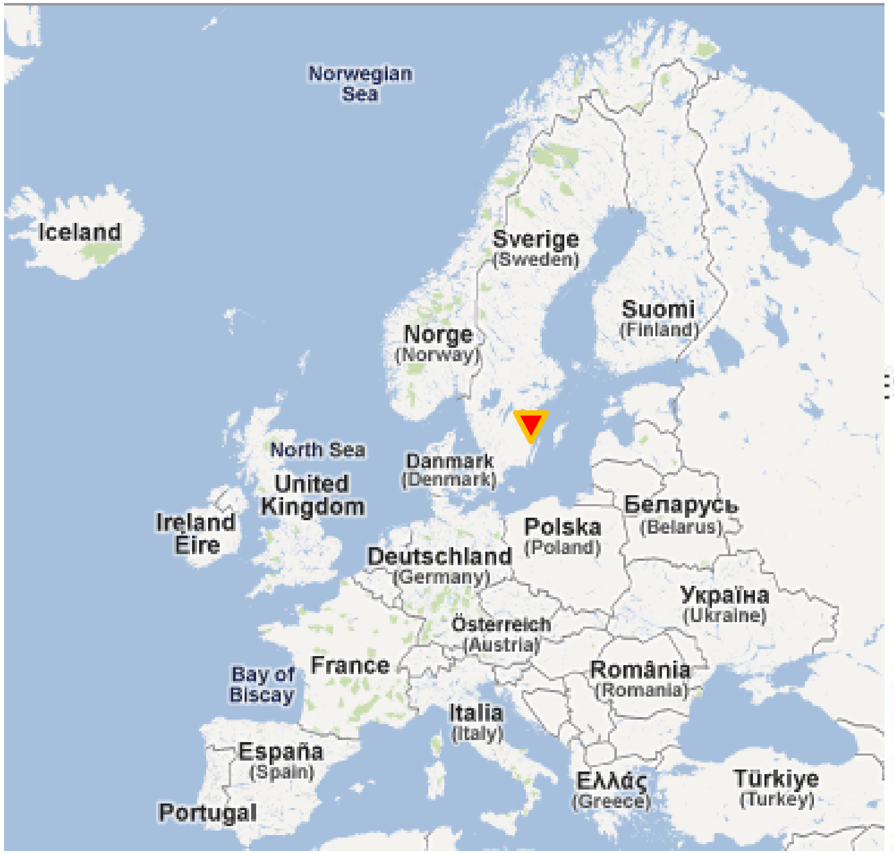
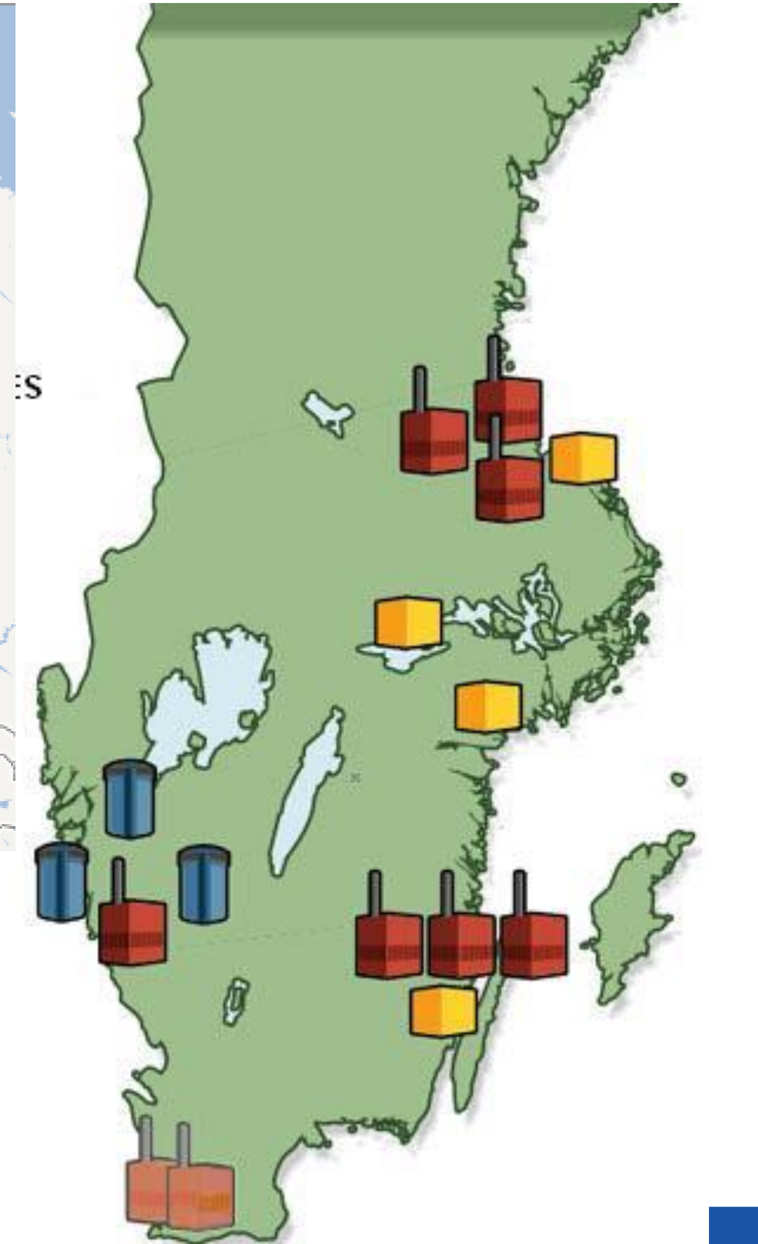
Oskarshamn-2 plant, the 1999 stability event

