SMART analysis with multi-scale multi-physics coupled codes involving TRACE SCF and PARCS

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Outlines

SMART analysis** with multi-scale multi-physics coupled **codes involving TRACE SCF and PARCS

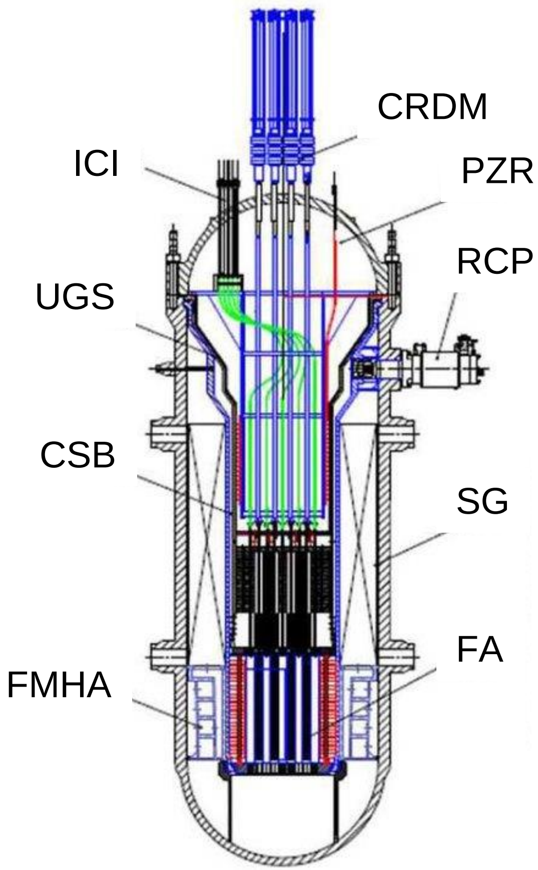
- SMART – introduction to the overall system
- Analysis 1 – accident: Loss Of FeedWater (LOFW)
- Code 1: TRACE/SCF
- Analysis 2 – accident: Steam Line Break (SLB)
- Code 2: TRACE/SCF/PARCS
- Conclusion and Outlook

For the four middle items:

- Codes coupling methodology
- Modeling
- Transient sequences
- Results

SMART Reactor

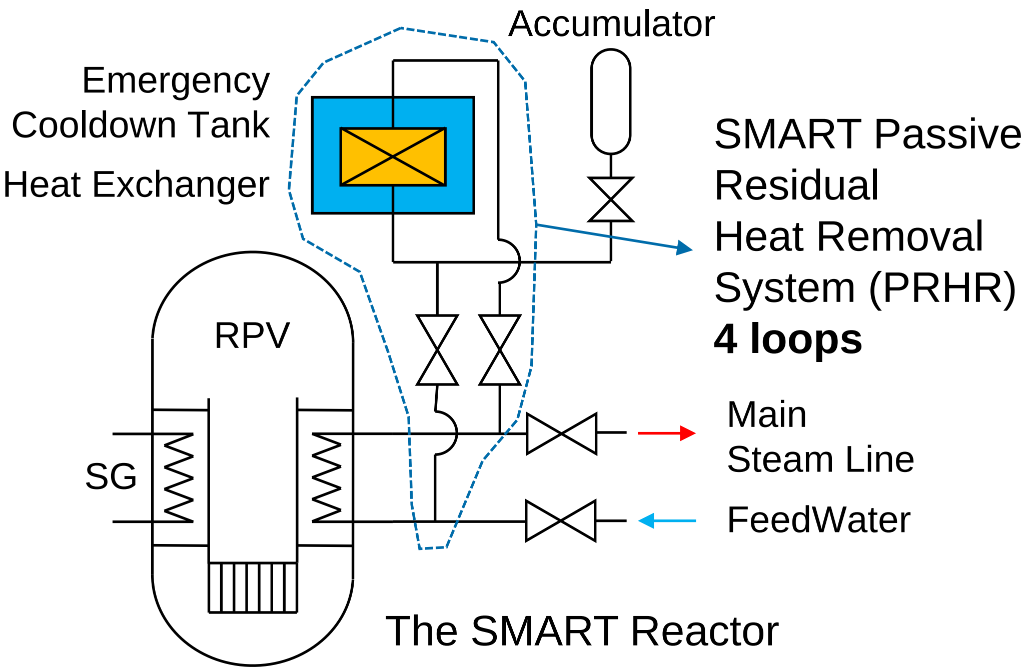
System-Integrated Modular Advanced Reactor (KAERI, South Korea)



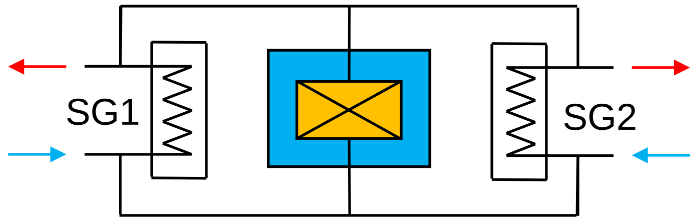
The SMART RPV

4 RCP
8 SG

CRDM: Control Rod Drive Mechanism
ICI: Incore Instrumentation
UGS: Upper Guide Structure
CSB: Core Support Barrel
FMHA: Flow Mixing Header Assembly
PZR: Pressurizer
RCP: Reactor Coolant Pump
SG: Steam Generator
FA: Fuel Assembly



The SMART Reactor



Two SGs share one PRHRS loop

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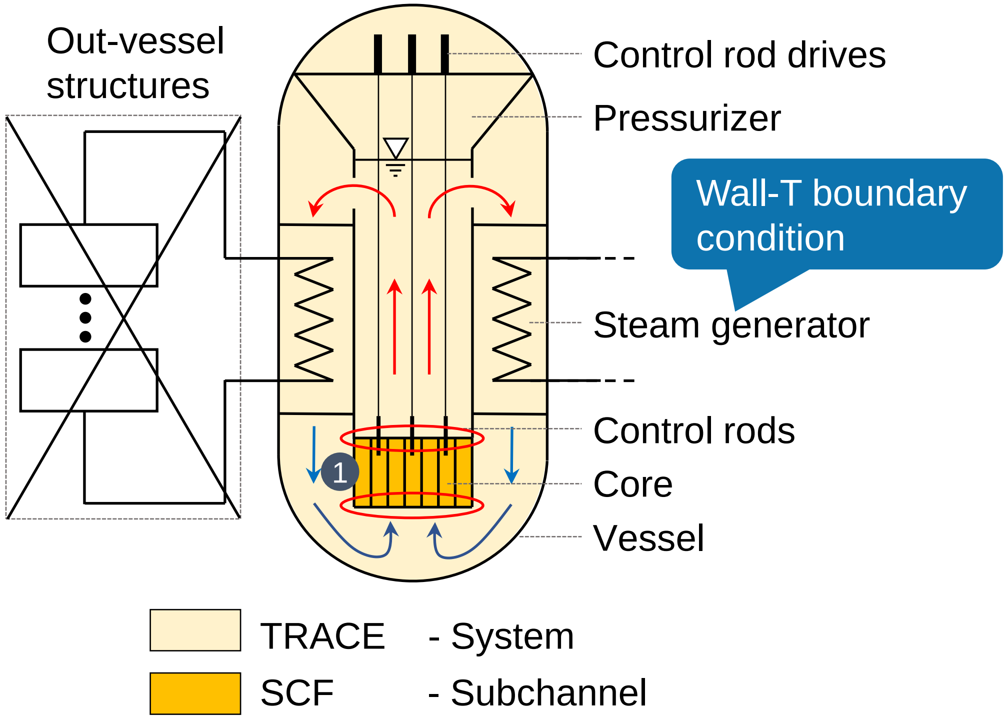
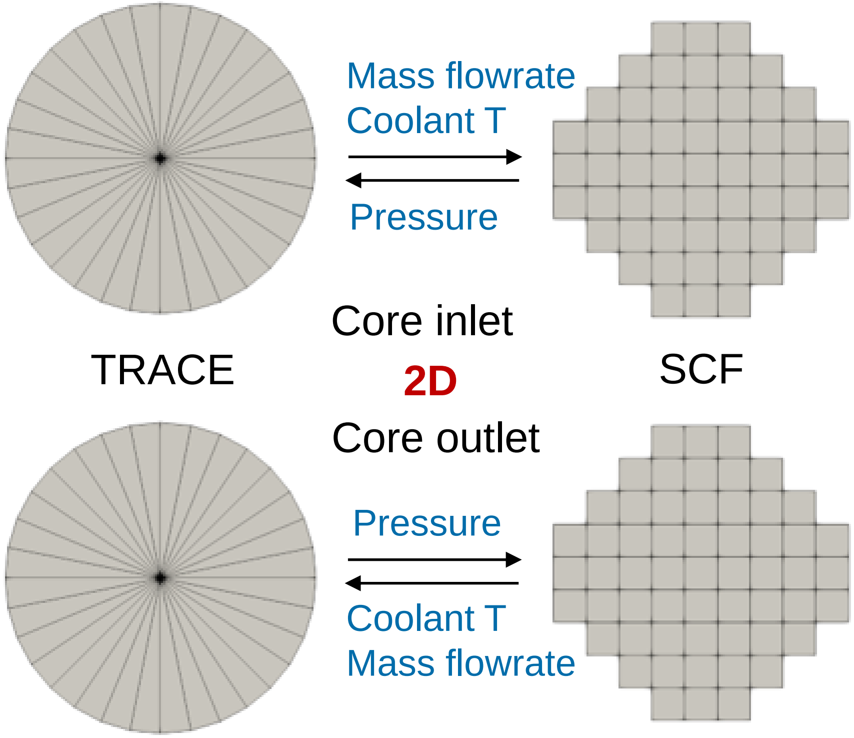
SMART Loss Of FeedWater (LOFW) – TRACE/SCF

