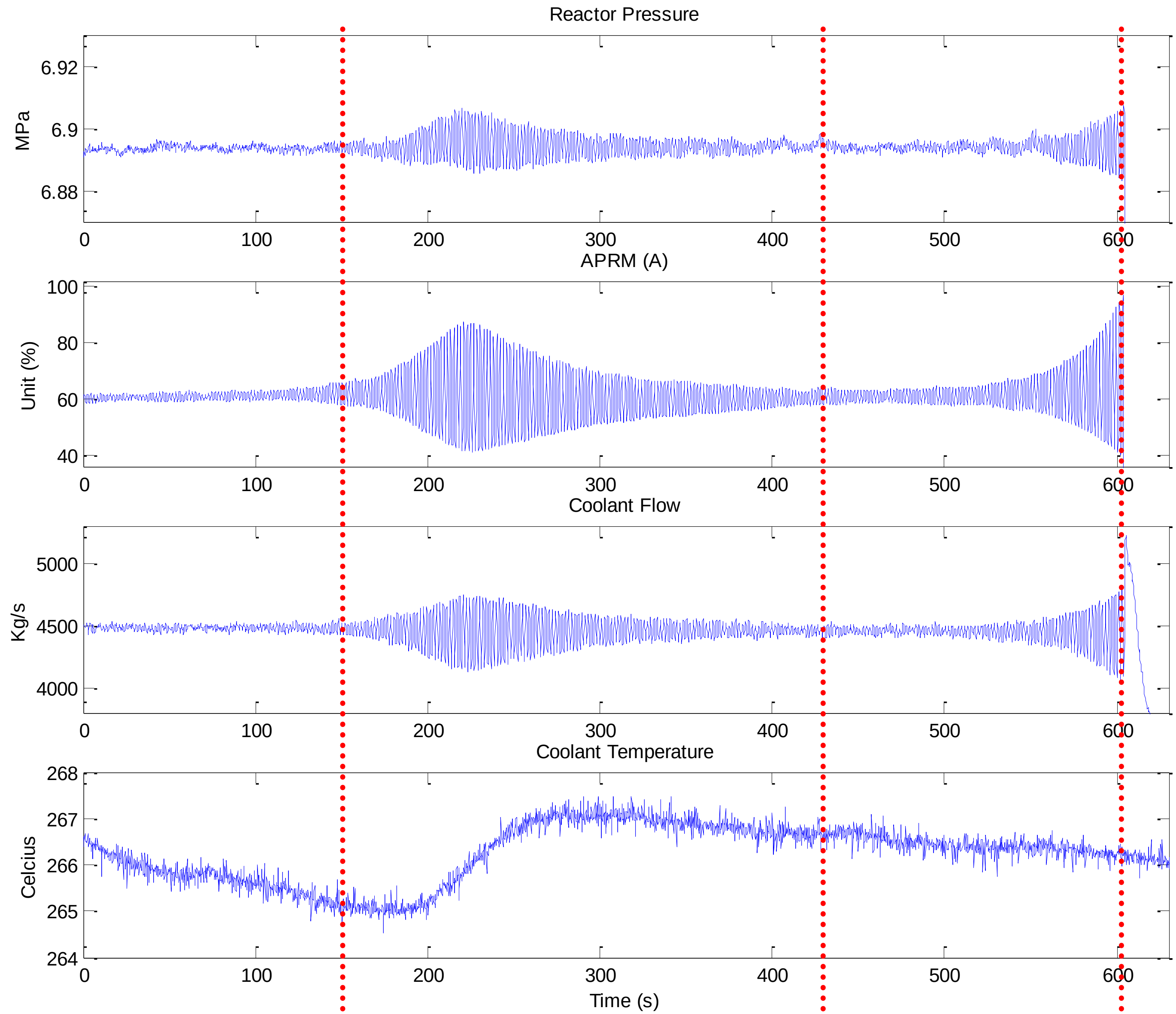
On February 1998 at 12:23, Oskarshamn Unit 3 (O-3) was starting up following a short maintenance shutdown.