Sean Roshan



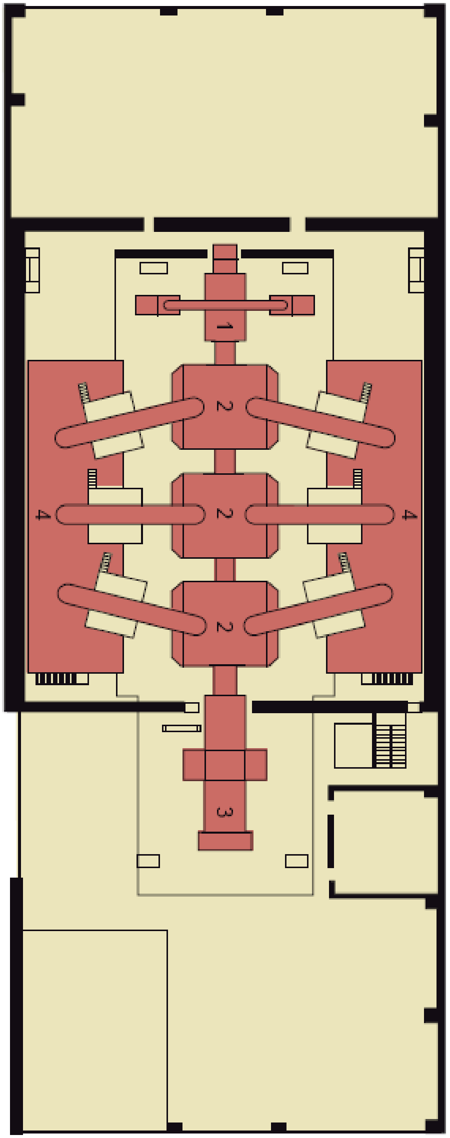


- **OKG owns and operates three BWRs 30 km north of Oskarshamn**
- **Owned by**
    - **E.ON (54.5 %)**
    - **Fortum (45.5 %)**

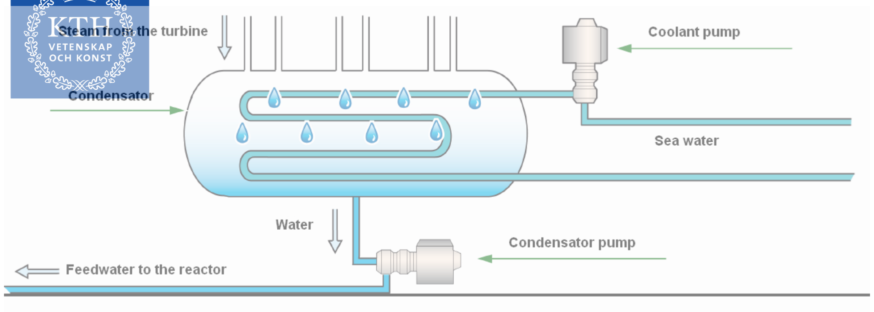
- BWR built by ASEA
- Start of operation: 1974
- Power uprate in early 1980s to 1800 MW (105.9 %)

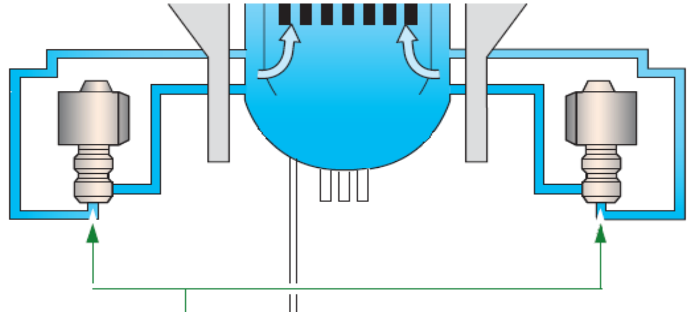
Oskarshamn 2		
Thermal power	MW	1800
Operation pressure	MPa	7.0
Steam Temperature	˚C	286
Steam flow rate	Kg/s	900
Maximum, total Recirculation flow	Kg/s	7700
Reactor pressure vessel		
Internal height	m	20
Internal diameter	m	5.2
Weight	kg	530,000
Wall thickness	mm	134
Core		
Equivalent core diameter	mm	3672
Equivalent core height	mm	3712
Number of fuel bundels		444
Burnup	MWd/ton U	45000
Average enrichment	% U-235	3.4
Control rods		
Absorbing material		B4C
Number of CR		109
Control rods are electro-hydraulically operated		

Turbines and Generator		
Generator rating	MW	627
Gross efficiency	%	35.0
Generator net rating	MW	602
Steam flow rate	Kg/s	900
Moist in the primary steam	%	0.5
Steam pressure before high pressure turbine	MPa	6.75
Steam temperature before high pressure turbine	˚C	283
Steam pressure after high pressure turbine	MPa	0.54
Steam temperature after high pressure turbine	˚C	158
Steam pressure in compensator	MPa	3.1
Steam temperature in compensator	˚C	30



1- High pressure turbine
2- Low pressure turbine
3- Generator
4- Intermediate superheater





Condenser		
Coolant flow (sea water)	m^3/s	26
Temperature rize	°C	10.7
Hotwell contents	m^3	210
Dumping capacity	%	110
Feedwater temperature	°C	185
Total number of pre-heating steps		5
Low pressure pre-heater		3
High pressure pre-heater		2

Main recirculation Pumps		
Total number of pumps		4
Nominal flow rate at nominal speed	Kg/s	1925
Pressure	MPa	0.55
Nominal speed	rpm	1400
Largest pressure difference at nominal speed and nominal flow rate	m	54.5
Nominal Hydraulic moment	Nm	6820
Inertia	Kg/m^2	26

Oskarshamn 2 event, February25th, 1999

At 14:59 The plant was operating at full power and minimum recirculation flow

During work at the switchyard, a short (150 ms) power interruption occurred while operating a breaker. This lead to Load Rejection which was interpreted differently by the turbine and the reactor.

