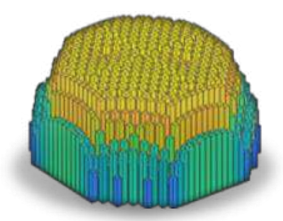
eigenvalue.ai

A prediction platform for eigenvalue in BWRs

AI Enabled Next-Gen Visibility into Boiling Water Reactors

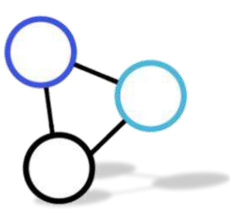
eigenvalue.ai is a state-of-the-art tool that yields real world, high value results via Artificial Intelligence and Machine Learning. It enables powerful predictive capability of one of the most fundamental parameters in nuclear engineering, reduces reload fuel costs, and ensures fuel cycle energy requirements are met.



Real World

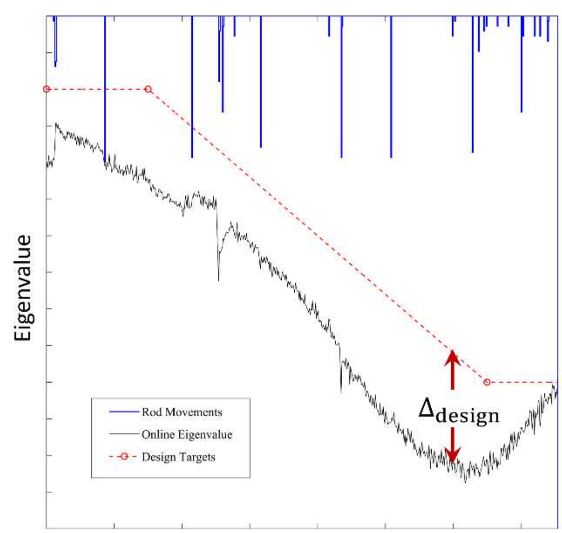
The hot reactivity parameter of the core (known as $k_{\text{effective}}$ or simply, the eigenvalue) is one of the most fundamental parameters in nuclear engineering and has been notoriously difficult to predict accurately in boiling water reactors (BWRs). Its trend directly impacts the energy capability of the reload core, and an inaccurate eigenvalue projection can be costly. If the actual eigenvalue is higher than predicted at rated power, then the designed core's reactivity is less than expected, thus leading to less generation output than desired. Whereas if the actual eigenvalue is lower than predicted at rated power, then the designed core's reactivity is greater than necessary, and more fuel was purchased and loaded than required.

Conventionally, eigenvalue predictions rely on estimates made by core designers looking at past eigenvalue behavior and the characteristics of the reload core being designed. This approach has its limitations, especially when new fuel or core designs are introduced, and on average has been sufficient to achieve a deviation $\Delta \sim \pm 0.002$ between the design and online eigenvalue. The possibility exists to reduce this deviation more than 4-fold, thereby leading, potentially, to millions in annual savings.