*Codes coupling methodology – via **ICoCo***



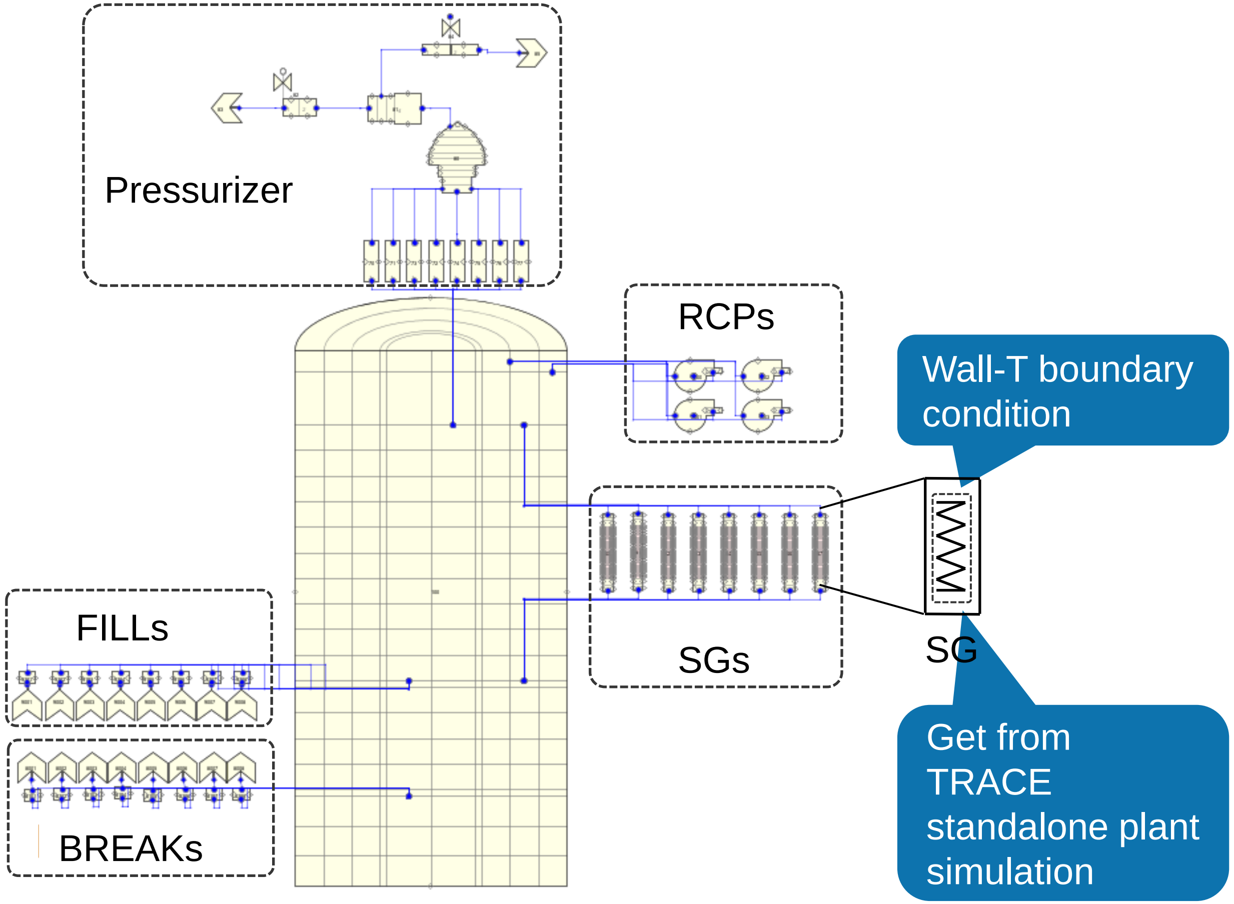


1 Interface between TRACE and SCF

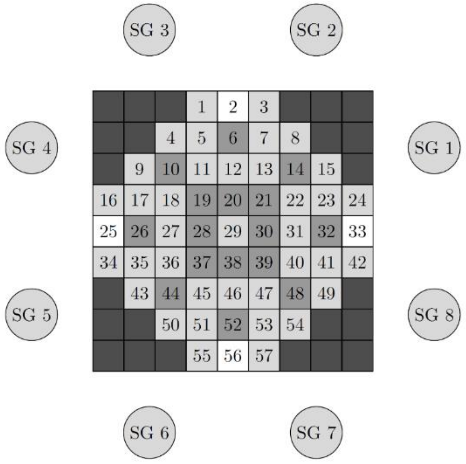
The field mapping between codes are by MEDCoupling

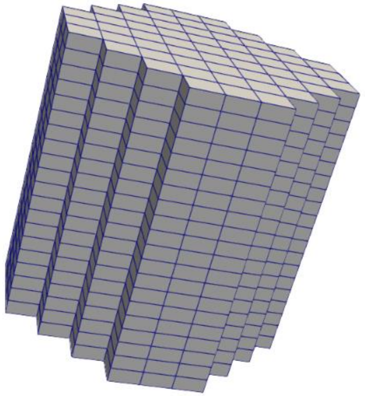
SMART Loss Of FeedWater (LOFW) – TRACE/SCF

*Modeling: TRACE – **RPV TH**, SCF – **Core TH**, SCF – **Core NK** (point kinetic)*



