Molten Salt Reactor Dynamics Approach to Material Accountancy

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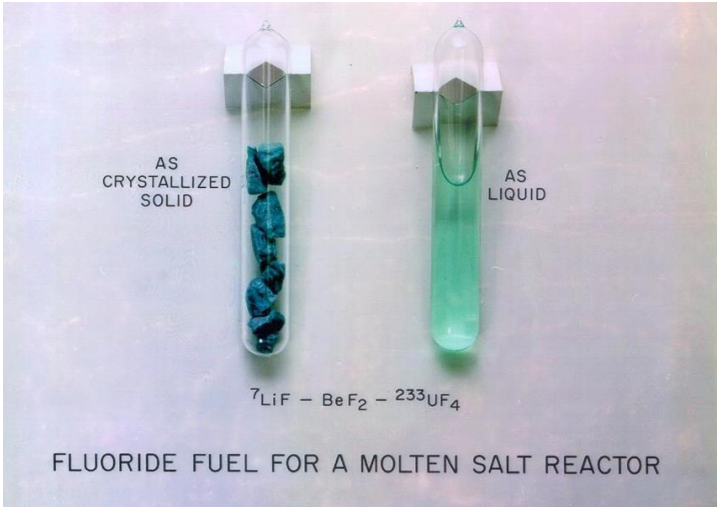
OUTLINE

- **MSR design**
- **Safeguards for MSRs**
- **Dynamic parameters dependence on Materials**
- **Assembling of a generic MSR model**
- **Frequency response in diversion cases**
- **Future work**



Acknowledgments

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Motivation and Background

- MSRs: GenIV concept with renewed interest
- Several start-up companies in North America*
- Broad spectrum of design concepts
- Limited R&D in the recent past
- Outside of nuclear engineering experience base

*Samuel Brinton, “The Advanced Nuclear Industry,” Third Way, www.thirdway.org/report/the-advanced-nuclear-industry

Specifics of MSR Design

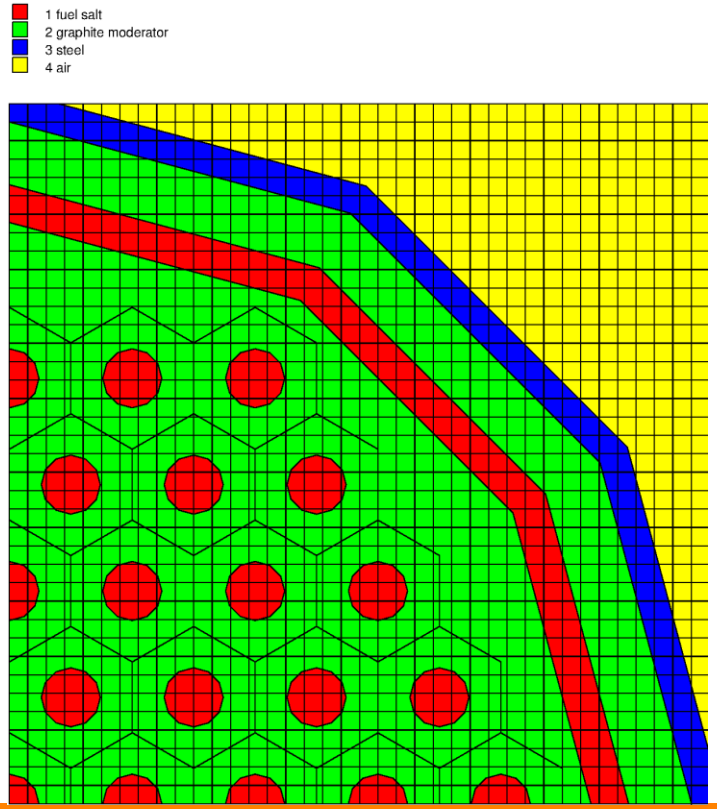
- Homogeneous fuel mixture with changing composition
- Fuel circulating in and out of core
- Fission products (FPs) in transit, some remain dissolved, others do not
- Off-gassing of Xe-135 and other gaseous FPs
- Migration of delayed-neutron precursors
- Online fueling and FP reprocessing

Difficulties in Safeguarding/MC&A MSRs

- International Safeguards are **required** for global deployment of any reactor design
  - IAEA significant quantity of Plutonium: **8kg**
- MSRs have no agreed upon method for safeguarding
- Traditional item counting does not apply here
- In a loss of the continuum of knowledge, there needs to be a means of material accountancy in the fuel salt

