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Project Title

Characterization of Relevance Vector Machine Performance for Reactor Burnup Predictions

Project Objective

The objective of this work is to determine in which conditions this RVM can accurately assay core plutonium production given a single core specimen with unspecified properties.

Project Description

Nuclear forensics objectives necessitate a robust means to distinguish between power and plutonium production reactor operations using reactor core specimens. The relevance vector machine (RVM) was developed to predict core-averaged burnup and plutonium production. The RVM was trained and tested on a synthetic dataset of spent fuel isotopics over a burnup range up to 1.05 GWd/MTIHM generated by the SCALE sequence TRITON. The resulting predictive models can determine core-averaged burnup from measurements of a single unknown position-independent core specimen.

This work investigated the accuracy of the RVM when subject to three conditions. 1) The RVM was trained and tested on different temperatures to quantify the errors introduced by unknown operating temperature. It was shown that training on a multiple temperature dataset precludes the need to specify temperature as an input parameter. 2) Limited sets of measurable nuclides were made available for model development to preserve simplicity and deployability. 3) Gaussian noise was introduced to the training isotopics to characterize the model's ability to discriminate between meaningful and unimportant variances in isotopic concentrations.

Project Relevance to Nuclear Nonproliferation

Developing the capability to independently verify operator-declared data on reactor fuel burnup with minimal measurements will discourage illicit plutonium production and the diversion of special nuclear materials. The strength of the RVM is the fact that core-averaged burnup can be determined from measurement of a single specimen with unspecified properties.

Products and Outcomes of Project

Training with multiple temperatures produced an average relative error in burnup of 20% as compared to 100% when training at a single temperature. A model developed with the isotopes: ^{235}U, ^{236}U, ^{238}U, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{133}Cs, ^{134}Cs, ^{135}Cs, ^{137}Cs, ^{83}Kr, ^{131}Xe, ^{133}Xe, and ^{135}Xe achieved 2% error. By adding Gaussian noise to training data, predictions made on noisy testing data were improved by up to a factor of 4.