Transient coupled calculations of the Molten Salt Fast Reactor using the Transient Fission Matrix approach

A. Laueau et al., Nuclear Engineering and Desing, 2017

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Outline

Introduction

- Foucs on modeling the fuel circuit of the Molten Salt Fast Reactor (MSFR) duirng transients.
- Neutronics and thermal hydraulics are strongly coupled
- Model the coupling during transients: RIA and load following
- Reference reactor configuration:
  - 3 GWth liquid fueled reactor
  - Salt volume of 18 m^3
  - Salt average temperature of 975 K
  - Salt is 75% LiF, 25% HMF (mix of Th and fissile material)
  - Salt circulation time is 4 s

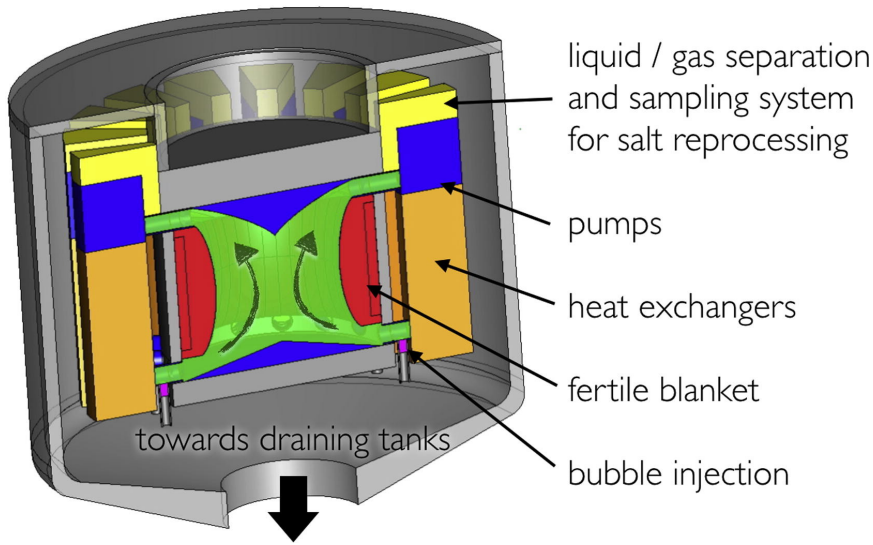
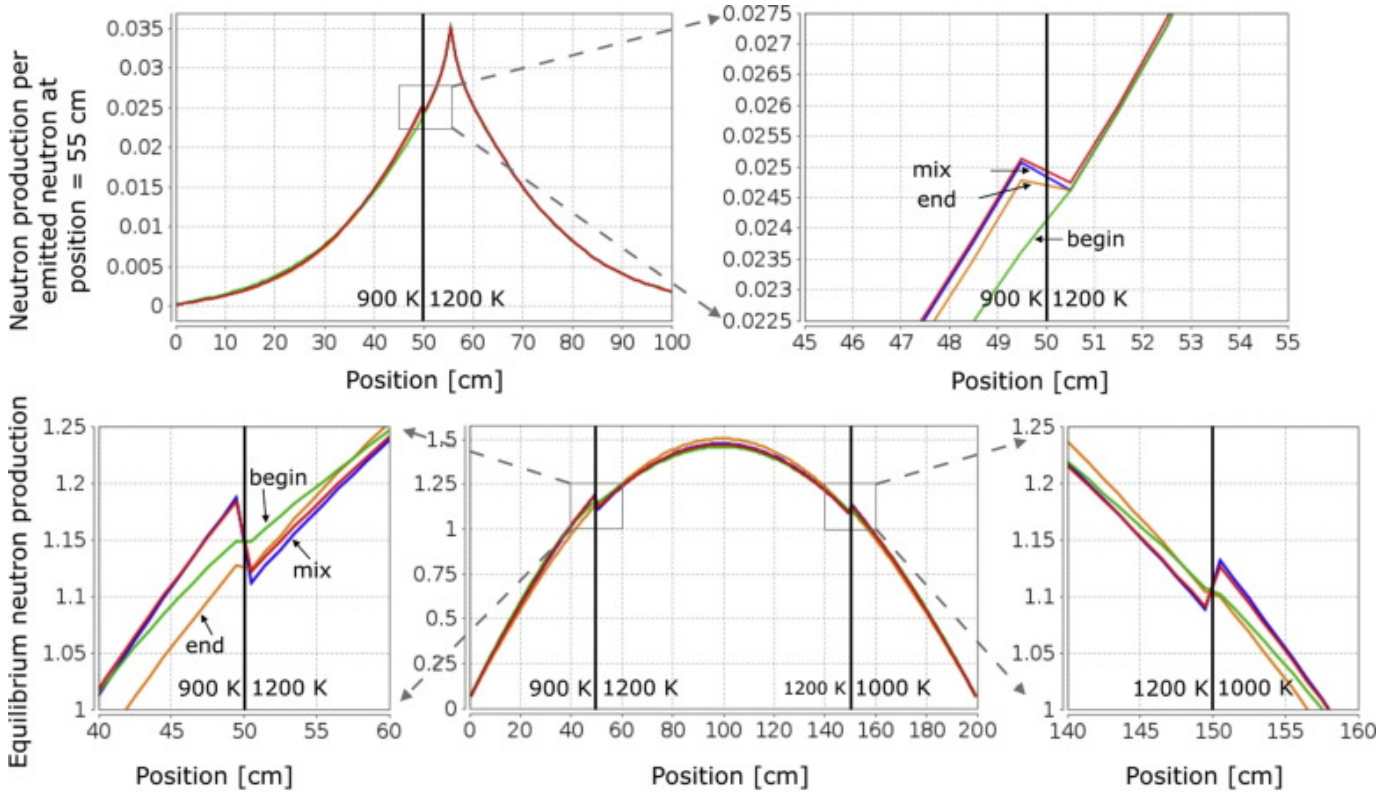