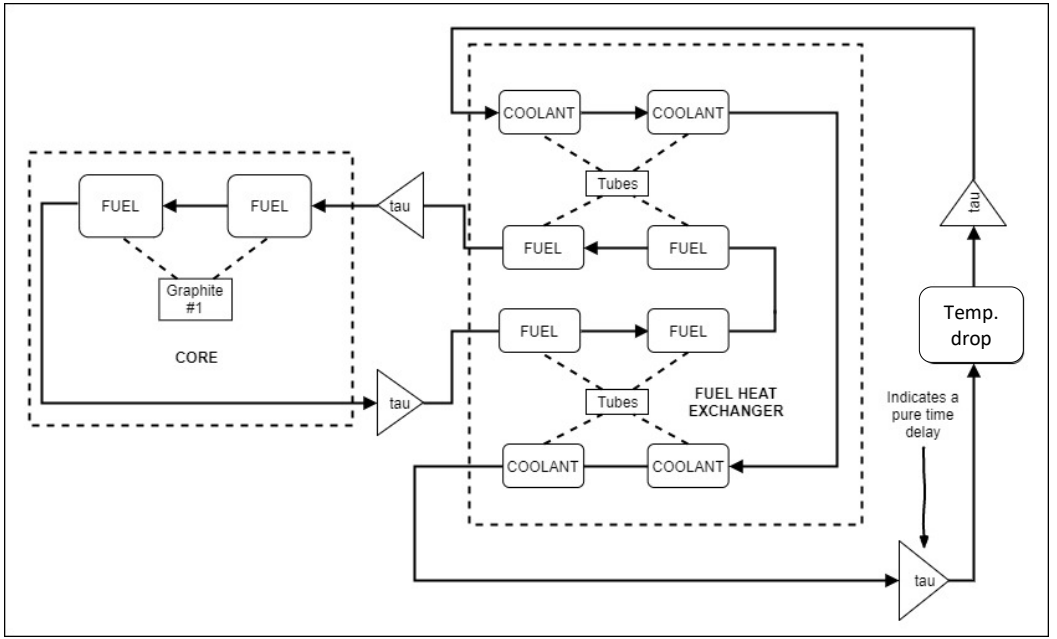
Depletion Calculation in an MSR

- Material data retrieved from MSR library
- Quarter core with Li-F-Be and LEU
- Burned at 20 MW/MTHM in SCALE/ORIGEN 6.2 for 3 years
- 20 MW reactor power



Dynamic Modeling Approach

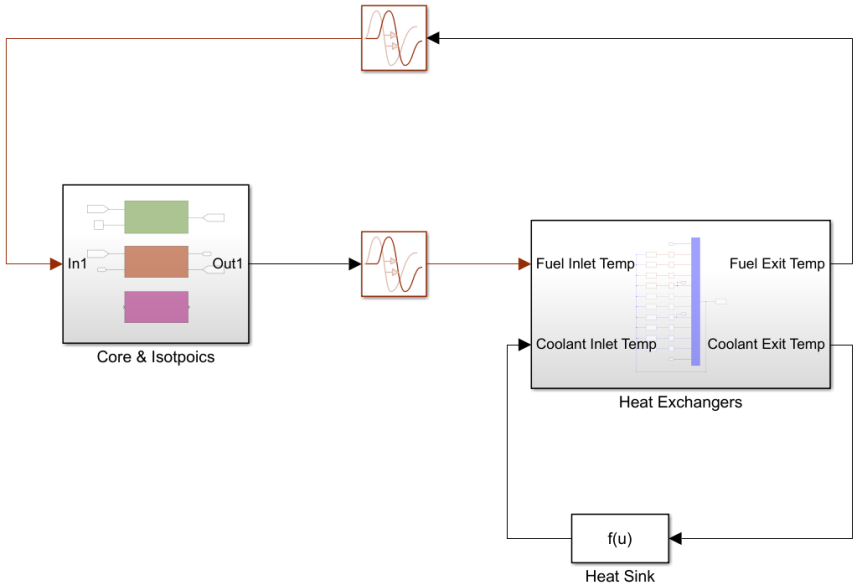
- Methodology inspired based off of published MSRE model*
- Lumped-parameter model
- Two liquid lumps for every solid lump



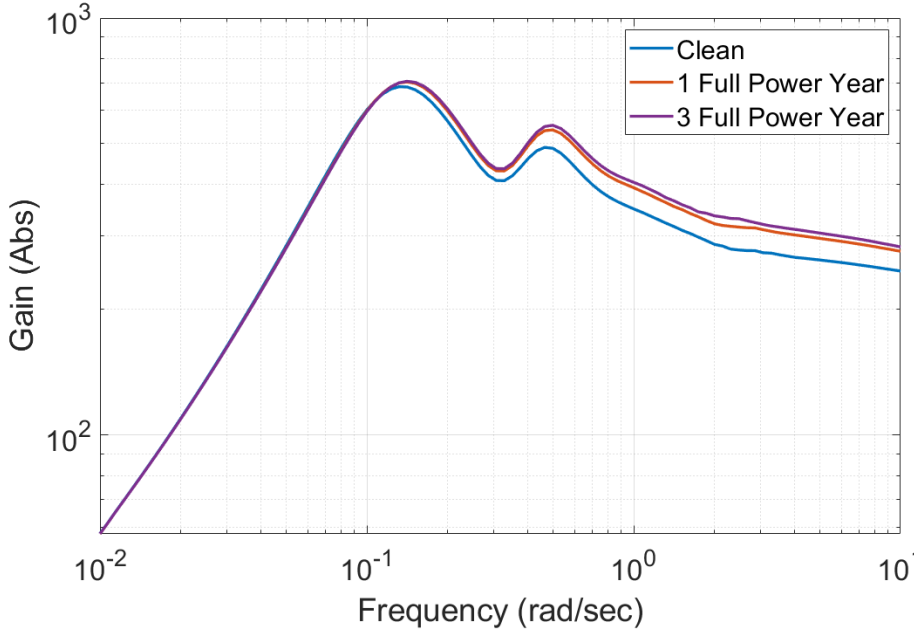
*V. Singh, et. al., “Nonlinear Dynamic Model of Molten Salt Reactor Experiment - Validation and Operational Analysis,” Annals of Nuclear Energy, 113, 177 – 193, (2018).