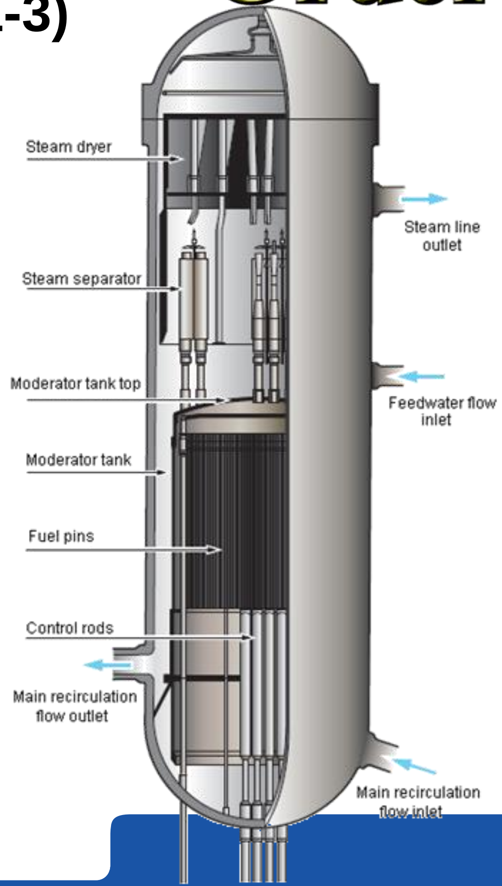
At that time the reactor got its' signals from the function "OFF", while the turbine got its' signal from the function "not ON".

The switch was somewhere in between ON and OFF

Load Rejection behaviour

- Fast Trip o R circu tion Pump 4.
- Partial Sc m.
- Pump run maining pumps (1-3)