Figure: MSFR circuit configuration

Methodology

Couple neuronics and thermal hyrdaulics using a Transient Fission Matrix (TFM) in Serpent and the CFD code OpenFOAM

- TFM contain the transport of neutrons during a generation in a spatially discretized reactor with a temporal aspect
- Used a modified Serpent code to calculate the TFM
- Used Reynolds-Averaged Navier Stokes approach for TH

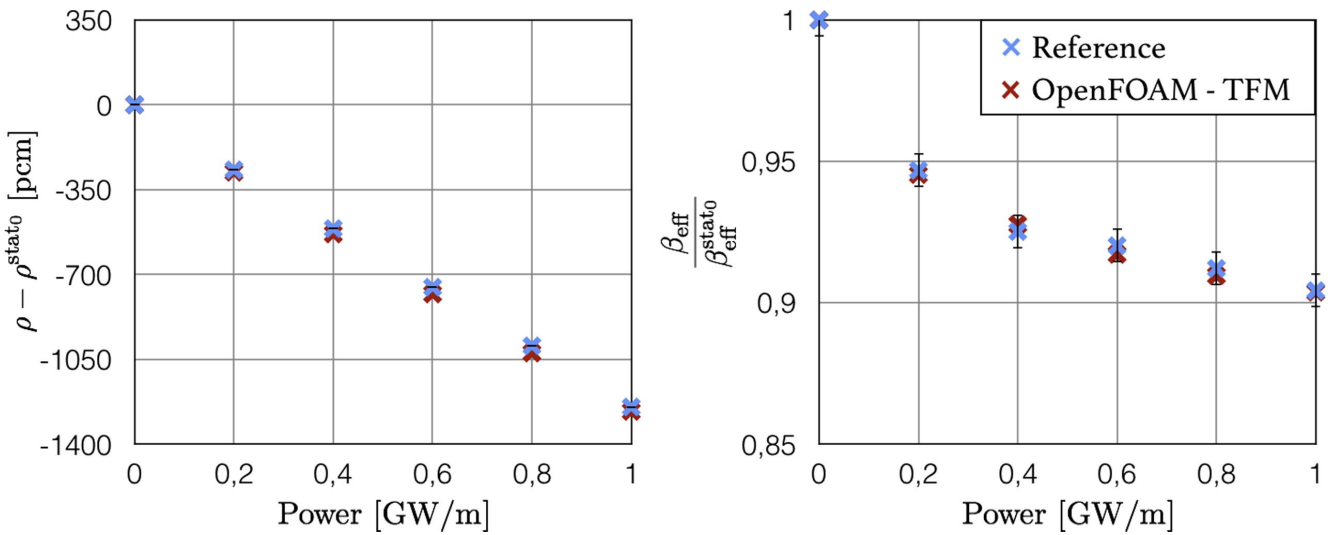


Validation

First had to couple the two components

- Serpent is used to calculate the TFM, prior to transients
- Integrate precursor calculation into TH source code

Used reference case using direct Serpent and OpenFOAM coupling previously defined



Transient Calculations

Load Following Results:

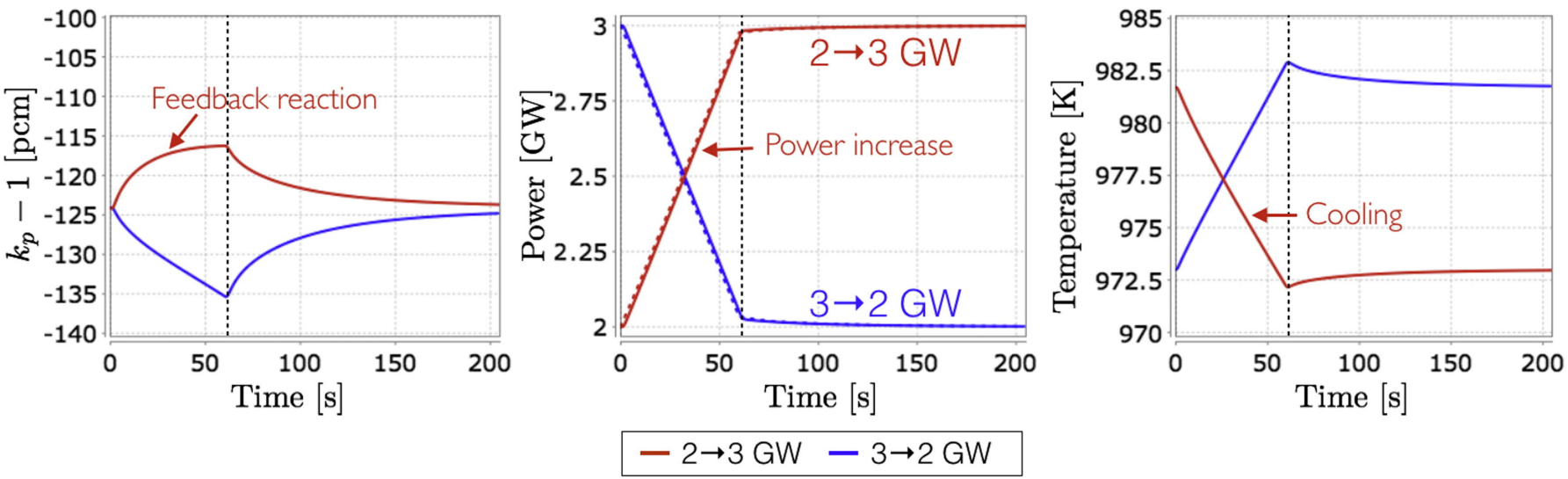


Figure: Evolution of metrics for 33% power variation in 60 s.

No active regulation of reactivity, don't need control rods to

Transient Calculations (cont.)