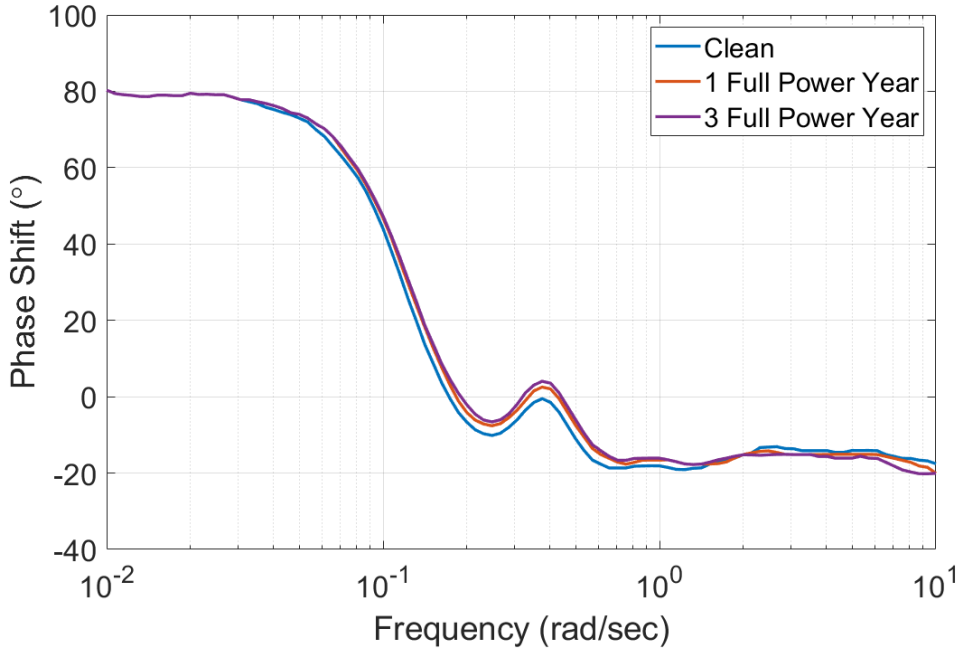
Modular Dynamic Modeling

- Model developed in MATLAB™-Simulink
- Nominal Power Scaling
- Modular organization
  - Plug and play components