- Power was being increased from 58.7% by control rod withdrawal.
- A second main feed-water pump was started and placed into service in automatic flow control.
- The operator continued control rod withdrawal to increase power to 60%.
- Approximately one minute after reaching the 60 % power, a high neutron flux alarm was received.
- 8 seconds later, an automatic reactor scram on high neutron flux occurred at approximately 96% reactor Power

Time-line of the event

12:23:00	Power level was 58.7 %
12:29:24	A second main feed-water pump was started
12:32:05	The feed-water pump was placed into service in automatic flow control
12:37:??	Alarm, Low hydraulic-oil pressure in high pressure turbine's valves.
12:41:00	Control rod withdrawal resumed by reactor operator
12:42:54	Power level reaches 60 % of full power
12:43:40	High neutron flux alarm received at 88% power
12:43:48	Reactor scram on unfiltered high neutron flux versus low recirculation flow (SS 14) occurred at 96% power





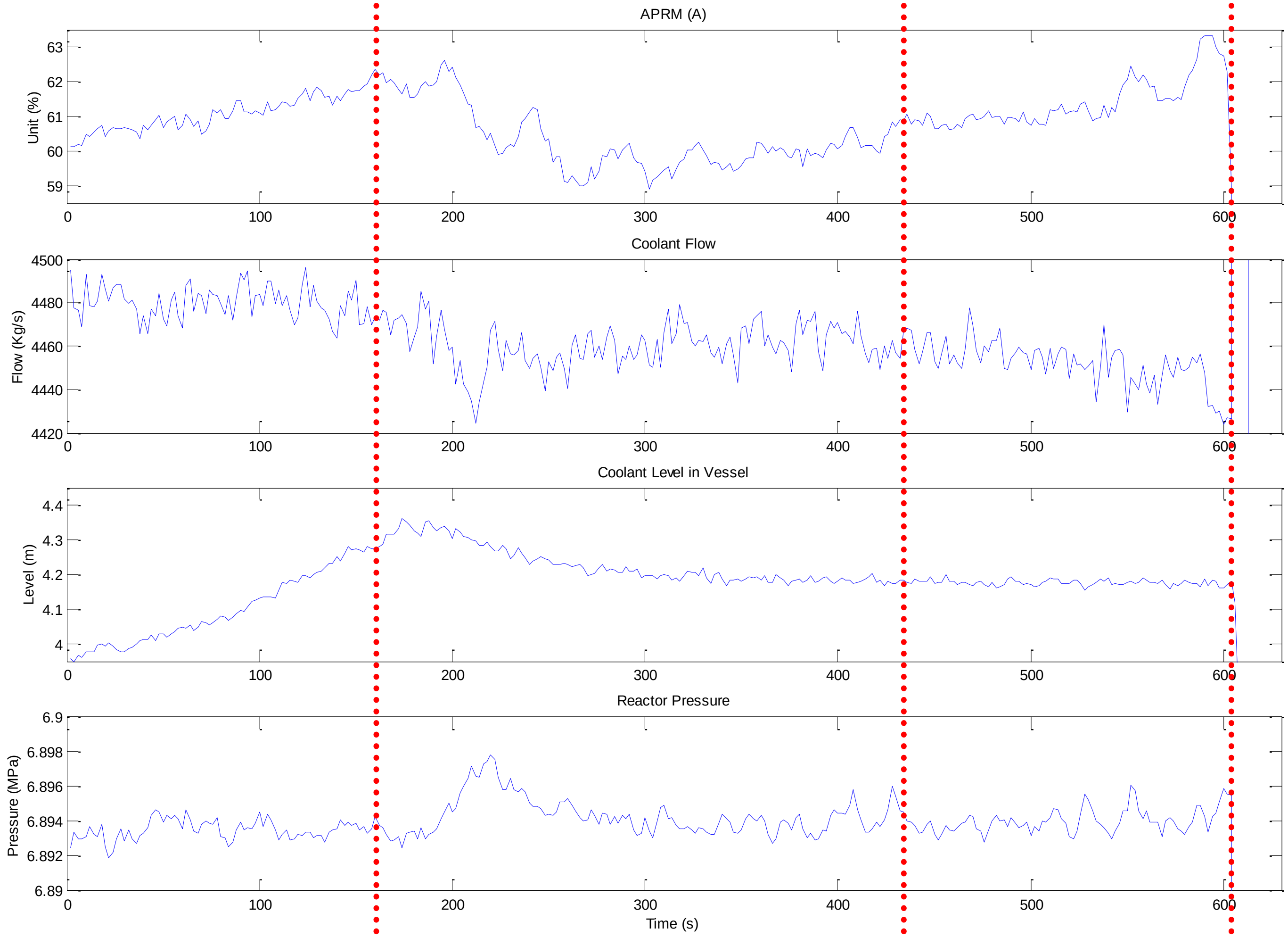
12:29:24
Feed-water Pump
Start

12:32:05
Feed-water Pump
In auto-control

12:37:??