TRACE model - RPV



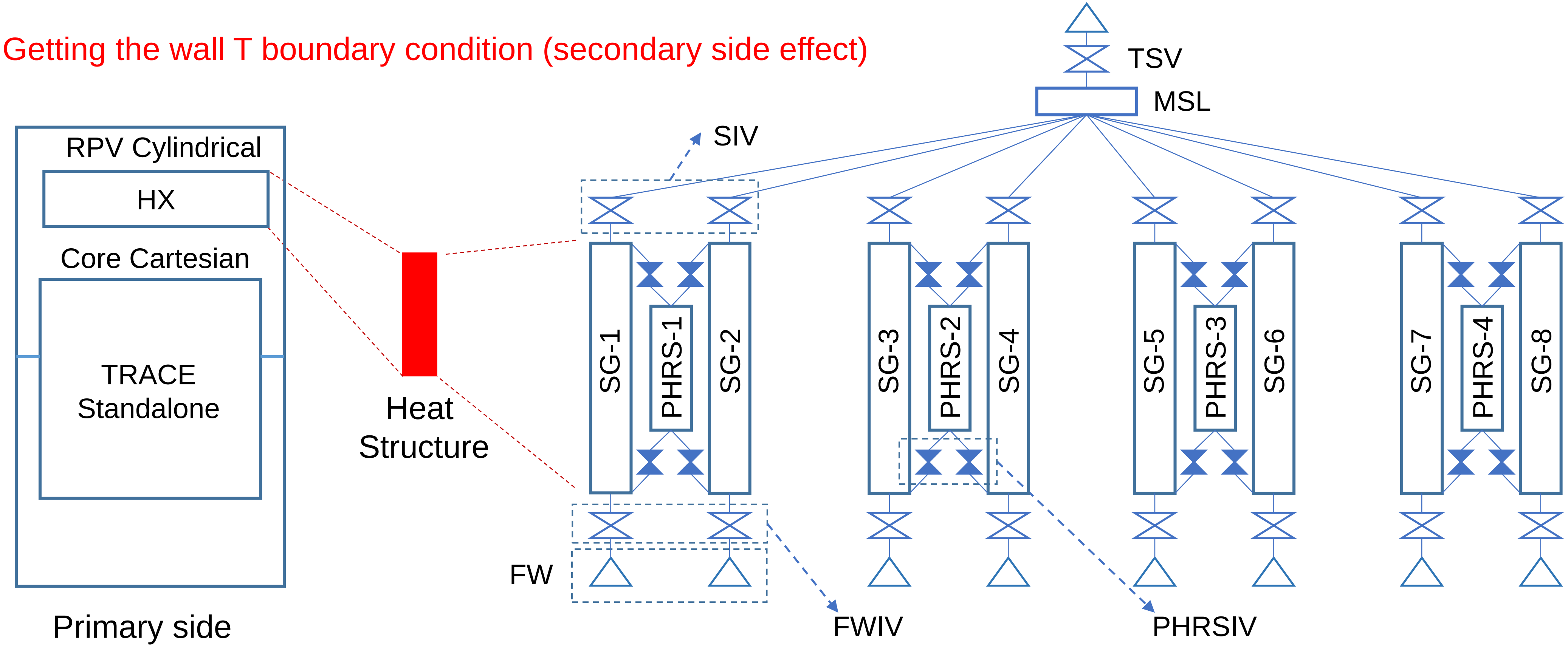


SCF model - Core

SMART Loss Of FeedWater (LOFW) – TRACE/SCF

*LOFW sequence: from Steady State (**SS**)*

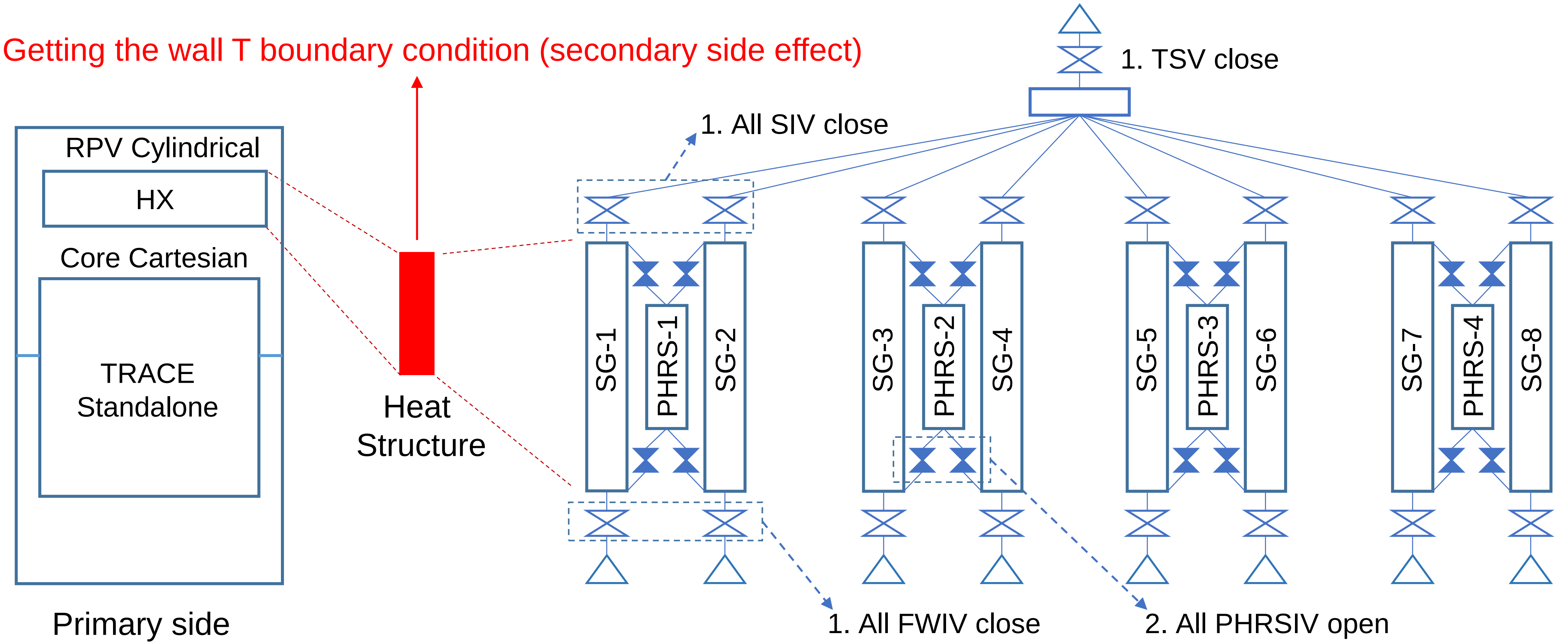
Getting the wall T boundary condition (secondary side effect)



Solid shapes – close
Empty shapes – open

SMART Loss Of FeedWater (LOFW) – TRACE/SCF

*LOFW sequence: transient **(TS)***



1. LOFW: all FWIV, SIV, and TSV close;
2. All PHRSIV open, no SCRAM, main PUMPs keep running.

Solid shapes – close
Empty shapes – open

SMART Loss Of FeedWater (LOFW) – TRACE/SCF

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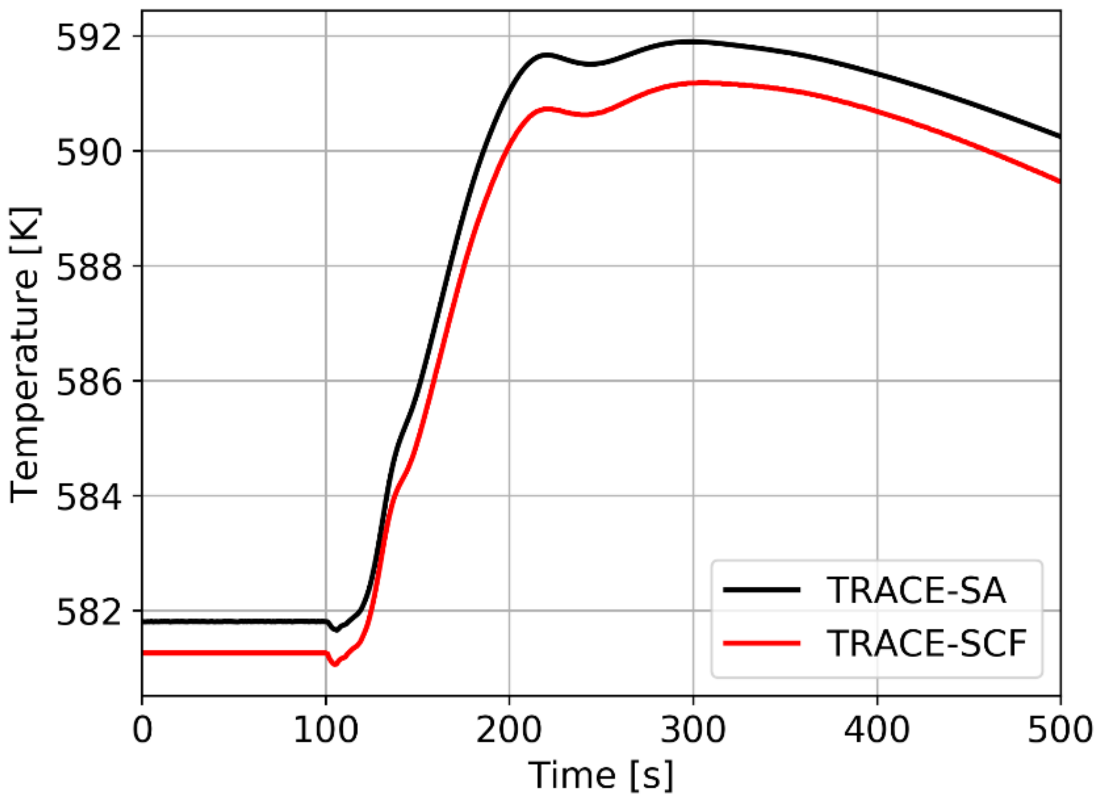
*Results: Steady State **(SS)***

Parameter	Reference	TRACE (error %)	TRACE-SCF (error %)
Primary pressure (MPa)	15.0	14.92 (0.5)	14.88 (0.8)
Core Power (MW)	330.0	330.0 (0.0)	330.0 (0.0)
Core inlet T (K)	568.85	568.56 (0.05)	568.28 (0.1)
Core outlet T (K)	596.15	594.07 (0.35)	592.37 (0.66)
Total mass flow rate (kg/s)	2090	2335 (11)	2337 (11)
Core pressure drop (kPa)	Between 5-45	25.7	26.3