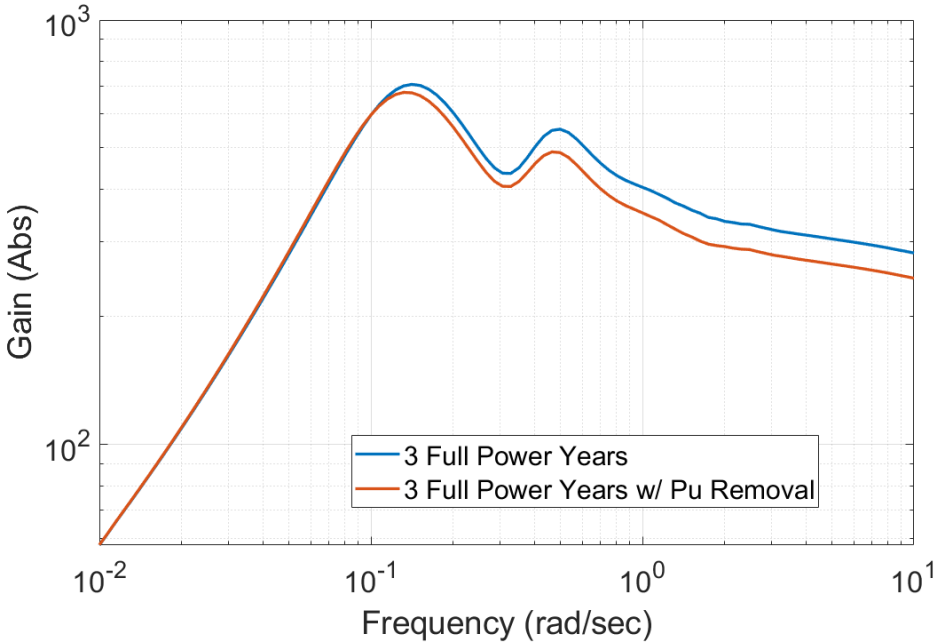


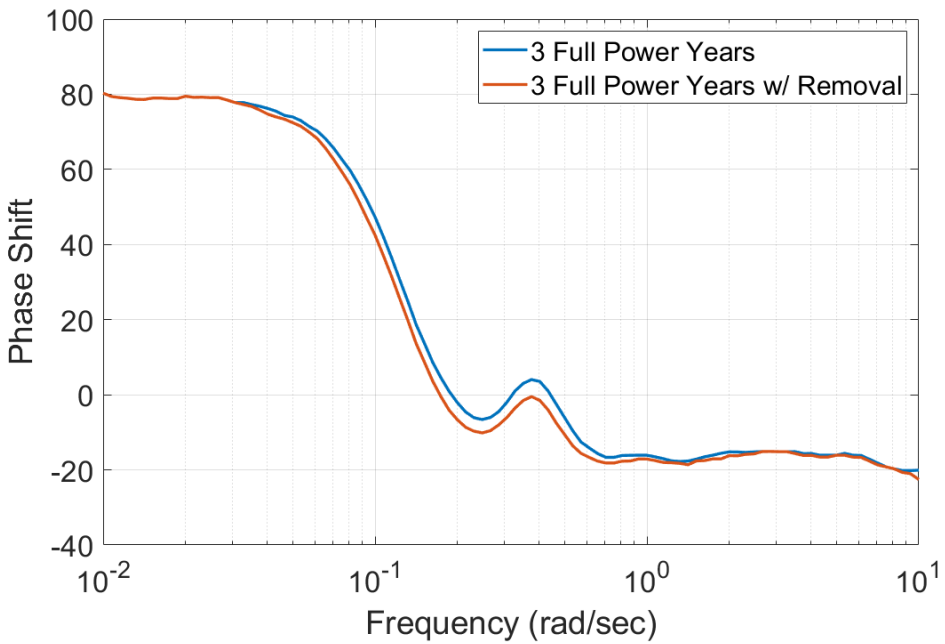
Frequency Characteristics over Burnup



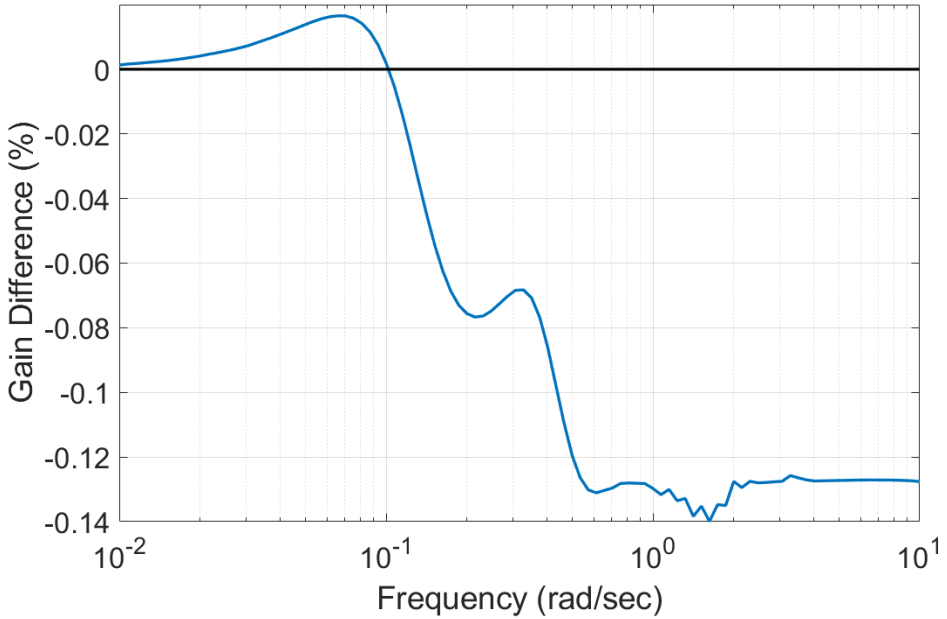


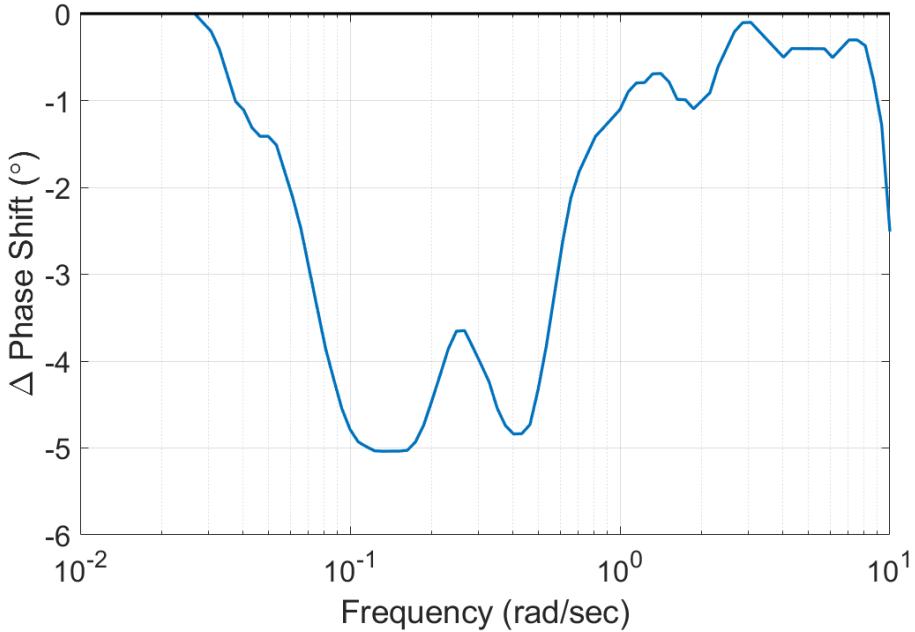
Frequency Characteristics in Removal



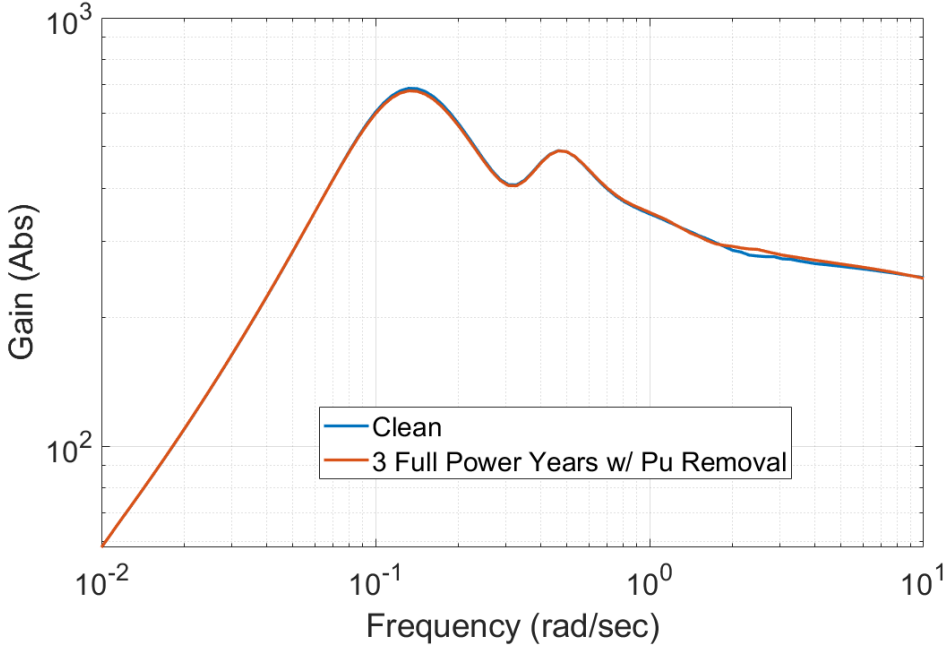


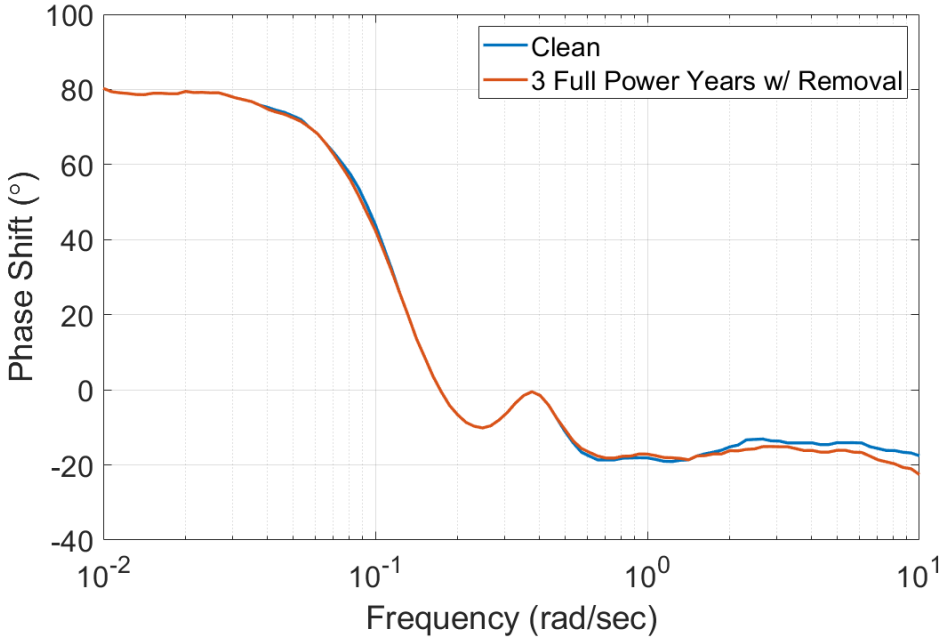
