PURDUE UNIVERSITY | School of Nuclear Engineering

Nuclear Engineering Seminar

Dr. Hitesh Bindra,

Associate Professor, Purdue School of Nuclear Engineering

Wednesday, February 15, 2023

3:30pm | WALC 1018

Statistical emulators to improve thermal-hydraulic modeling and uncertainty quantification in Nuclear Reactor

Abstract

Despite the tremendous growth of computational resources in recent years, the ``curse of dimensionality'' associated with the canonical evolutionary partial differential equations in nuclear reactor engineering and thermal-hydraulics such as direct numerical solution to Navier-Stokes equations at reactor scale is still a challenge to tackle. To solve this fundamental problem and to get a reasonable answer in the time-constrained engineering design and optimization process, reduced spatio-temporal complexity models are required. Typically, this is done by linearization and spatio-temporal averaging of parameters in the context of thermal-hydraulic applications. This procedure may lead to an inaccurate depiction of the system behavior--with a number of structural errors in the model. These structural errors can also arise because of the principles on which the model relies. Since it is almost impossible to completely decipher the principles on which the model rests and a certain degree of distortion is always required to build a system of equations. Current tools for system analysis lack capabilities in resolving detailed 3D thermal-fluidic behavior that are crucial for design and performance evaluation of advanced reactors. The risk evaluation and uncertainty envelop of passive safety features in advanced reactors are highly dependent on 3D physics that is in contrast to probabilistic failure rates of active safety features. Therefore, accurate physical depiction of thermal-fluidic behavior in system analysis tools is essential for risk quantification.

To tackle these uncertainties this work takes a unique approach of using the high-resolution datasets to learn the dynamics of uncertainties in a statistical approach. While doing so it is inherently assumed that the Navier-Stokes equation is a structurally perfect and correct model. The unique contribution in the general context of nuclear engineering is the constraining of non-linear Langevin equation on the high-resolution datasets via the non-equilibrium statistical mechanics route. Some applications of this approach will be shown by advecting passive scalars via the trained model relevant to nuclear engineering.

Hitesh Bindra is an Associate Professor of Nuclear Engineering at Purdue University. He is the director of the Nuclear Energy Systems Transport (NuEST) laboratory where his research group focuses on thermal-fluid sciences with applications in advanced nuclear reactors and heat storage systems. His group members have developed multiple scaled experimental facilities to investigate safety and design issues in Gen 4 small-modular reactors. He has several years of industrial experience as a nuclear power plant engineer and thermal systems engineer. Dr. Bindra has co-invented and developed heat storage technologies for combined cycle power plants, nuclear hybrid energy systems and other localized applications.