Alarm, Low Oil
Pressure, TA7,TB7

12:41:00
CR- withdrawal

12:43:48
SCRAM



12:29:24 Feed-water Pump Start

12:32:05 Feed-water Pump In auto-control

12:37:?? Alarm, Low Oil Pressure, TA7,TB7

12:41:00 CR- withdrawal

12:43:48 SCRAM

Simulation of the event

ABB – Atom - RAMONA

Studsvik - SIMULATE 3K

GSE - Signal analysis

RAMONA

Parameters studied at ABB-Atom:

Coolant flow, Power, Inlet temperature, Control rod pattern and Xenon.

Conclusions:

- Decay Ratio is affected very much by
  - Flow
  - Power
- The event in O-3 is explained by
  - Lower inlet temperature
  - Higher Control rod density caused unfavorable power disturbance in the core
- Stability of the core was not affected very much by Xenon in the core.
- Frequency of the oscillations is relatively insensitive to changes.

SIMULATE 3K

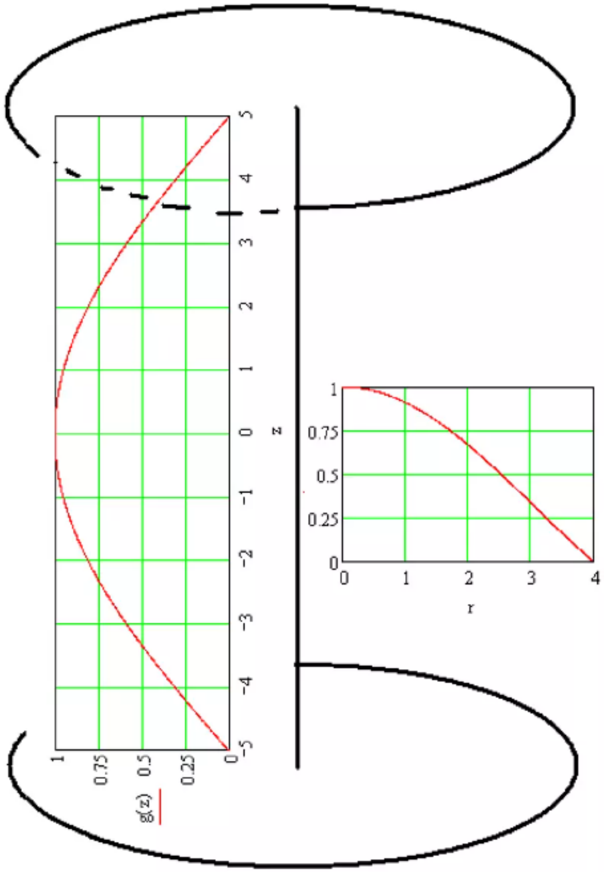
Parameters studied at Studsvik :

Reactor governing/automatic system, the general power distribution in the core, interruptions of the feed-water supply changes of the core inlet temperature, the gradual control rod withdrawal from pattern to pattern and Xenon concentration