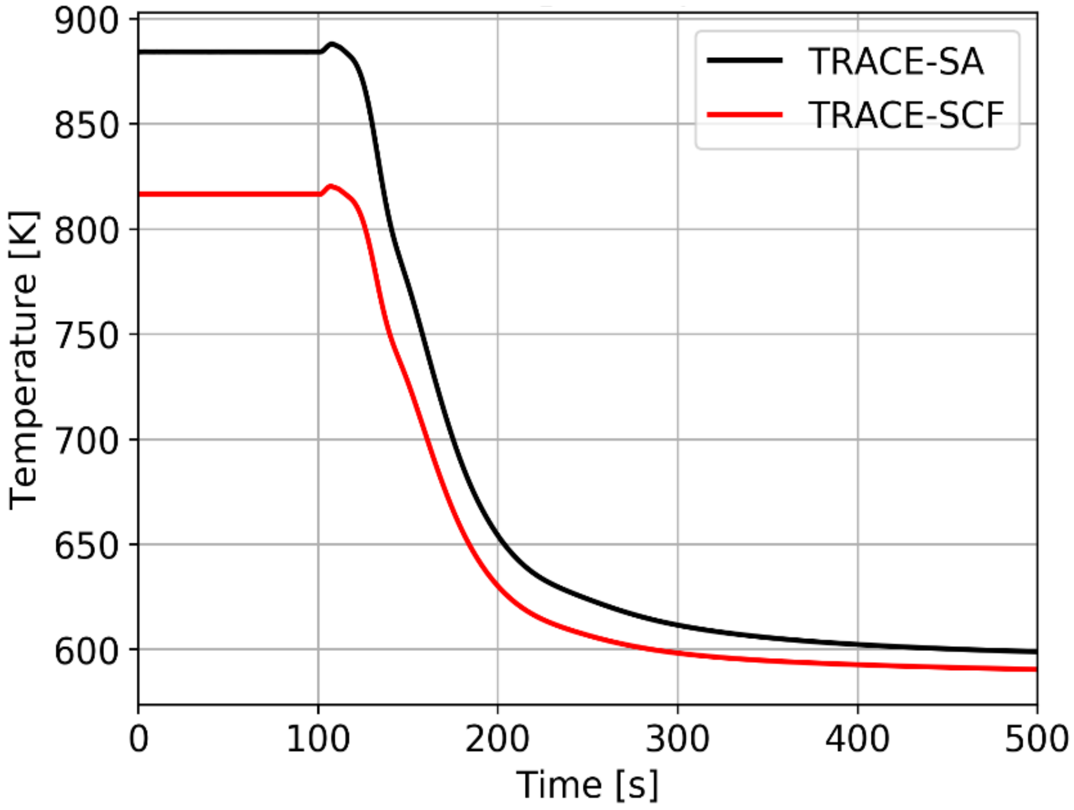
SMART Loss Of FeedWater (LOFW) – TRACE/SCF

Results: transient ***(TS)***

Coolant average temperature in the core



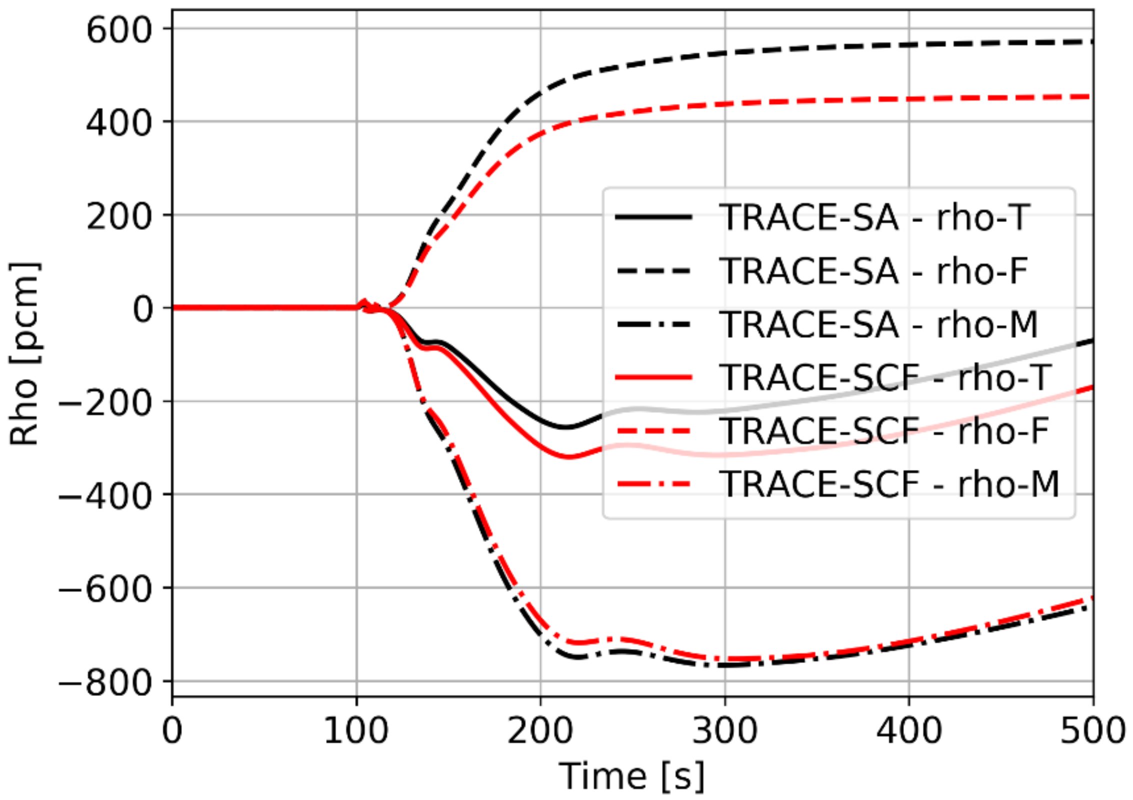
Fuel average temperature



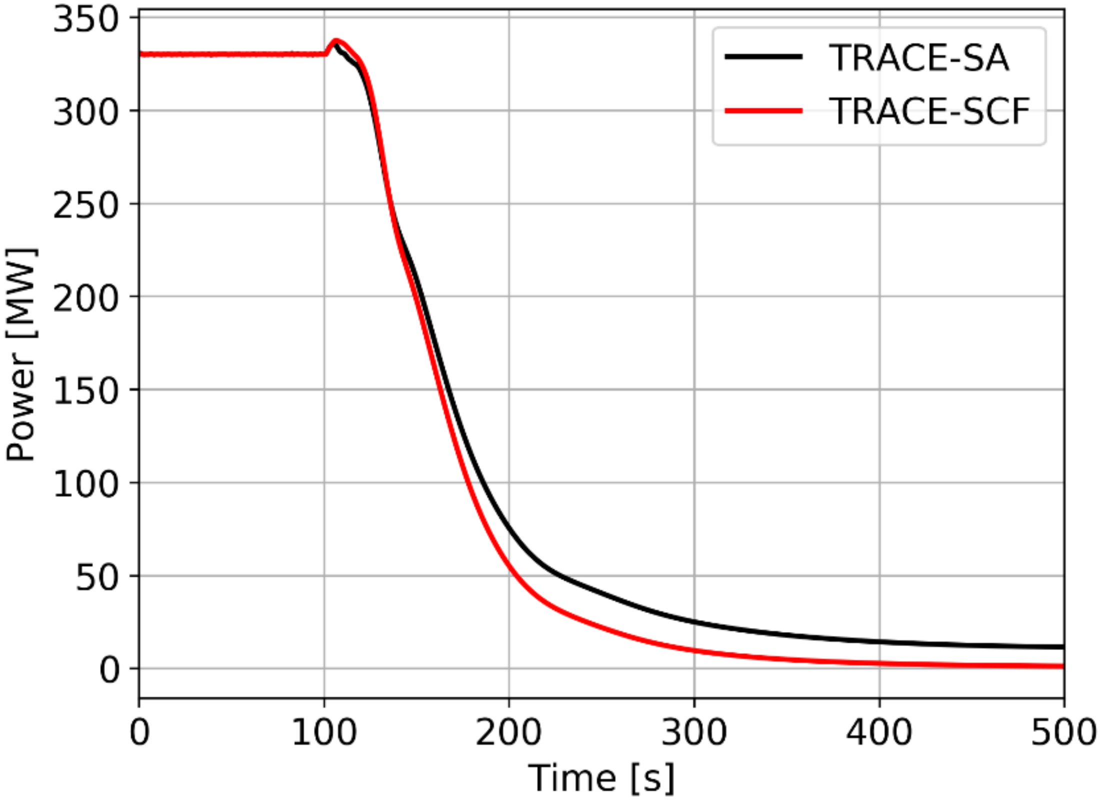
SMART Loss Of FeedWater (LOFW) – TRACE/SCF