Change in Frequency Characteristics





Removal Compared to Clean Fuel Salt





Conclusions

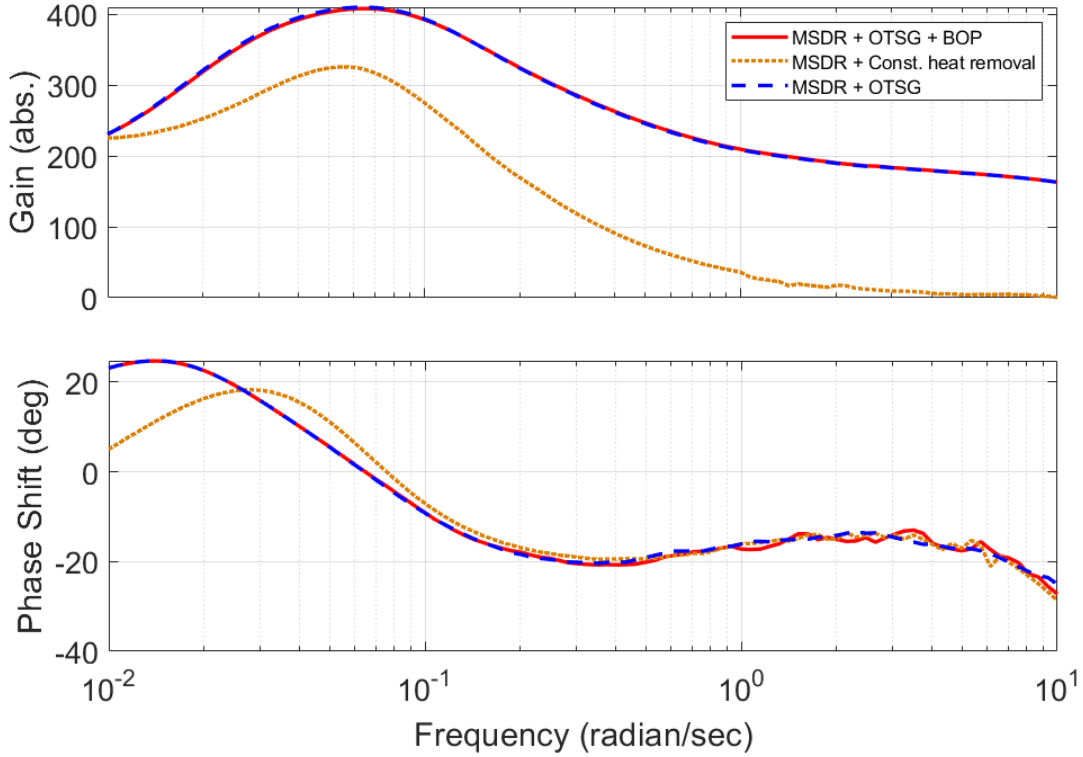
- Dynamic behavior of MSRs are relevant to safeguards
- Pu removal leads to characteristic patterns in frequency response
- Frequency characteristics can be established continuously and while operating