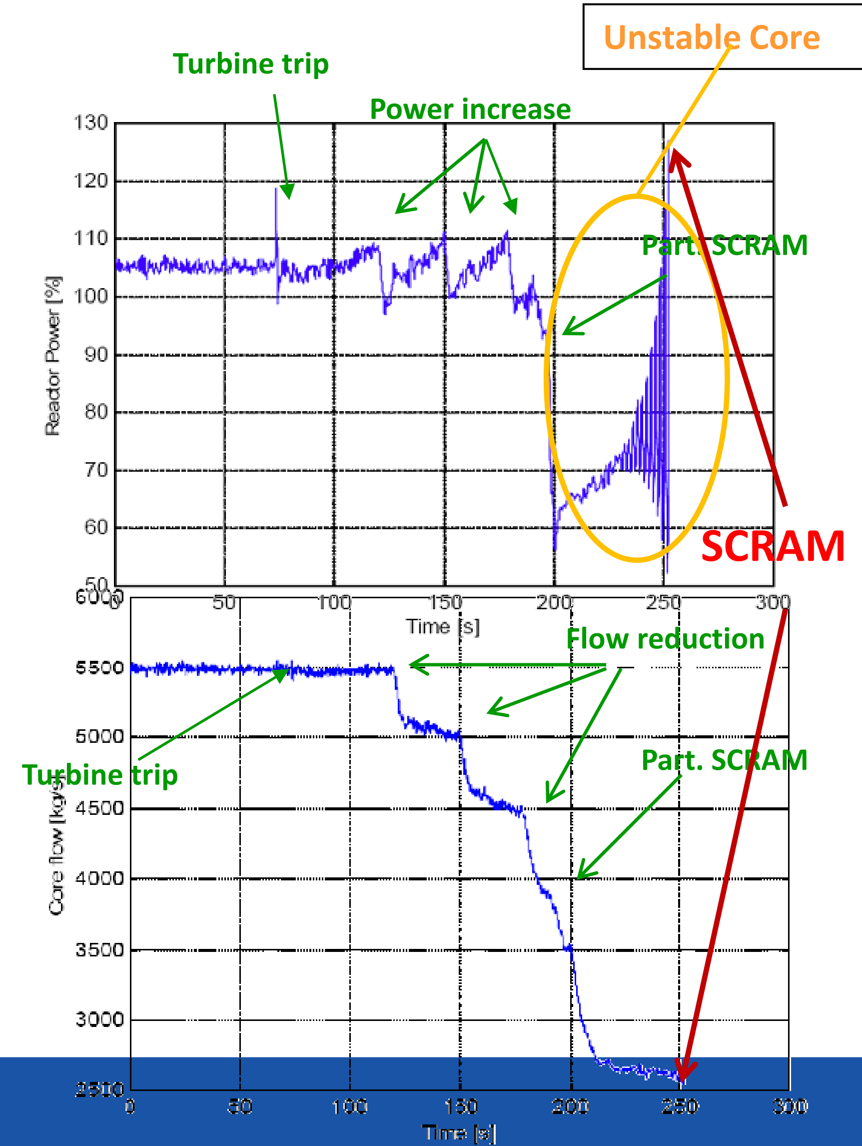
25 February 1999



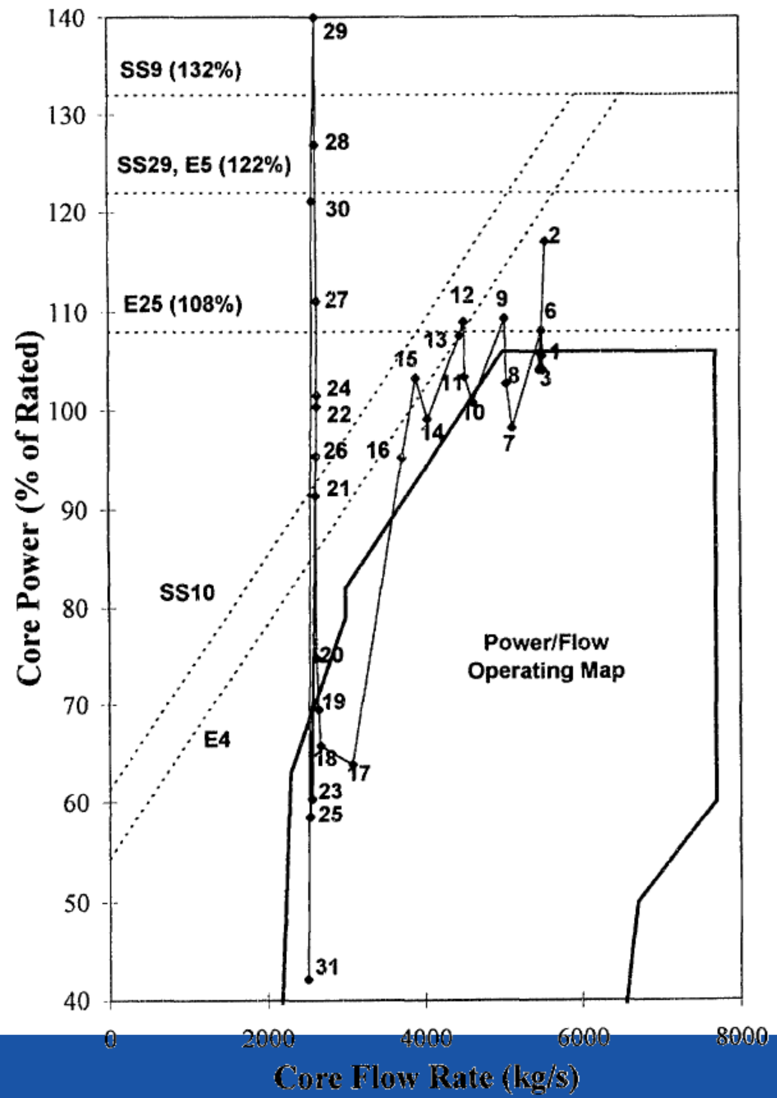
- Non of reactor functions did get any signal
- Reactor remained at full power
- Additionally, the Rundown of the Feedwater flow was too slow.

Oskarshamn 2 event, February25th, 1999

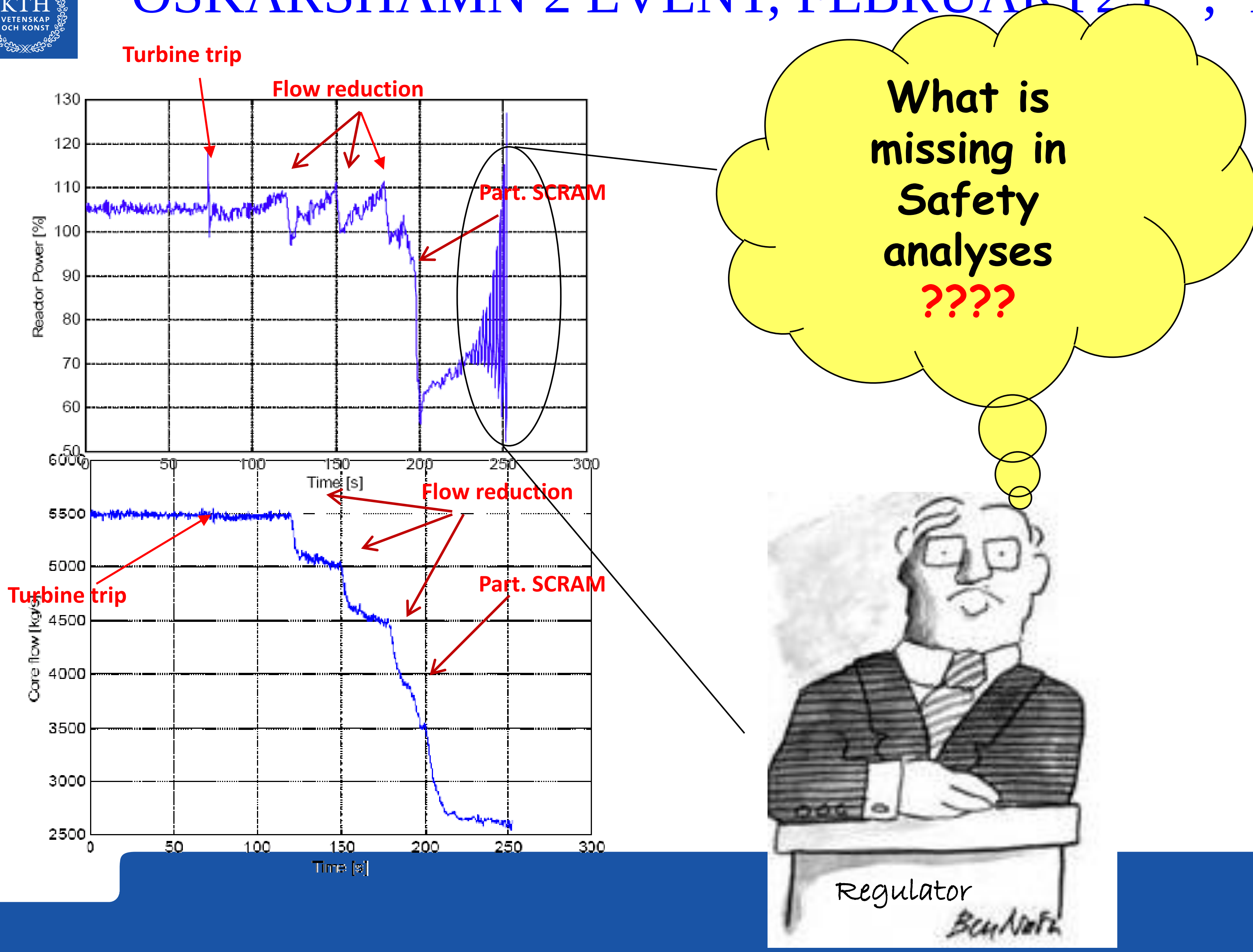
- Turbine trips, loss of pre-heaters
- While at full power, feedwater temperature decreased
- Reactor Power increases
- When reaching 108 % (signal E25) the power is automatically reduced below 108 % by pump speed reduction
- The operating point travels left after numerous such short rundowns
- Manual Partial scram because operating point is far outside the allowed area of the power-flow map
- The core gets unstable (Decay Ratio ~1.4) In about 10 oscillations the amplitude is 60%
- The reactor automatically SCRAMS at 132 % power. (SS9)