*Results: transient **(TS)***

Total reactivities (T) and its compositions



The core power



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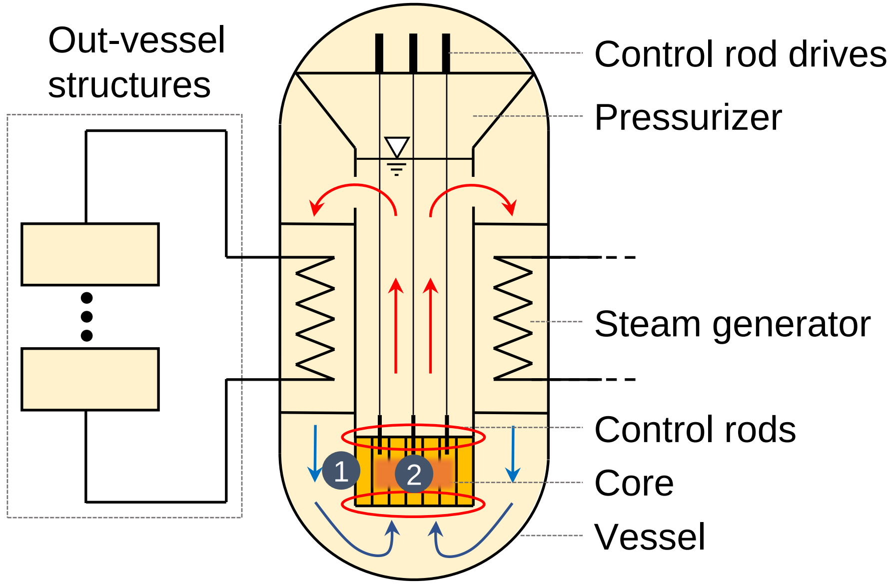
SMART Steam Line Break (SLB) – TRACE/SCF/PARCS

*Codes coupling methodology – via **ICoCo***



TRACE - System

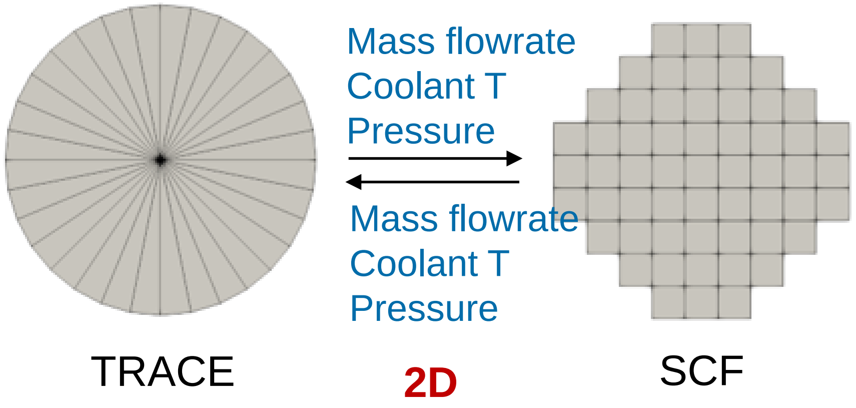
SCF - Subchannel

PARCS - Neutronic

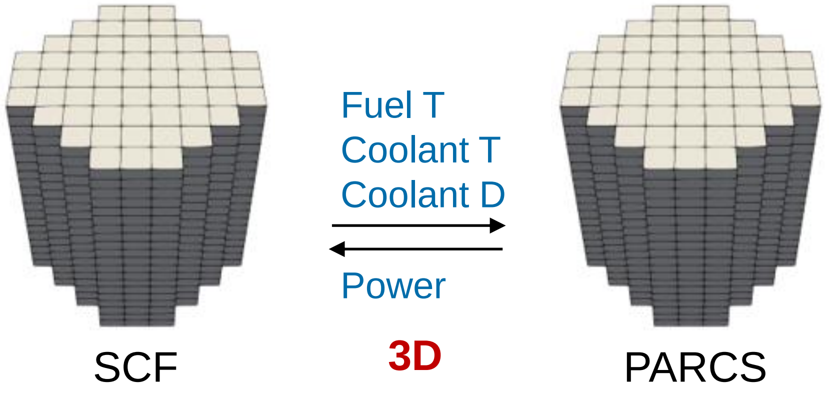
1 Interface between TRACE and SCF

2 Interface between SCF and PARCS

1 Interface between TRACE and SCF



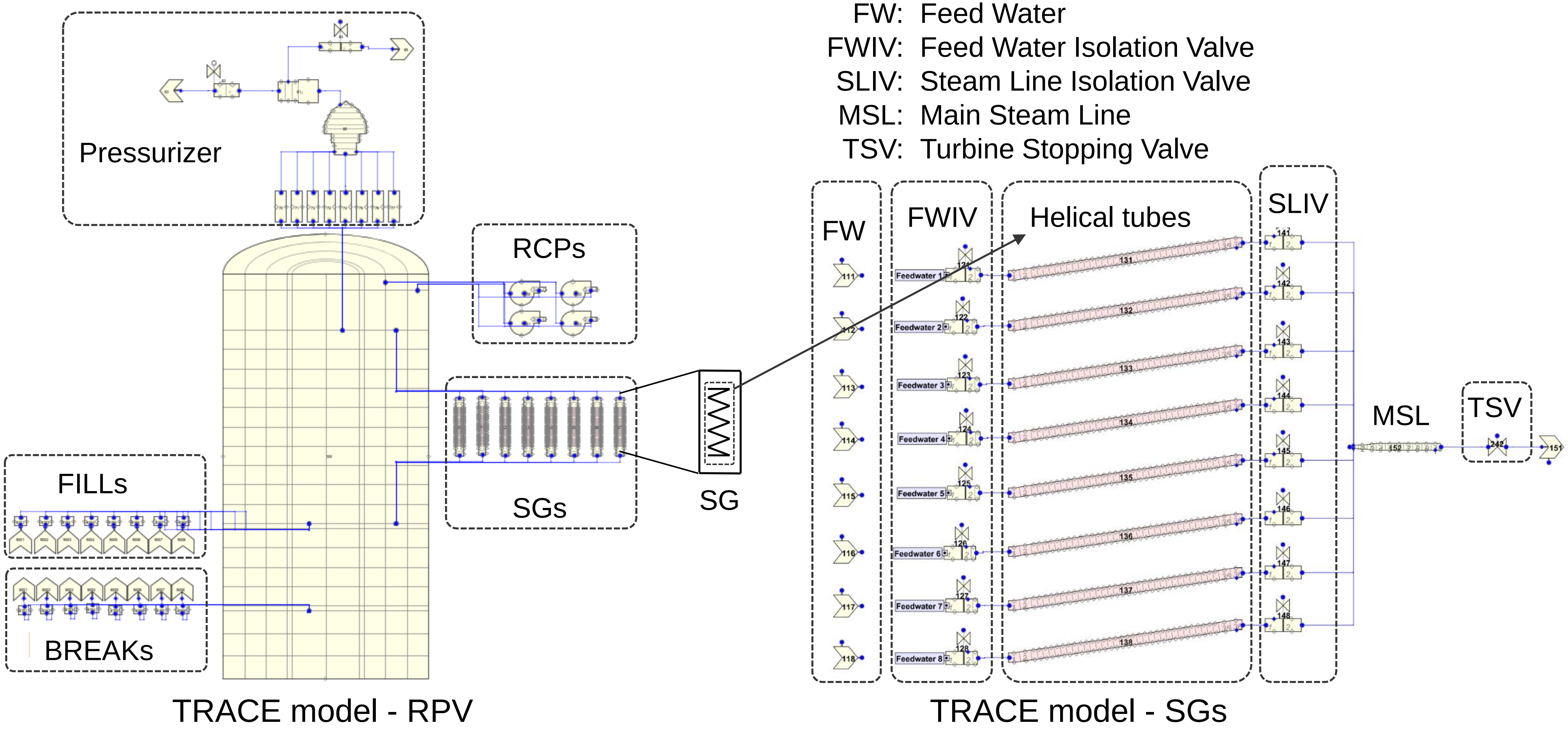
2 Interface between SCF and PARCS



SMART Steam Line Break (SLB) – TRACE/SCF/PARCS

*Modeling: TRACE – **RPV TH**, SCF – **Core TH**, PARCS – **Core NK***

FW: Feed Water
FWIV: Feed Water Isolation Valve
SLIV: Steam Line Isolation Valve
MSL: Main Steam Line
TSV: Turbine Stopping Valve



SMART Steam Line Break (SLB) – TRACE/SCF/PARCS

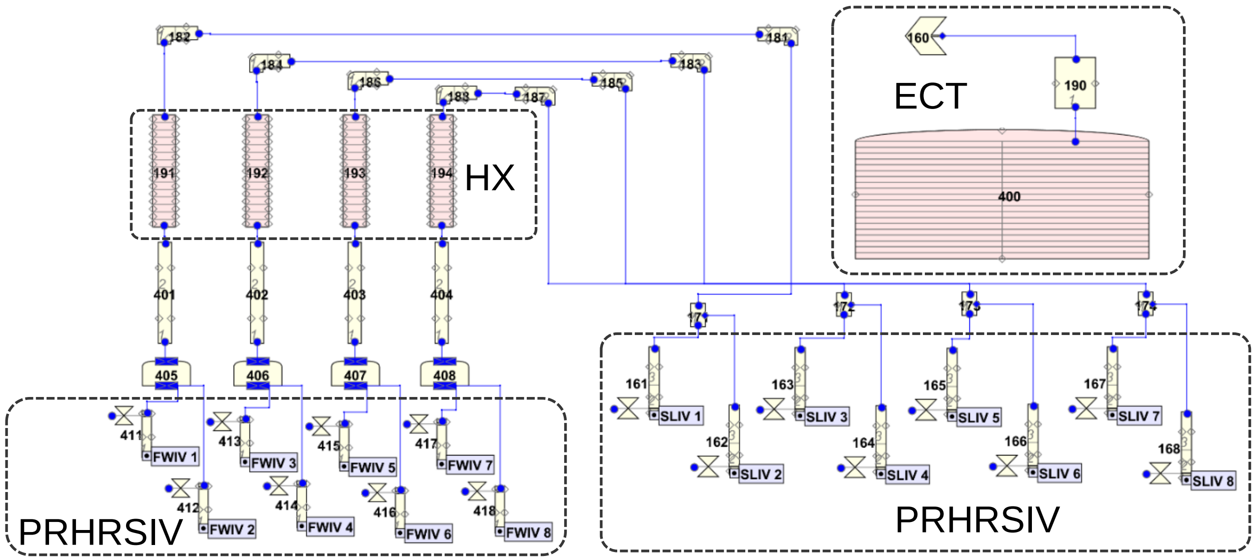
*Modeling: TRACE – **RPV TH**, SCF – **Core TH**, PARCS – **Core NK***

