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Optimization of Radiation Shielding in TNG-40 Using Machine Learning-Enhanced Monte Carlo Simulations

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The TNG-40 is a cutting-edge 40 MWe mobile pressurized water reactor (PWR) designed as a floating small modular reactor (SMR) to support Saudi Arabia's energy diversification goals. Its compact and efficient design, featuring UO_2-Silumin composite fuel and optimized enrichment strategies, enables safe, reliable, and flexible power generation for maritime logistics, emergency coastal power, and dual civil-military applications. The multilayer radiation shielding, inspired by proven designs like the KLT-40S and NS SAVANNAH reactors, is rigorously modeled using OpenMC Monte Carlo simulations to ensure safety while minimizing material use. A novel closed-loop integration strategy combines high-fidelity Monte Carlo simulations, Artificial Neural Network (ANN) surrogate modeling, and Non-dominated Sorting Genetic Algorithm II (NSGA-II) multi-objective optimization. This approach balances computational efficiency and accuracy by iteratively refining shielding designs based on surrogate predictions validated through additional simulations. The TNG-40's modularity and multi-purpose capabilities, including electricity generation, industrial steam, and desalination, position it as a versatile solution for future energy and industrial needs, adhering to international safety standards and operational reliability.

Technical Track

Student Competition

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