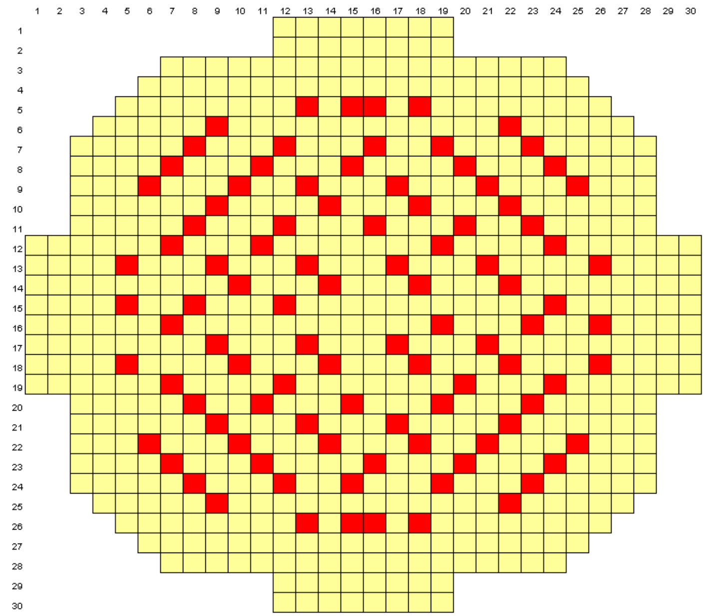
Conclusions:

- No significant effect of Xenon concentration, Control rod withdrawal and reactor control system.
- Power distribution played a major roll in the event due to
  - Local areas with very high bottom peaked power.
  - An average axial power profile with accentuated bottom peaked power.
  - High degree of Double- Humped axial power profile

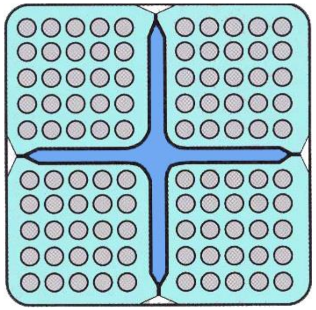
POWER SHAPE



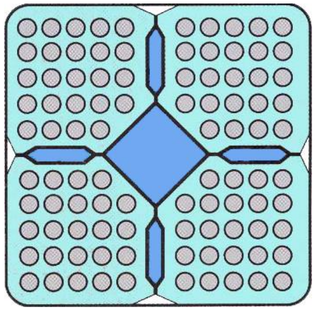
Nominal axial and radial power shape



98 Fresh fuel bundles loaded in the Core = 14%



SVEA 100



SVEA 96

Pressure control

We strive to keep the steam dome pressure at a constant level while the core power changes. Therefore, the steam flow out of the reactor pressure vessel has to adjust and match the steam production in the core.

We achieve this by a pressure control which controls the position of the high-pressure turbine's valves and regulates the steam flowrate to the turbine.