Power – Flow map



OSKARSHAMN 2 EVENT, FEBRUARY25TH, 1999



SAFETY ANALYSIS

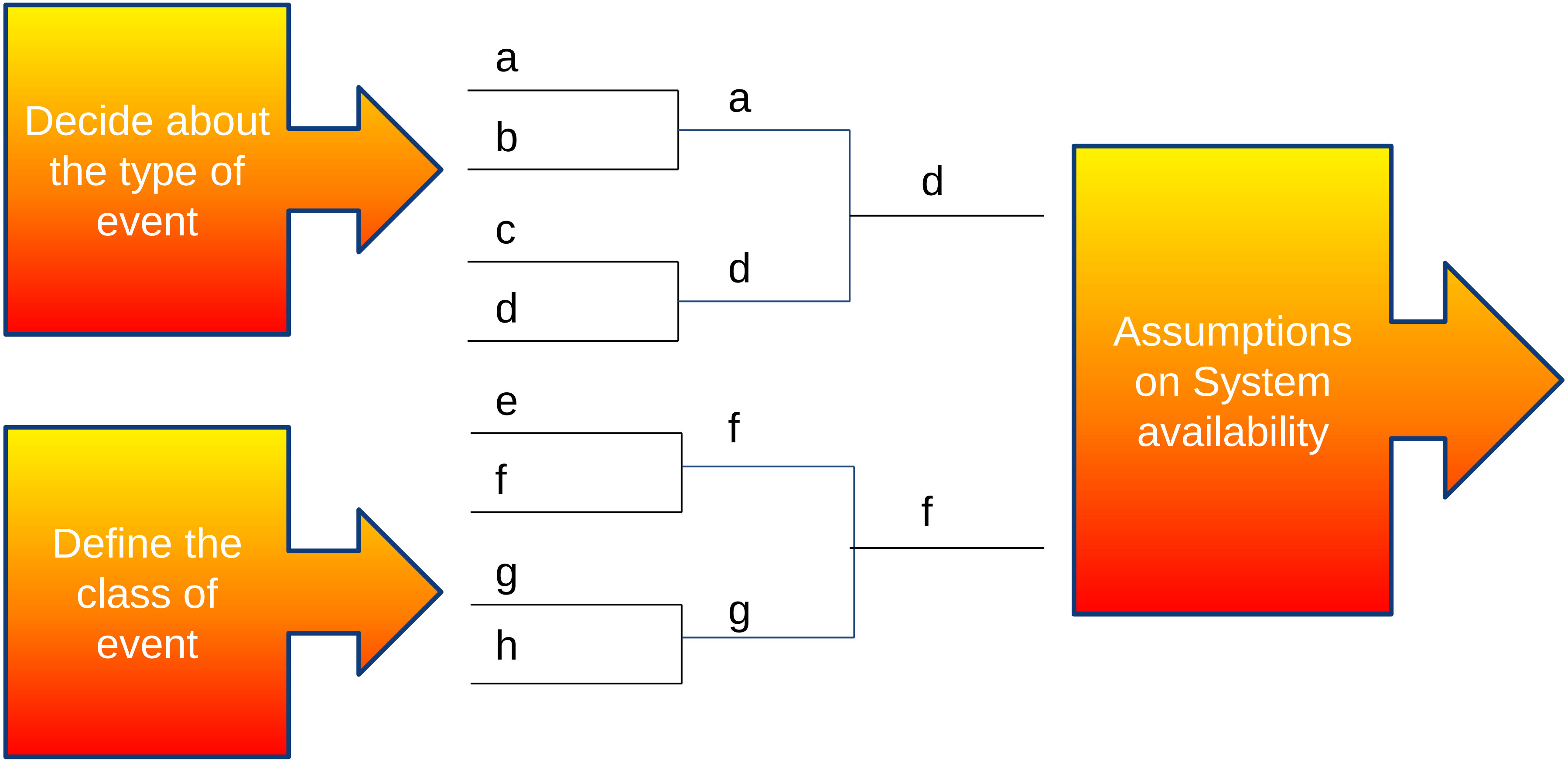
keeping the regulator happy IS the GOAL.