PRHRS: Passive Residual Heat Remove System

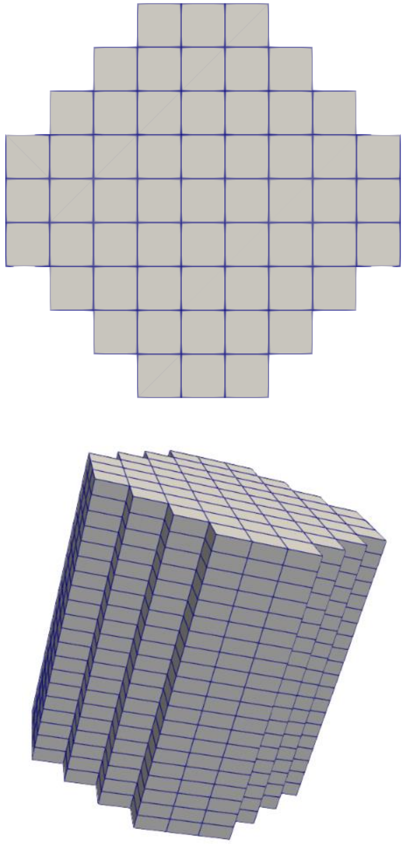
PRHRSIV: Passive Residual Heat Remove System Isolation Valve

ECT: Emergency Cooldown Tank

HX: Heat Exchanger



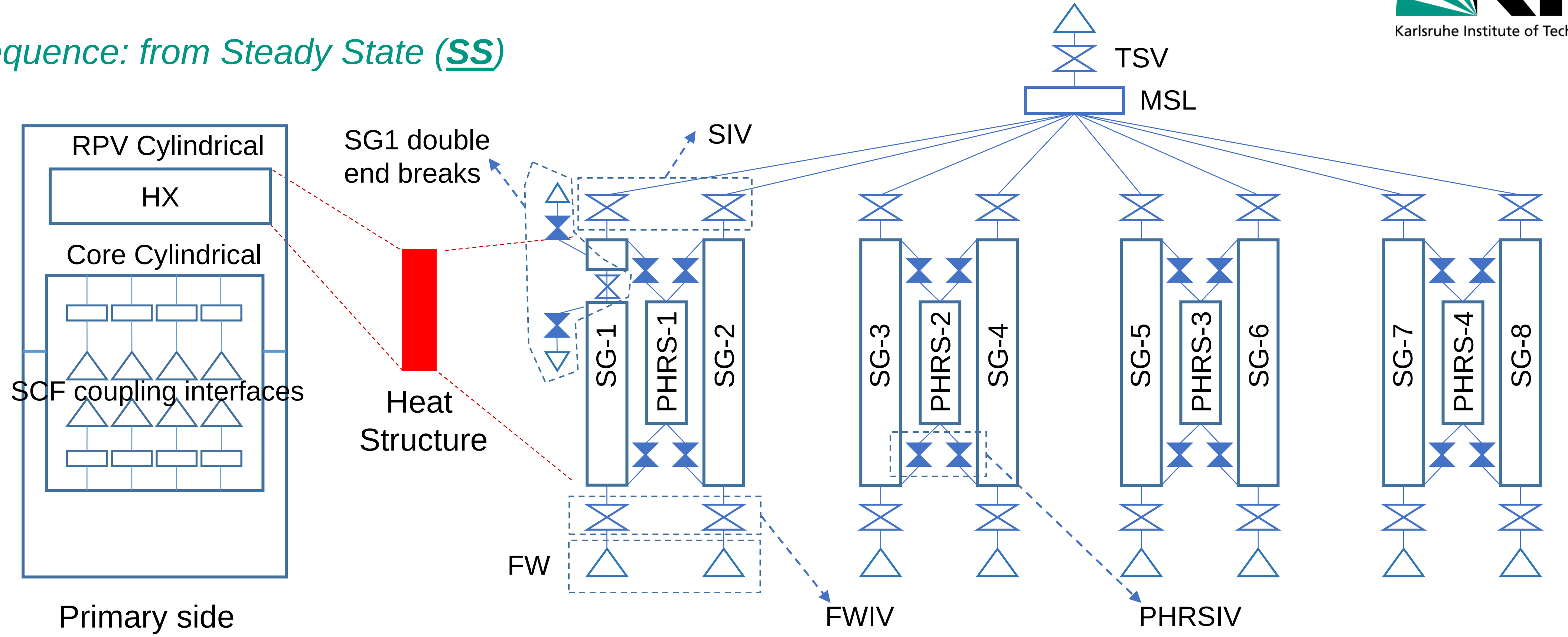
TRACE model - PRHRS



PARCS/SCF model - Core

SMART Steam Line Break (SLB) – TRACE/SCF/PARCS

*SLB sequence: from Steady State (**SS**)*



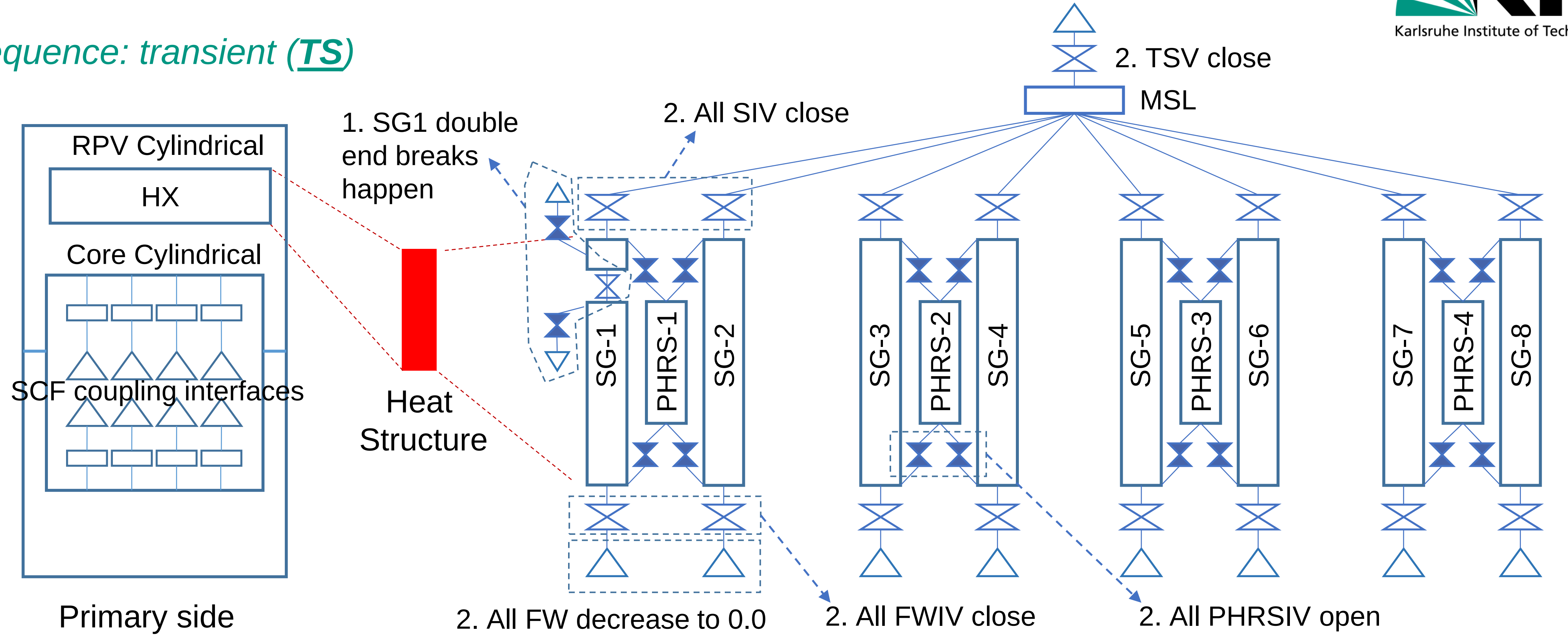
Initial Conditions

Thermal power (MW)	330.0	Core outlet temperature (K)	596.15
Core mass flow rate (kg/s)	2006.4	Main steam line mass flow (kg/s)	160.8
Core inlet temperature (K)	568.6	Main steam line pressure (MPa)	5.2

Solid shapes – close
Empty shapes – open

SMART Steam Line Break (SLB) – TRACE/SCF/PARCS

*SLB sequence: transient (**TS**)*



1. SG1 double end break happen, Loss of offsite power , at the same time;
2. Pumps coasting down, SG1 pressure decrease under 2.0 MPa;
3. SCRAM, SIV / FWIV / TSV close, PHRSIV open.