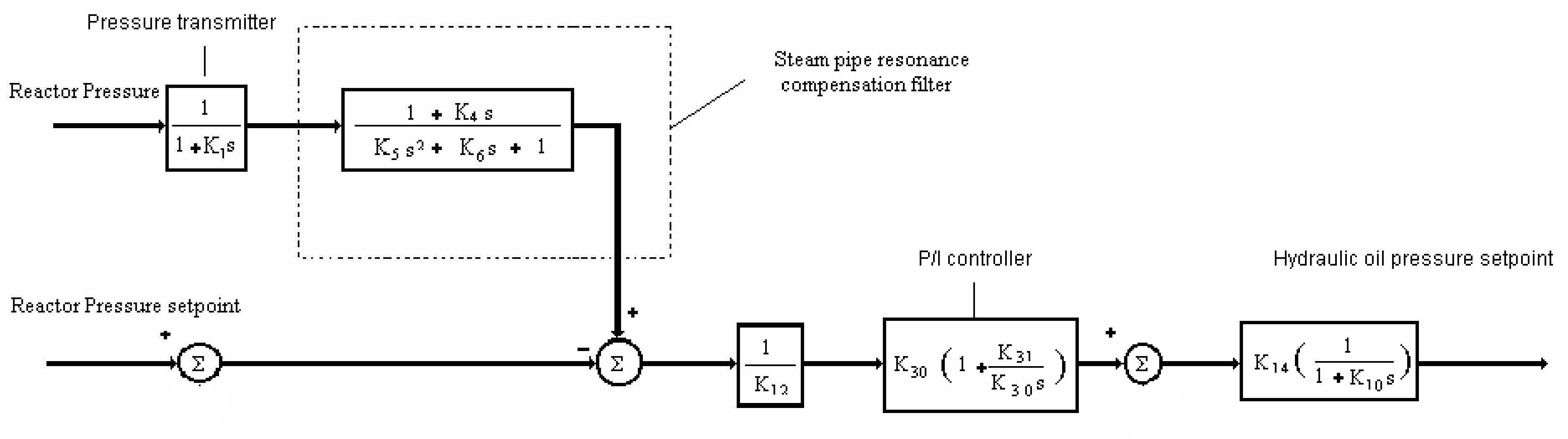
Pressure controller operation principle

The actual steam dome pressure is measured by a set of presure sensors

The measured pressure is compared with the setpoint pressure ($p - p_{ref}$)

If the values of p and p_{ref} differs the control system will open or close the turbine admission valve, depending on the magnitude and sign of the pressure difference.

Pressure controller operation principle



Problem of pressure controller

This pressure controller is usually adequate for taking care of core power changes of modest rate.

However, during a rapid power production rate change, e.g., scram, due to the long time constant of the steam dome, the turbine valve is unable to follow the corresponding rate of steam production in the core as quickly as necessary to obtain a constant pressure in the steam dome.

Solution: NFF

In order to overcome this problem a ”Neutron Flux Filter” (NFF) was introduced by ASEA-ATOM and is currently in use at all Swedish BWRs.

- Register the changes in the neutron flux, as measured via APRM signal
- And let this registered signal pass through a filter, which simulates the *assumed* time constant (5 s).