Level of conservatism is unknown

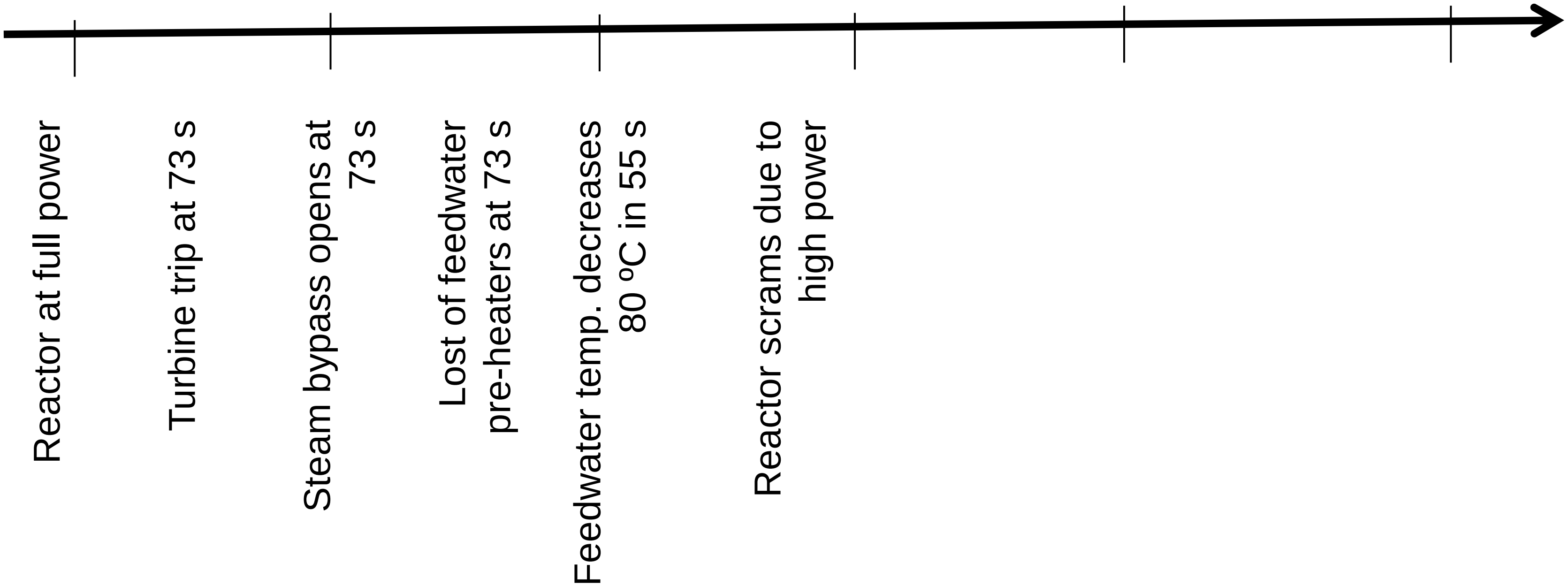
Results may be misleading, intentional conservatism may not lead to conservative results (unrealistic behavior predicted)

Uncertainties are not always known or responded to.

HOW SCENARIOS ARE SELECTED?



EXAMPLE: FEEDWATER TEMPERATURE TRANSIENT



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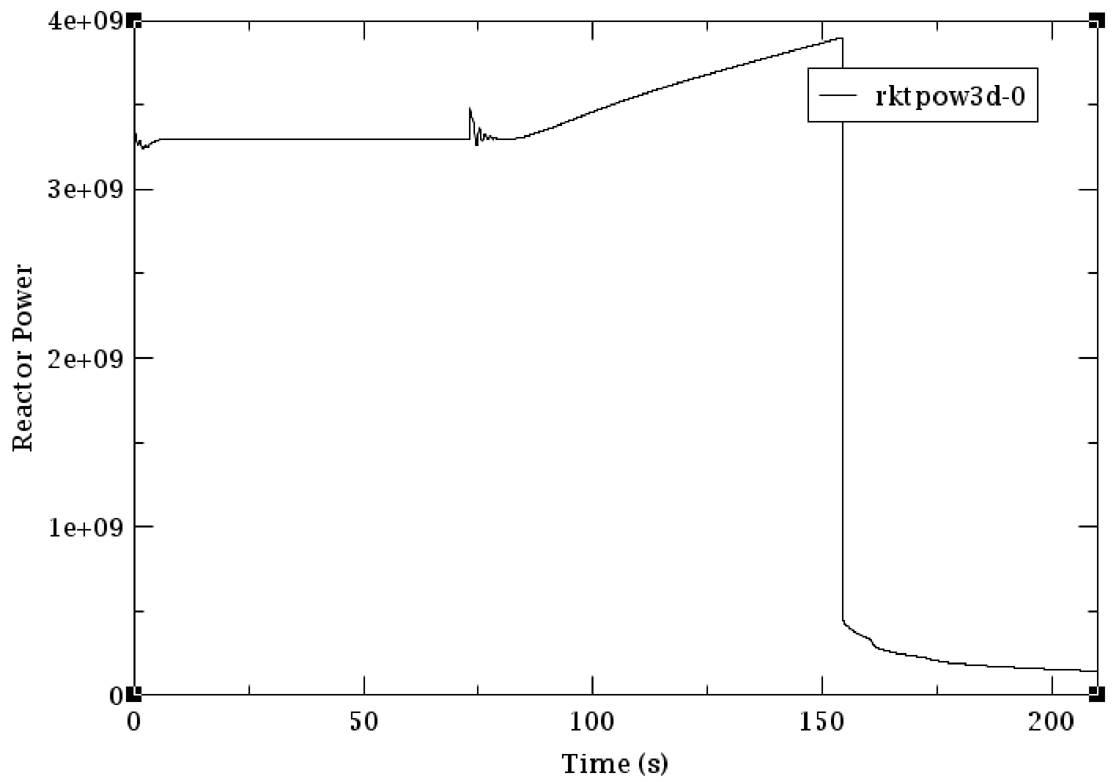