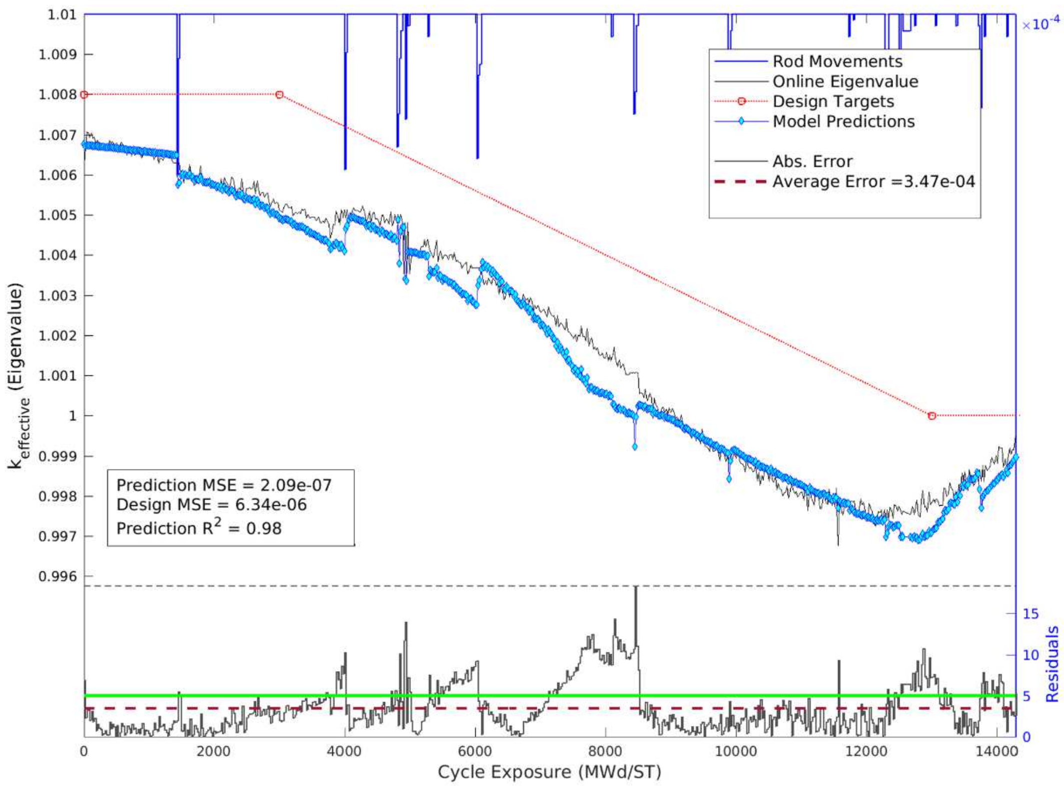


New Methodology

Blue Wave is pioneering eigenvalue prediction capability with the creation of **eigenvalue.ai** to address these deficiencies to meet the demands of current and future core designs. Our proprietary approach uses artificial intelligence (AI) coupled with machine learning (ML) to leverage historical fuel cycle data, outputs from core simulators, and past eigenvalue behavior. Through clever transformation of each reactor statepoint into a three-dimensional image of the reactor core—viewed through various "filters" of exposure, void, power and so on—we exploit a convolutional neural network (CNN) architecture, which has been shown to be very effective with tasks like image recognition and natural language processing. This enables us to retain tens of thousands of bundle and nodal parameters, hundreds of thousands of pin-by-pin fuel attributes, and dozens of global reactor variables to develop high-fidelity models with all the parameters affecting eigenvalue behavior.



Disparity between the on-line eigenvalue (black) and design targets (red) obtained through conventional means.



High Value Results

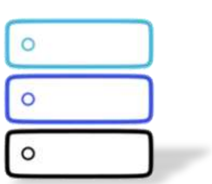
The predictive capability of eigenvalue.ai is illustrated on the left for a recently completely 24-month BWR fuel cycle. The eigenvalue model performance demonstrates greater than a 4-fold reduction in prediction uncertainty when compared against the current state of practice (conventional design targets), with an average error less than ±0.0005. Moreover, this level of performance is extensible across the BWR fleet, with recent advancements in model architecture demonstrating remarkable resilience when new fuel types and product lines are introduced into the core. Comparable levels of accuracy have been obtained at multiple other BWRs that have adopted this enabling technology.

Data Requirements

A number of techniques have been employed to enhance the datasets, including data augmentation for maintaining expected distributions, interpolation of training targets, and transfer learning to take maximum advantage of information from multiple sites. These techniques have made it possible to extend the development of highly accurate models to reactors possessing less data than would otherwise be required. Typical situations require approximately three fuel cycles worth of data for a given reactor unit.

Features

eigenvalue.ai is a robust state-of-the-art SaaS application for the nuclear power industry that provides unparalleled accuracy for eigenvalue forecasting in both ***reload core design*** and ***cycle management*** engineering applications. Additional features include the abilities to:

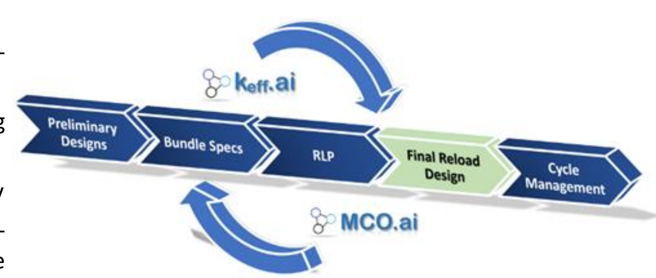


- Upload historical data in multiple formats (.zip, .dat or HDF5) for model evolution and training, resulting in powerful predictive capabilities.
- Upload cycle depletions in multiple formats for prediction reports and scenario planning
- Generate, delete, download, and email eigenvalue projection reports in multiple formats
- Graph and view historical cycle data for trending and comparisons
- Filter and sort data tables quickly and seamlessly
- Create 'Design' or 'Operating' scenarios to minimize reload fuel costs during design or manage energy output during operation
- Store and archive historical cycle data, design files, and projection reports.

Requirements for eigenvalue.ai

- Eigenvalue.ai is rendered via web browser and is available for all standard computing platforms with a high-speed Internet connection, running most modern 32- and 64-bit operating systems and mobile operating systems: Linux, Windows, macOS, Android, iOS, and UNIX architectures are all acceptable environments for eigenvalue.ai.
- Compatible with outputs from most vendor and vendor-independent nuclear fuel analysis software (e.g., core simulators).

Energize reload design with the BWnuclear.ai software suite. These AI-based predictive algorithms integrate seamlessly, whether it be for reload core design or cycle management applications.



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