Time-constant of NFF

The filter used in NFF is

$$G = \frac{1}{(1 + j\omega\tau_f)}$$

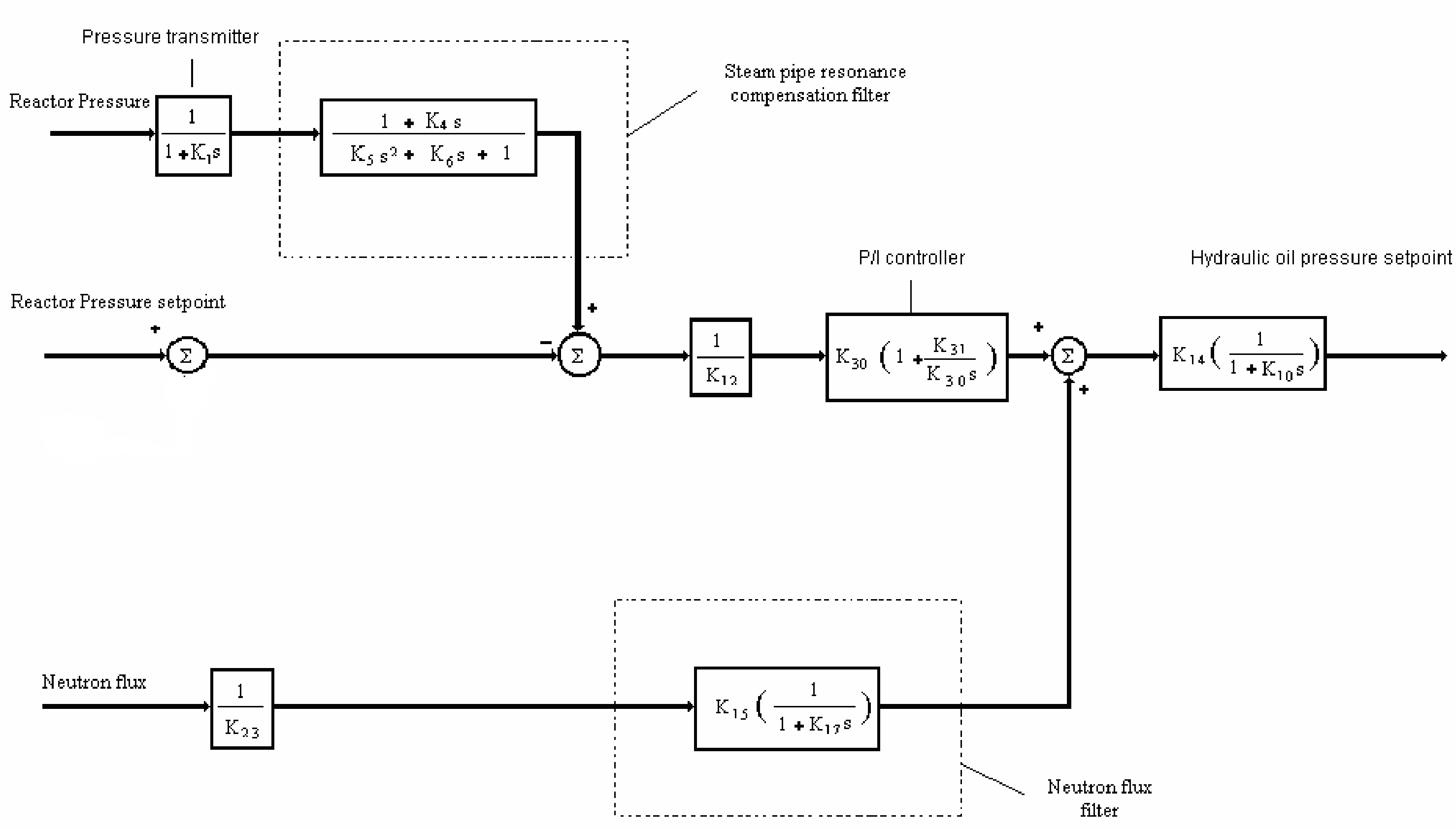
The time constant (τ_f) is calculated according to