Flow Controller

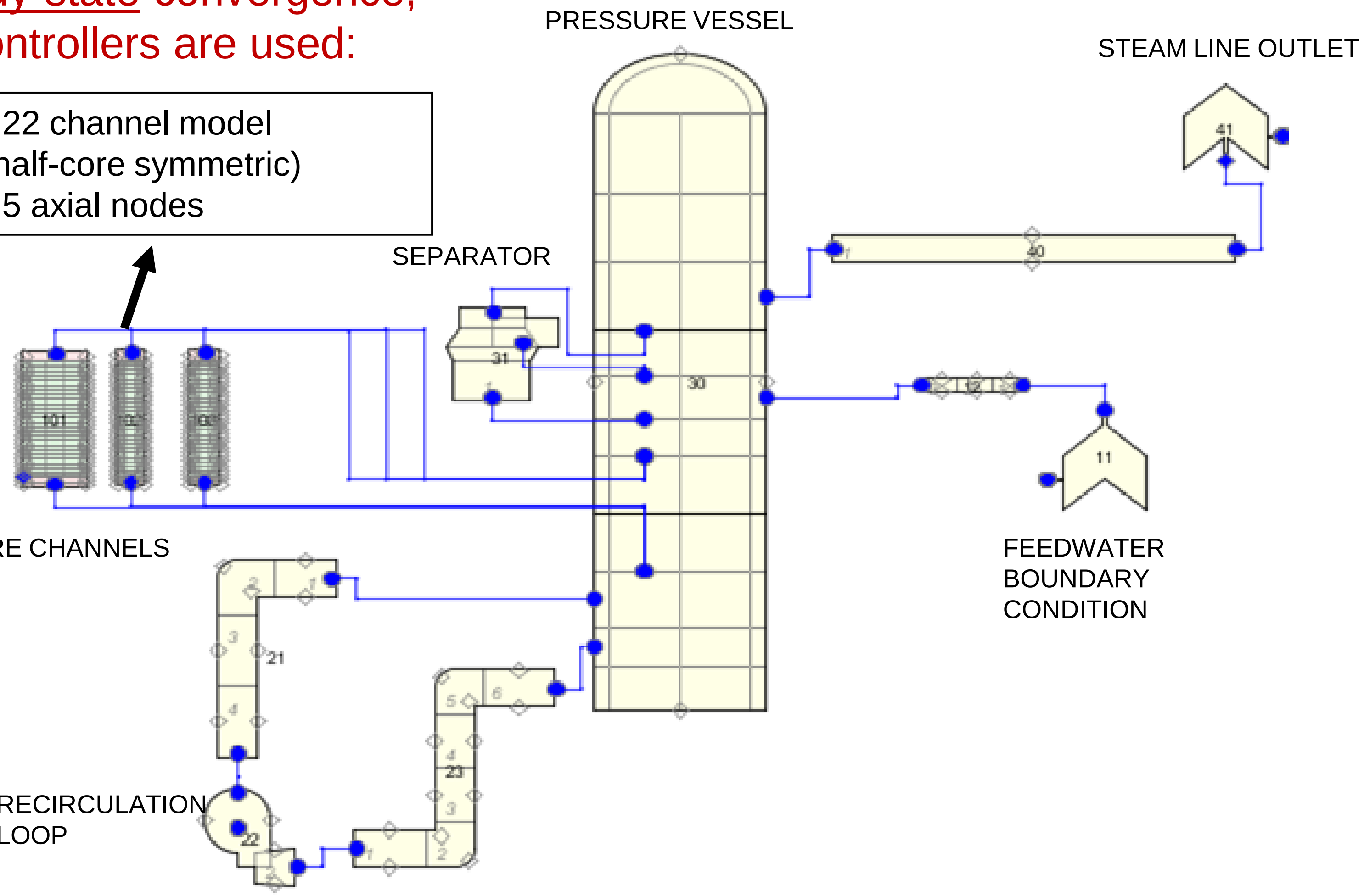
In a Swedish designed BWR main recirculation pumps are of rotation type. Hence, it is possible to by changing the revolution of the pump, change the flow rate through them and control the power of the reactor. This possibility has been used in a controller called Flow Controller. The main task of this controller is to regulate the power against a set point via controlling the main recirculation pumps' rotation speed.

The controller should be able to regulate the power in the reactor when small power changes occur without control rod movement.