Solid shapes – close
Empty shapes – open

*The total transient is **500s** and the SLB happens at **100s**.*

SMART Steam Line Break (SLB) – TRACE/SCF/PARCS

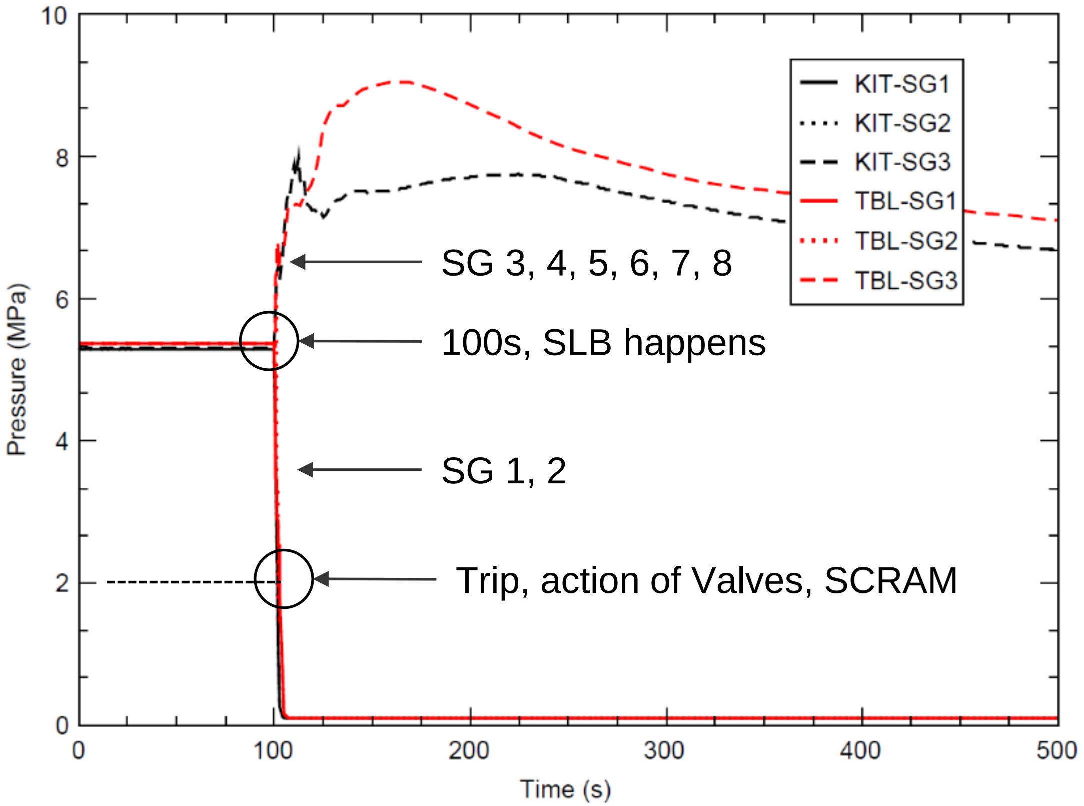
*Results: Steady State **(SS)** compared with **TRACE/PANTHER** by TBL*

Parameter	Reference	TBL (diff. %)	KIT (diff. %)
Primary pressure (MPa)	15.0	15.0 (0.0)	15.0 (0.0)
Core Power (MW)	330.0	330.0 (0.0)	330.0 (0.0)
Core inlet T (K)	568.85	567.9 (0.2)	563.3 (1.0)
Core outlet T (K)	596.15	596.15 (0.0)	591.0 (1.0)
Total RPV flow (kg/s)	2090.0	2090.0 (0.0)	2088.3 (0.1)
Core mass flow rate (kg/s)	2043	2058 (0.7)	2088.3 (2.2)
Core pressure drop (kPa)	Between 5-45	24.3	27.9

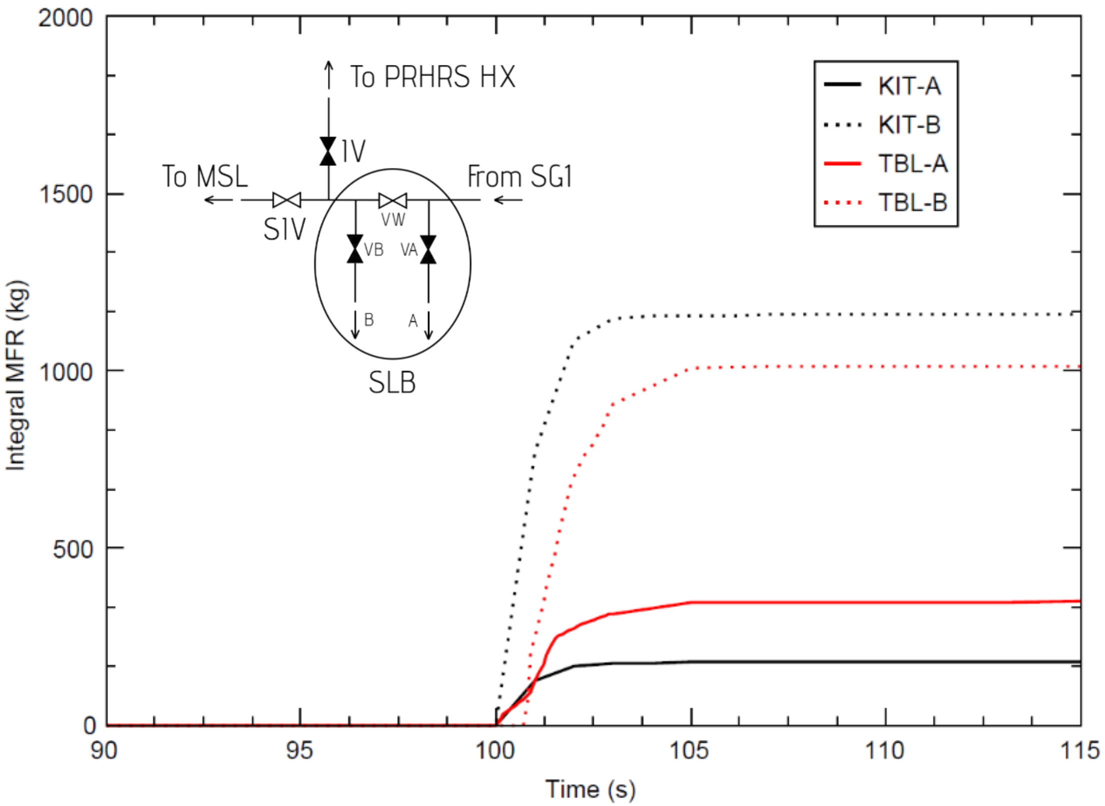
SMART Steam Line Break (SLB) – TRACE/SCF/PARCS