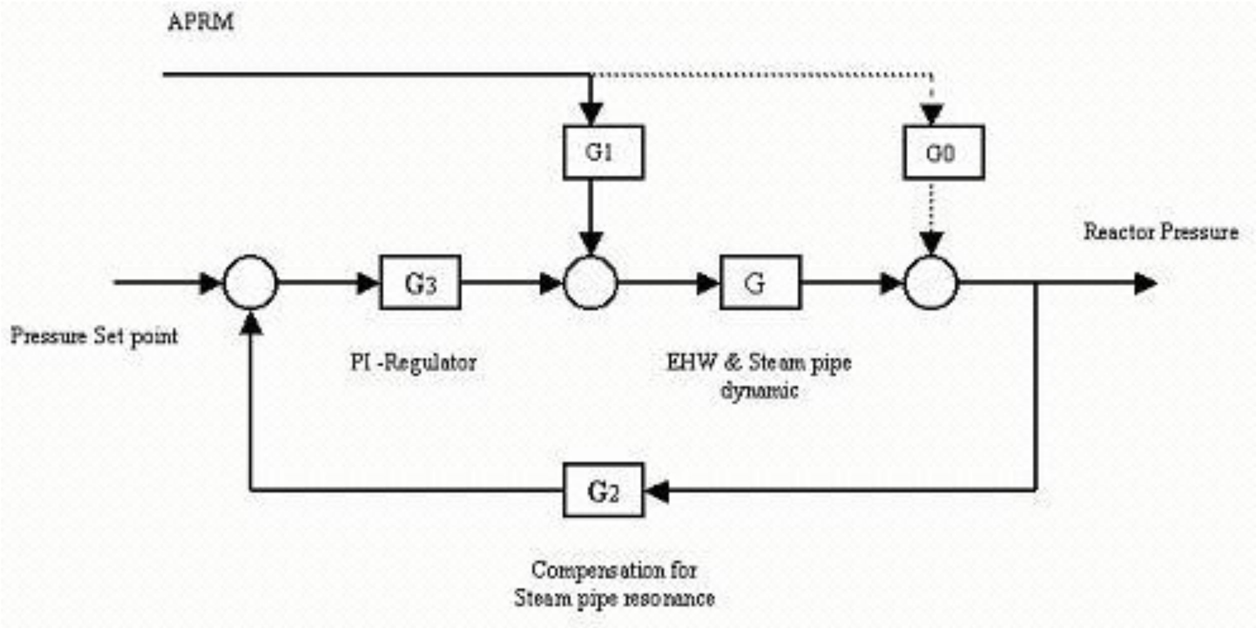
$$\tau_f = \frac{\rho C_p R^2}{8k}$$

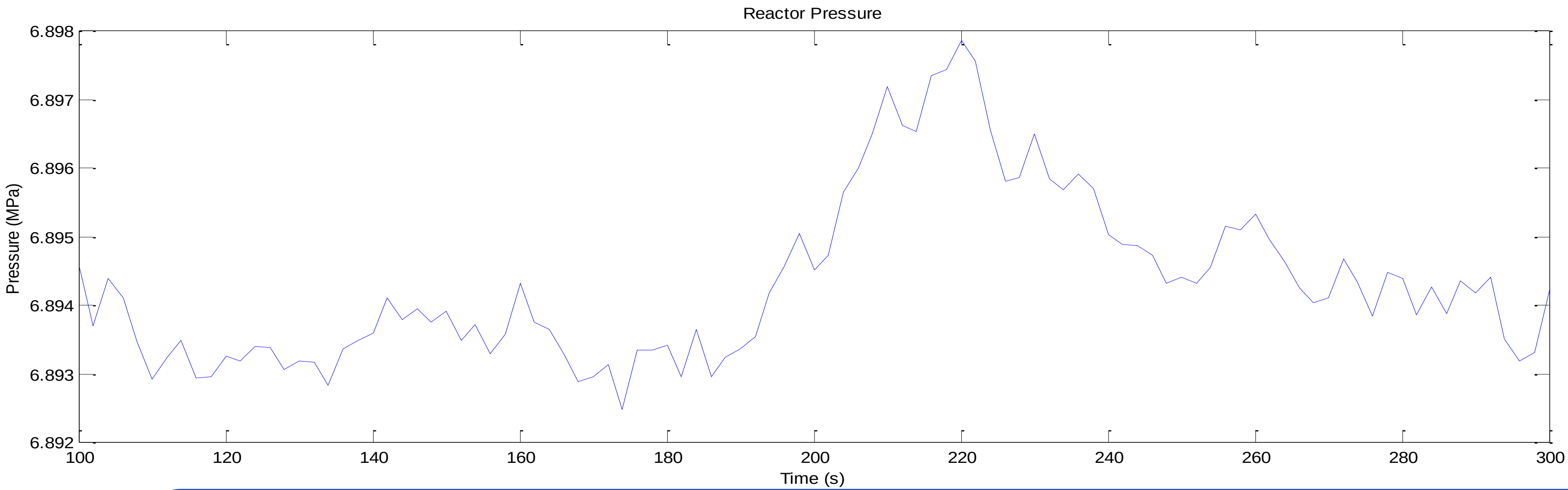
ρ	=	10.5	g / cm³
C_p	=	0.3	J / g K
k	=	0.028	W / cm K
R	=	0.5	cm