- Novel approach to MSR safeguards - avoids core liquid sampling

Further Discussion

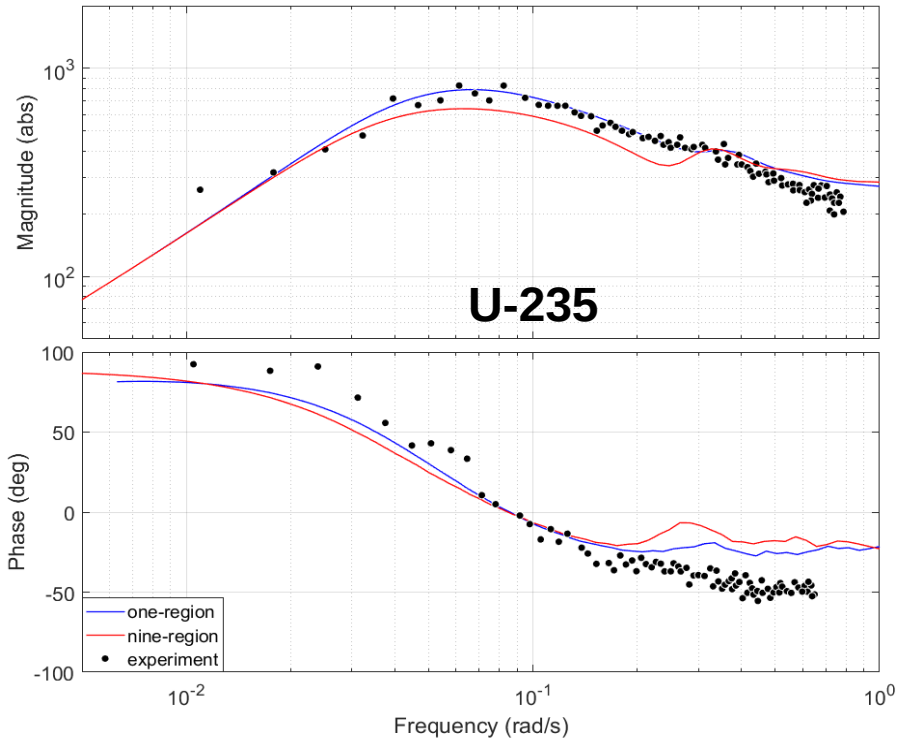
- Determine sensitivities to model parameters
  - Core size
  - External loop length
- Evaluation of delayed neutron population in external loop
- Other forms of diversion (e.g. slow trickle)
- Explore other dynamic effects of Pu removal