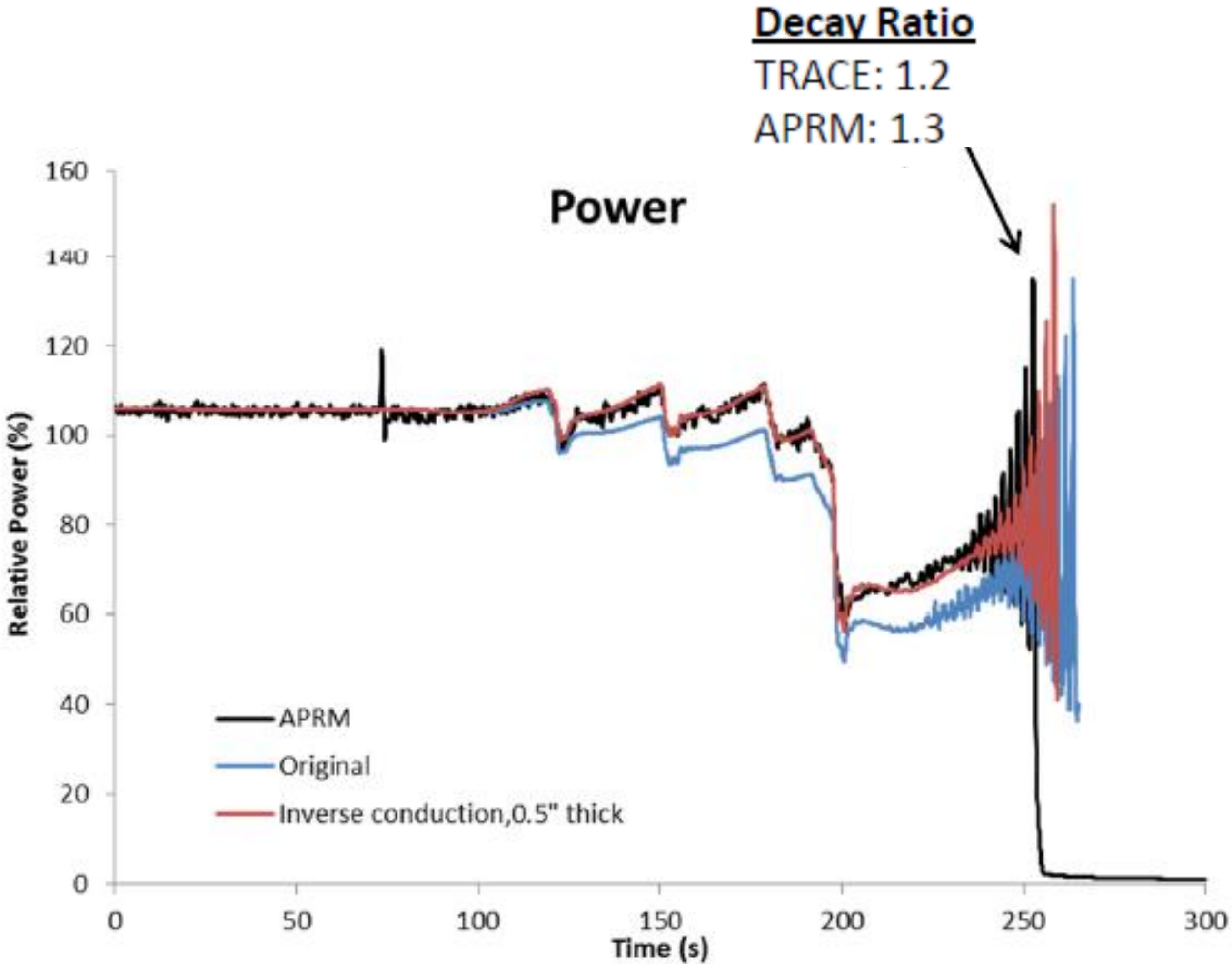
OSKARSHAMN-2 1999 INSTABILITY EVENT TRACE/PARCS MODEL

→ For steady-state convergence,
Standard controllers are used:

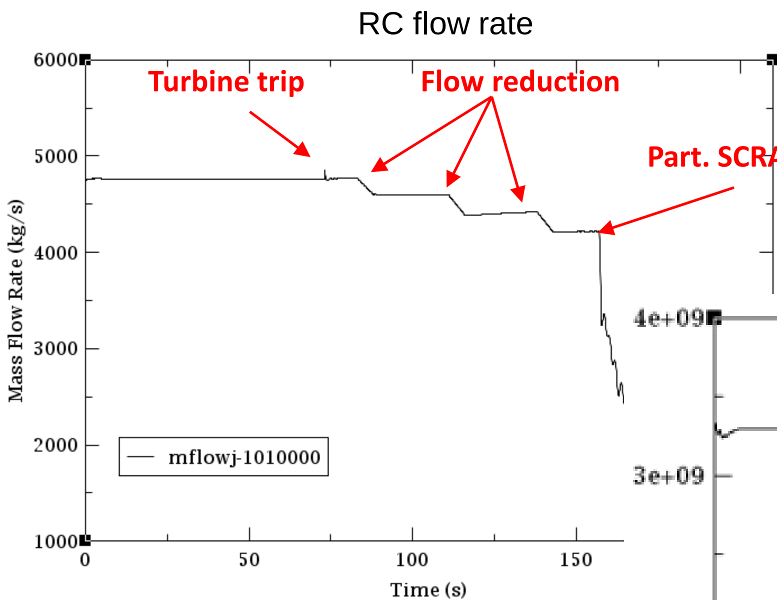
- 222 channel model
  (half-core symmetric)
- 25 axial nodes

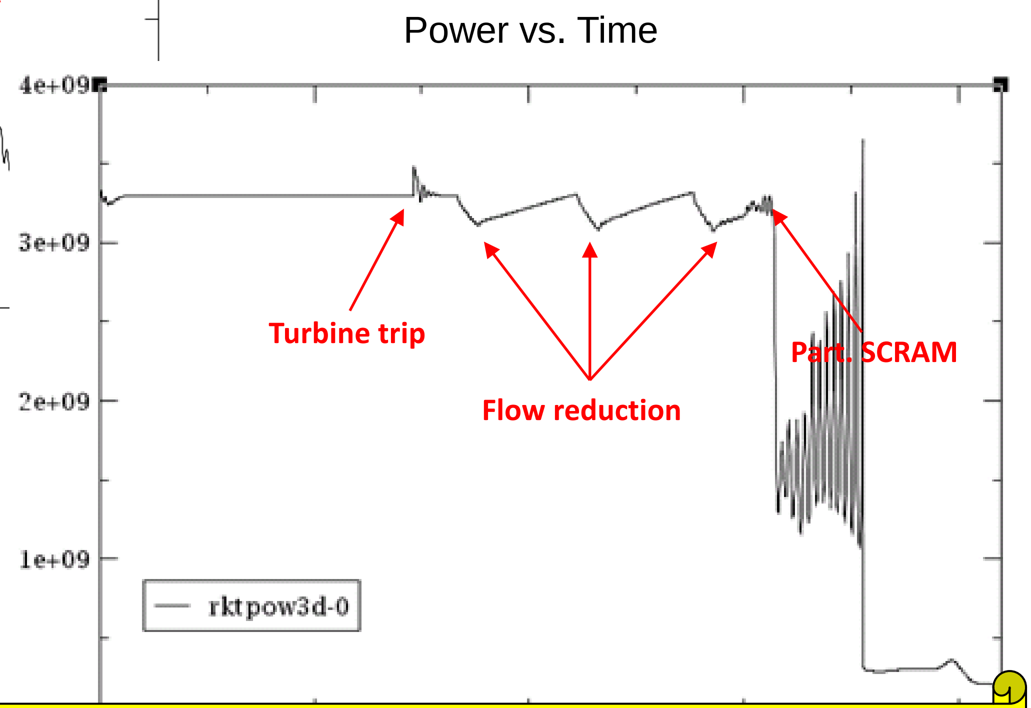


OSKARSHAMN-2 1999 STABILITY EVENT CORRECTED FW TEMPERATURE BC



SIMULATION OF THE OSKARSHAMN 2 1999 SCENARIO IN A GENERIC SWEDISH BWR





Results of Conservative Assumptions may be misleading,

intentional conservatism may not lead to conservative results

(Not taking the operational systems into account during the analysis as a conservative assumption for worst case scenario)

Actions taken after the Event

1. Signals changed. Same signal to the turbine and the reactor.

2. New unfiltrered sloped Partial-scram line.

3. Filter removed from Scram line (SS10)

4. Core Stability Monitoring (CSM) detects increasing amplitudes in APRM and LPRM signals and initiates partial-SCRAM or SCRAM automatically

5. Snakeskin Partial-SCRAM and SCRAM lines (ongoing)