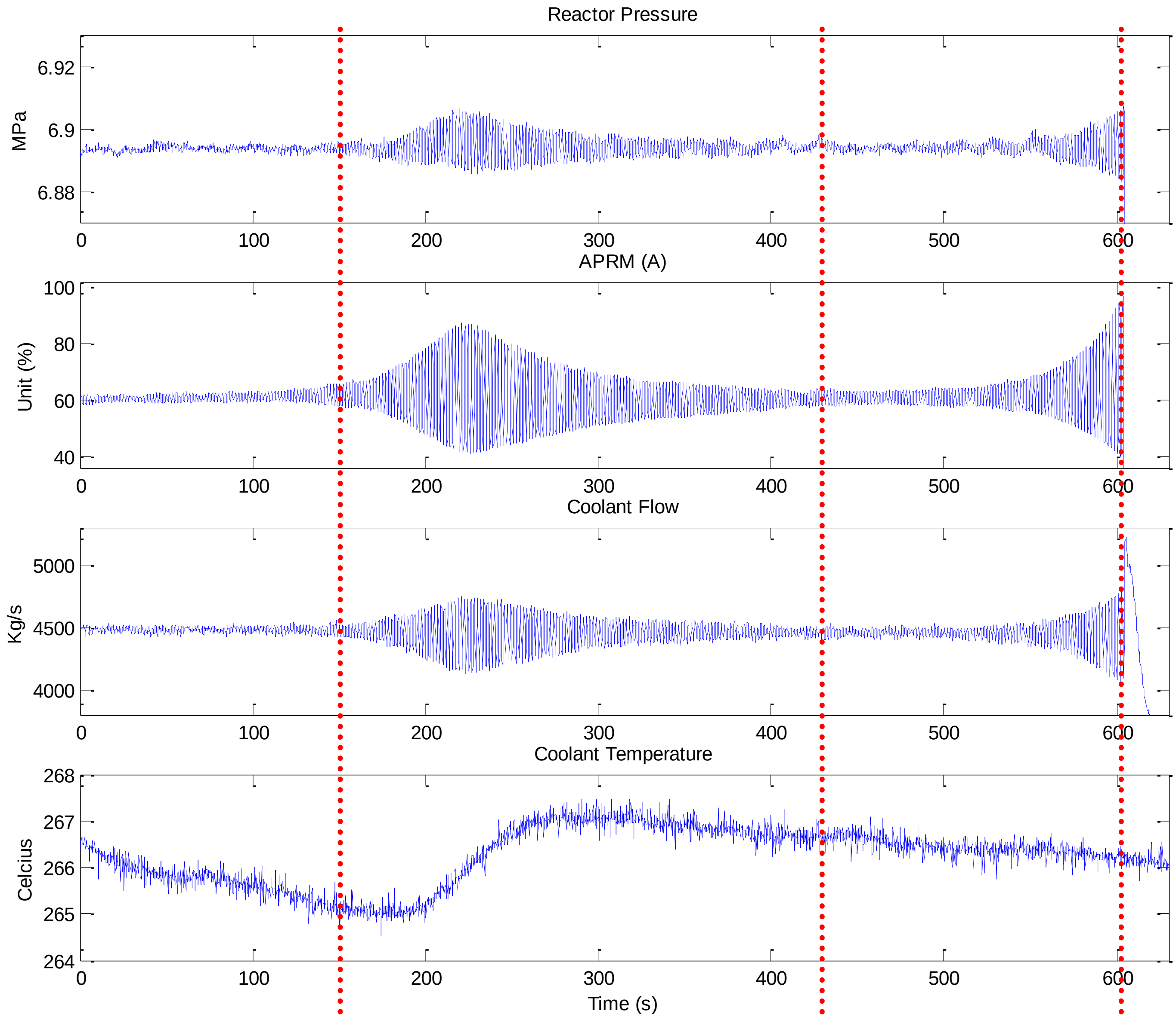
τ_f = 3.5 s + gap + cladding = 5s

Pressure controller and NFF operation principle




APRM
G1
G0
Reactor Pressure
G3
G
Pressure Set point
PI -Regulator
EHW & Steam pipe dynamic
G2
Compensation for Steam pipe resonance


Reactor Pressure
Pressure (MPa)
6.898
6.897
6.896
6.895
6.894
6.893
6.892
100
120
140
160
180
200
220
240
260
280
300
Time (s)



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