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Physics informed neural networks for surrogate modeling of accidental scenarios in nuclear power plants

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Modeling and Simulation (M&S) have a fundamental role in the nuclear industry for their ability to investigate system response to many operational conditions, identify possible accidental scenarios and predict their evolution to undesirable consequences that are to be prevented or mitigated via the deployment of adequate safety barriers. Deep Learning (DL) and Artificial Intelligence (AI) can support M&S computationally by providing surrogates of the complex multi-physics high-fidelity models used for design. However, DL and AI are, generally, low-fidelity 'black-box' models that do not assure any structure based on physical laws and constraints, and may, thus, lack interpretability and accuracy of the results. This poses limitations on their credibility and doubts about their adoption for the safety assessment and licensing of novel reactor designs. In this regard, Physics Informed Neural Networks (PINNs) are receiving growing attention for their ability to integrate fundamental physics laws and domain knowledge in the neural networks, thus assuring credible generalization capabilities and credible predictions. This work presents the use of PINNs as surrogate models for accidental scenarios simulation in Nuclear Power Plants (NPPs). A case study of a Loss of Heat Sink (LOHS) accidental scenario in a Nuclear Battery (NB), a unique class of transportable, plug-and-play microreactors, is considered. A PINN is developed and compared with a Deep Neural Network (DNN). The results show the advantages of PINNs in providing accurate solutions, avoiding overfitting, underfitting, and intrinsically ensuring physics-consistent results.