Overcooling Accident Results:

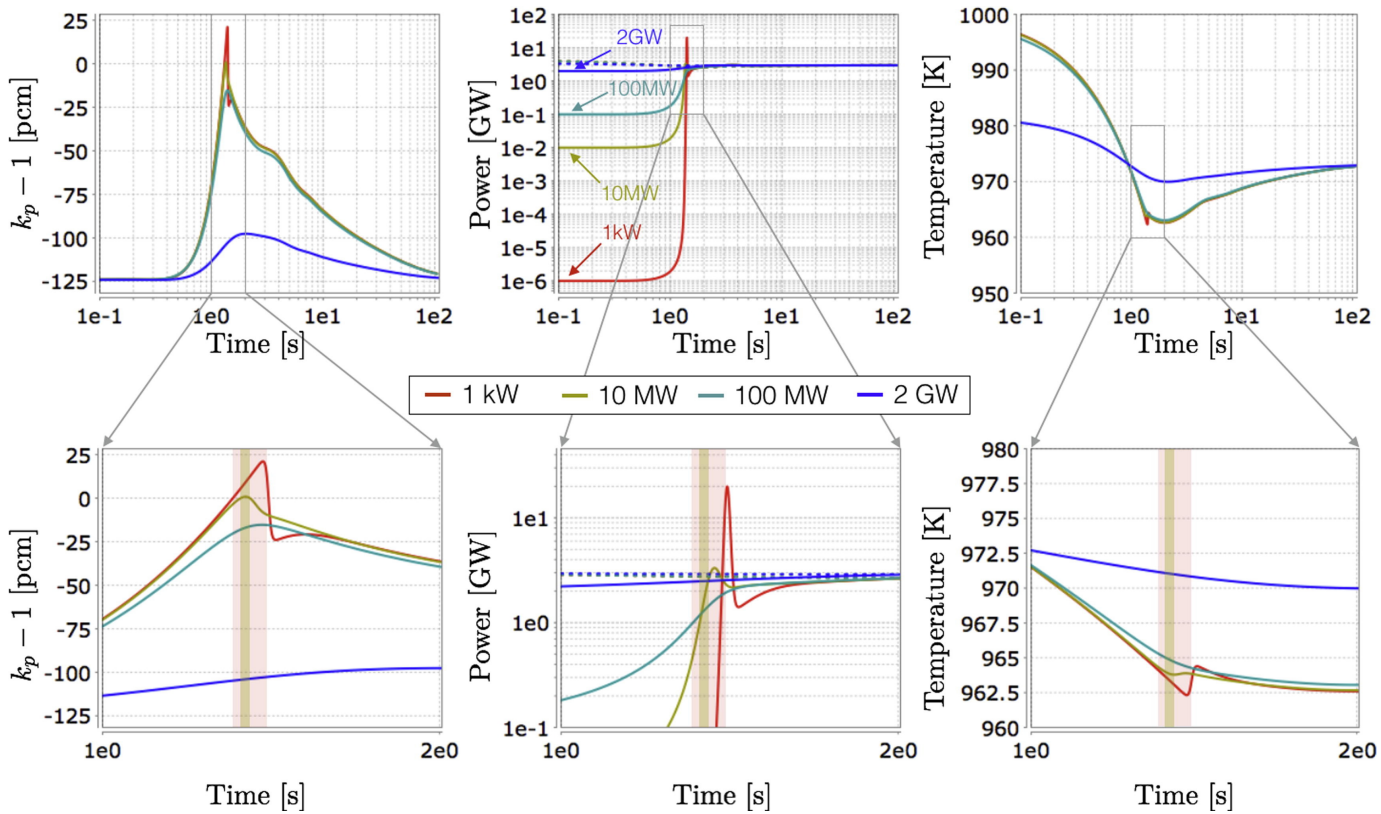


Figure: Evolution of metrics for instantaneous overcooling.

Transient Calculations (cont.)

Overcooling Accident Results (cont.):