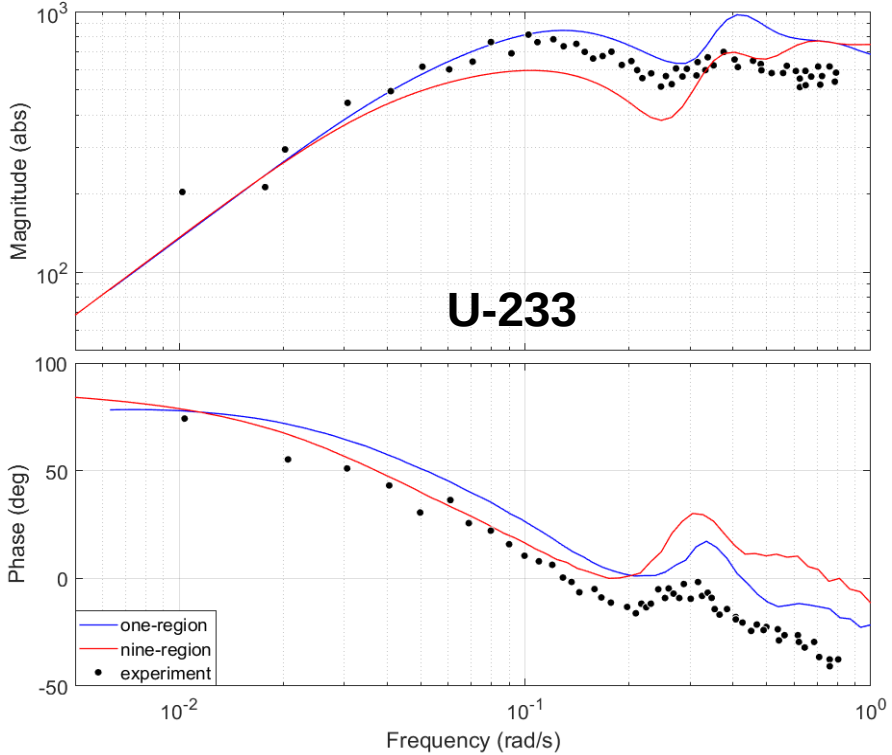
Backup slides

Addition of OTSG

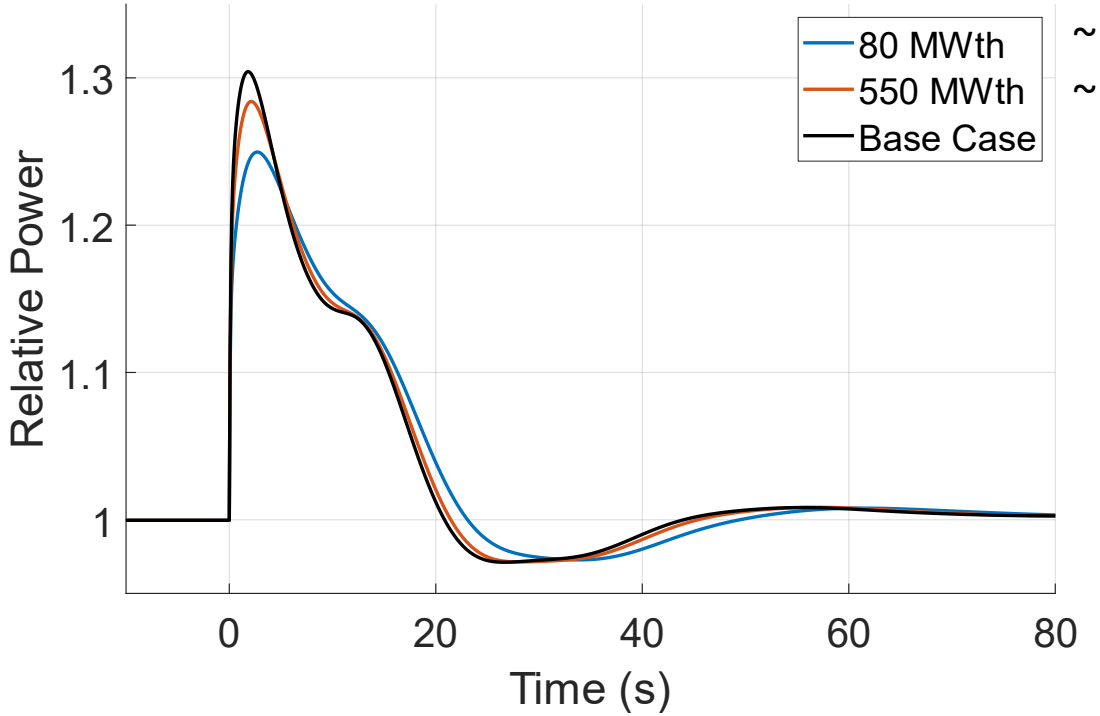


Frequency characteristics



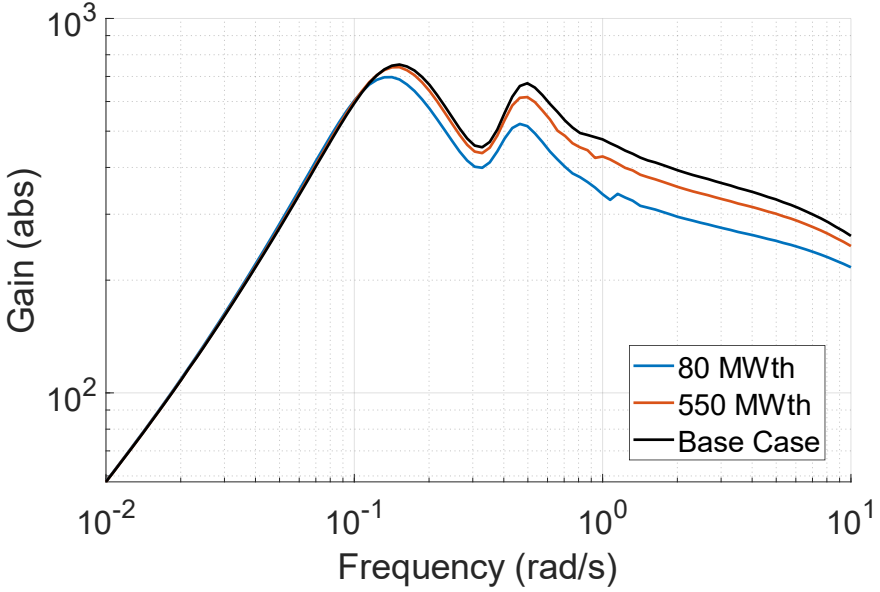