*Results: transient **(TS)** compared with **TRACE/PANTHER** by TBL*

Pressure in the SG tubes



Integral mass flowrate through SLB ends

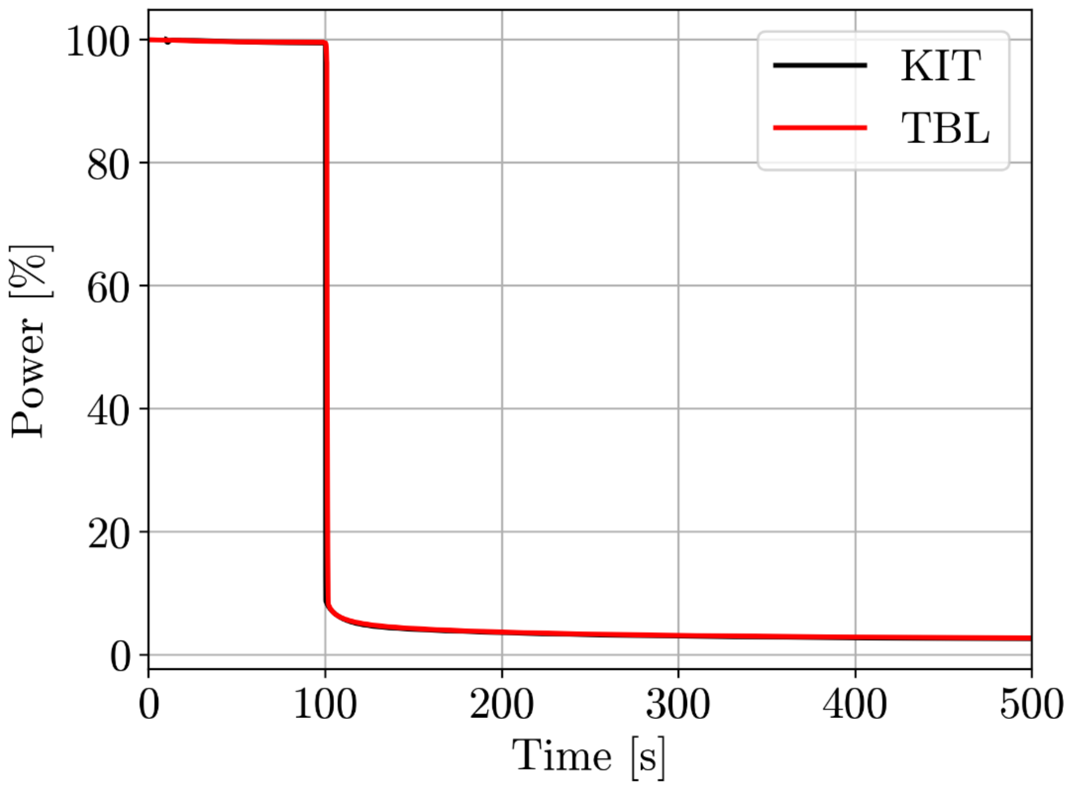


Workshop on Core and Plant Simulation with an Emphasis on Fuel Behaviour in Light Water Reactor Based Small Modular Reactors
IAEA, Vienna, 2024

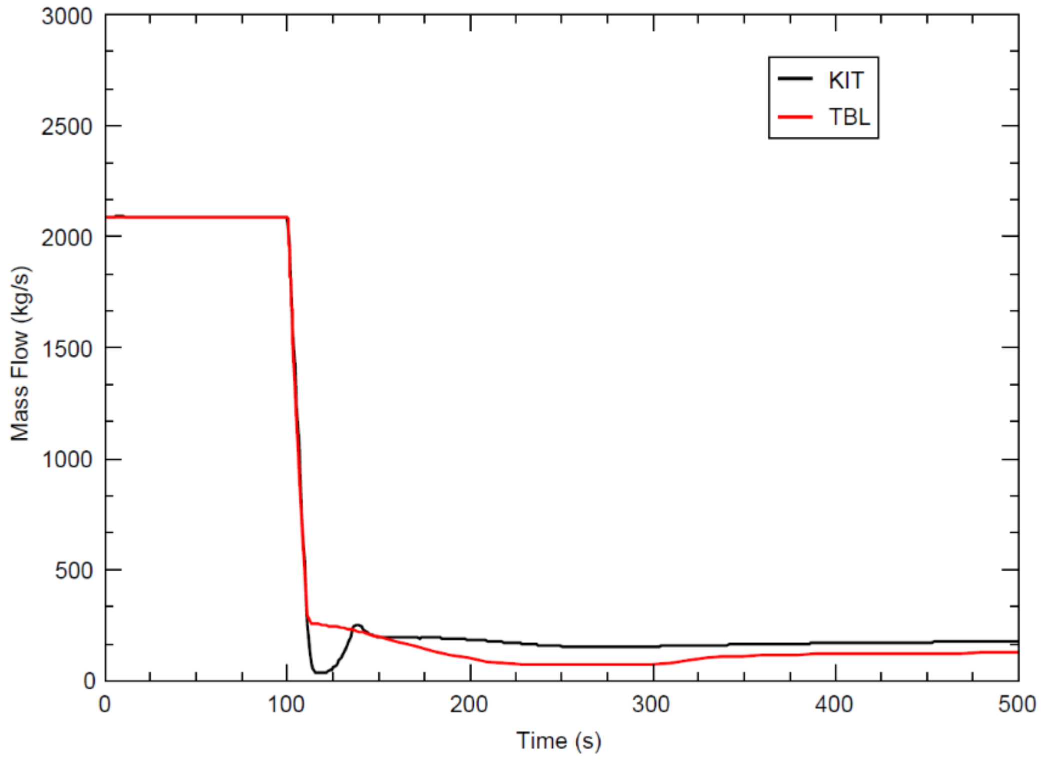
SMART Steam Line Break (SLB) – TRACE/SCF/PARCS

*Results: transient **(TS)** compared with **TRACE/PANTHER** by TBL*

Total core power



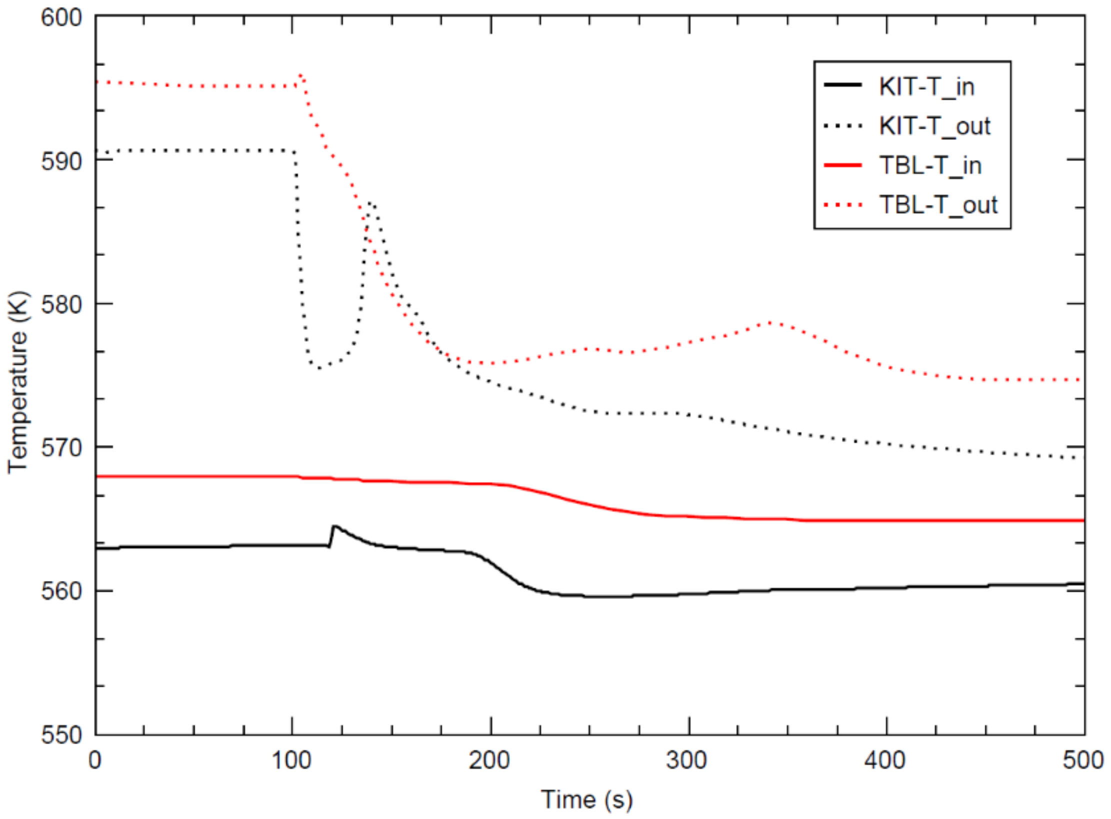
Integral mass flowrate through the core



SMART Steam Line Break (SLB) – TRACE/SCF/PARCS

*Results: transient **(TS)** compared with **TRACE/PANTHER** by TBL*

Coolant temperatures at the core inlet and outlet



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(For the Analysis and Code items:)

- Codes coupling methodology
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Conclusion and Outlook

Conclusions from the LOFW (ATWS) accident with TRACE/SCF-ICoCo:

- During the LOFW:
  - The coolant temperature increase due to lost of heat remove, in the primary loop;
  - Core power decrease to very low level thanks to strong negative TH feedback;
  - The coolant temperature decrease in sequence, in the primary loop.
- The reactor **stay safe** in and after the LOFW accident.

Conclusions from the SLB accident with TRACE/SCF/PARCS-ICoCo:

- During the SLB:
  - SCRAM and stopping of main pumps due to SLB in the secondary side;
  - Core power suddenly decrease to low level and pump speed gradually go to 0;
  - Stable natural circulation established, residual heat sufficiently removed from the core.
- The reactor **stay safe** in and after the SLB accident.

Future work:

- Improve the running stability of the coupled code TRACE/SCF/PARCS-ICoCo.

Acknowledgements

Karlsruhe Institute of Technology

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The content of this presentation reflects only the authors' views and the European Commission is not responsible for any use that may be made of the information it contains.

Thanks for your attention.