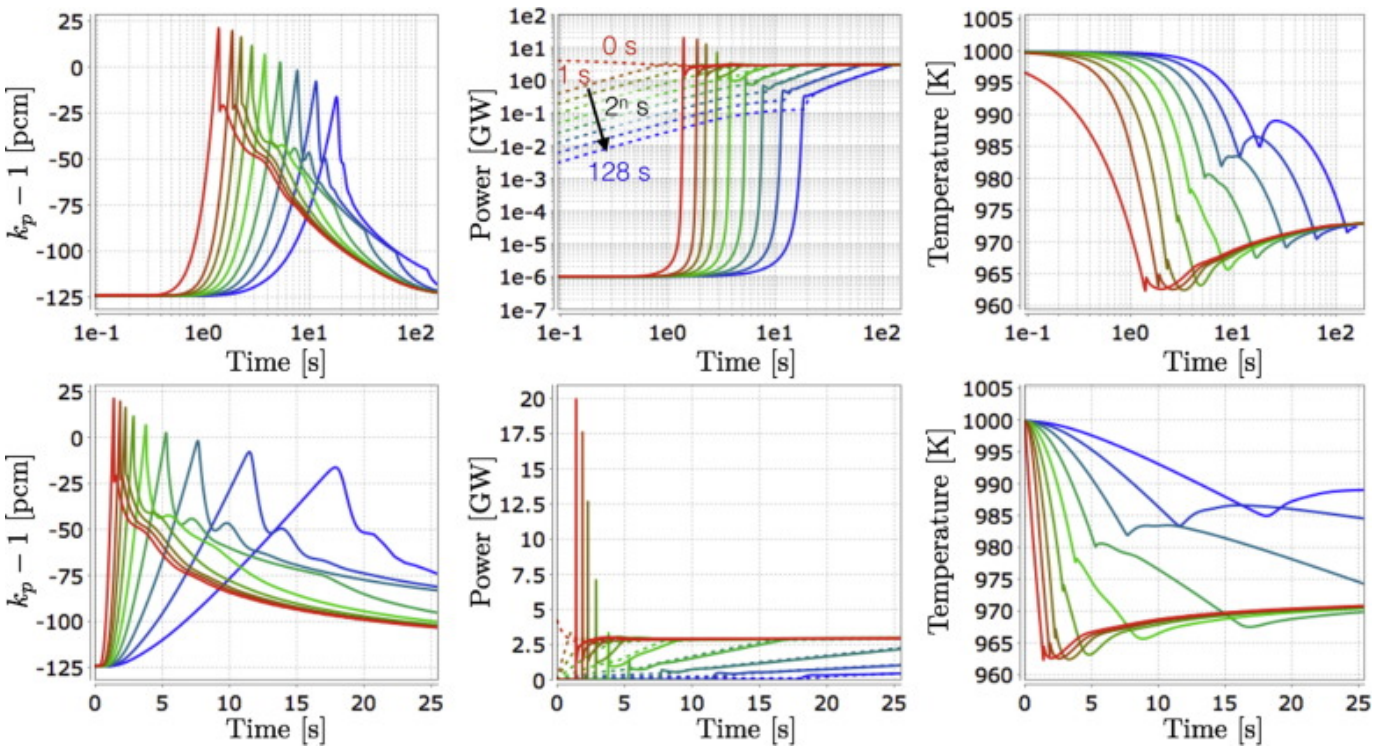


Figure: Evolution of metrics for overcooling of various time constants.

Transient Calculations (cont.)

Reactivity Insertion:

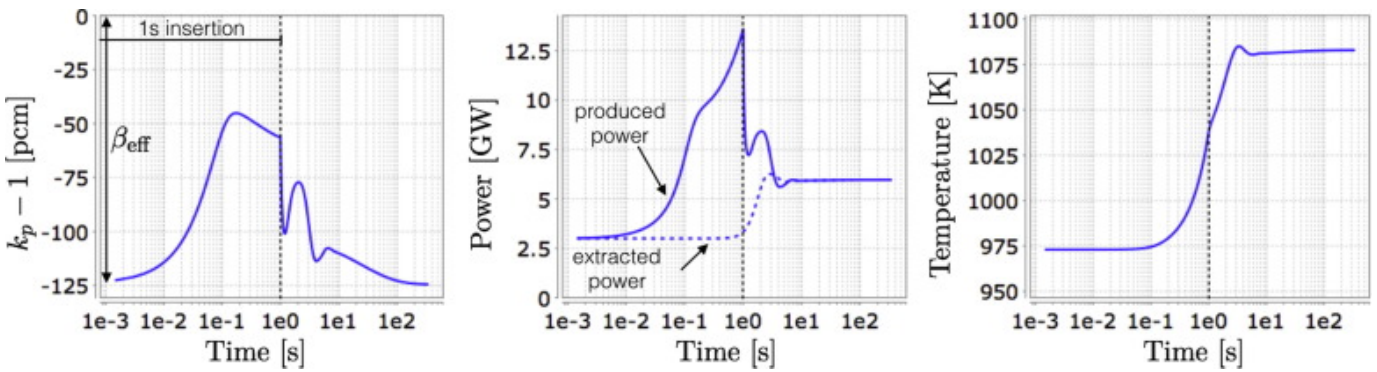


Figure: Evolution of metrics for 1000 pcm reactivity insertion in 1 s.

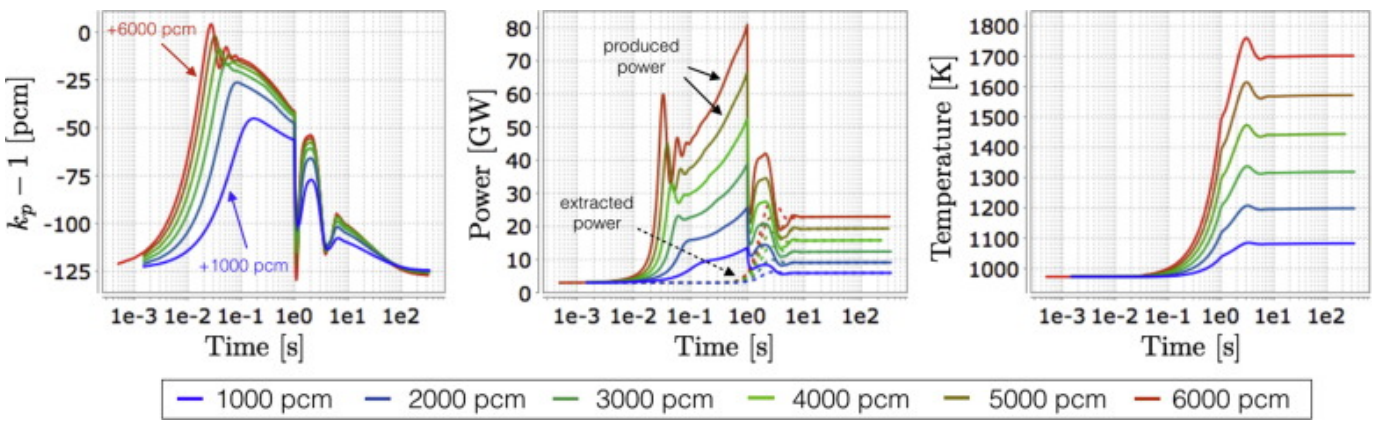


Figure: Evolution of metrics for various reactivity insertion in 1 s.

Outline

Critiques

Overall, a pretty well written paper with lots of figures to discuss the results

- Math was a little hard to follow – often happens when not familiar with subject
- Concerned with prompt criticality, but what about the normal criticality
- Modeled the pumps and heat exchangers as porous media

Outline

Extensions

- Look at results of normal criticality, compare them with limits
- Evaluate how some of these changes affect reactor materials
  - Large temperature swings, inducing stresses and strains
  - Computationally look at how these affect material performance and expected lifetime
- Investigate how the times tep size impacts the results
- Authors propose examining other transient scenarios
  - Look specifically at start up and shot dowm scenarios – normal operation of their transients and accident scenarios
- Authors also propose using this methodology for analysis of other reactor types
  - Sodium Fast Reactors
  - HTGRs, both with TRISO and prismatic fuel
  - Authors suggest PWRs – could gain insight for heat carried by the water

Outline

Conclusion

Demonstration of the Fission Matrix neutronics approach coupled to thermal hydraulics to investigate coupled phenomena

- Can evaluate perturbed fission matrices
- Interpolated solution closely approaches reference calculation
- Studied normal and incident transient scenarios
  - Can sustain a 1000 pcm insertion in 1 s
  - Showed results of load following scenairos
  - Can reach prompt critical during overcooling incident

Questions