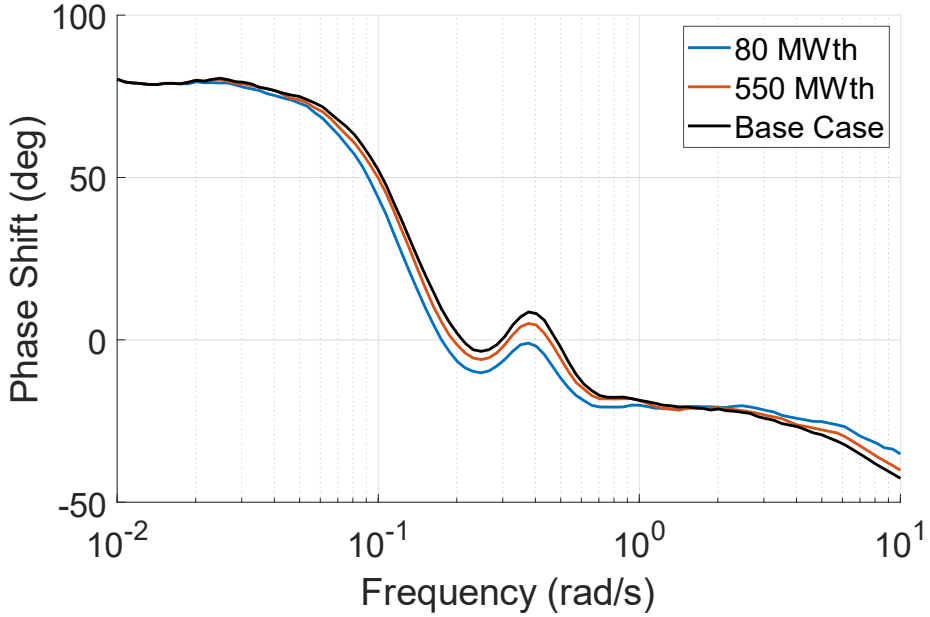
Response to 50 pcm Step Insertion



% Pu removed
~100%
~15%

Frequency Characteristics





Change in Frequency Characteristics