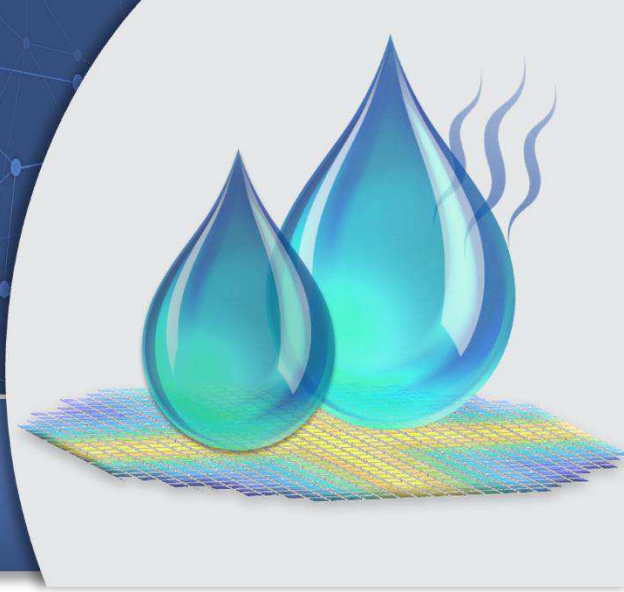
BLUE WAVE AI LABS

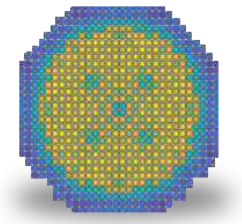
MCO.ai

A prediction platform for Moisture Carryover in BWRs



AI Enabled Next-Gen Visibility into Boiling Water Reactors

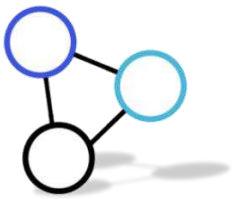
MCO.ai is a Clean Energy tool that yields real world, high value results via Artificial Intelligence and Machine Learning. MCO.ai predictions enable visibility into moisture carryover, reduce exposure risk, ensure long-term viability of key plant assets, enhance core efficiency, and reduce reload fuel costs.



Real World

The amount of liquid water mixed with steam leaving a boiling water reactor's moisture separators, referred to as moisture carryover (MCO), has been nearly impossible to predict by conventional methods. There are design specifications limiting how much MCO is permissible before operators must take remedial action (of which one costly option is a power derate). New boiling water reactor (BWR) core designs and aggressive operating strategies can push steam separators beyond optimal performance windows, causing elevated levels of MCO.

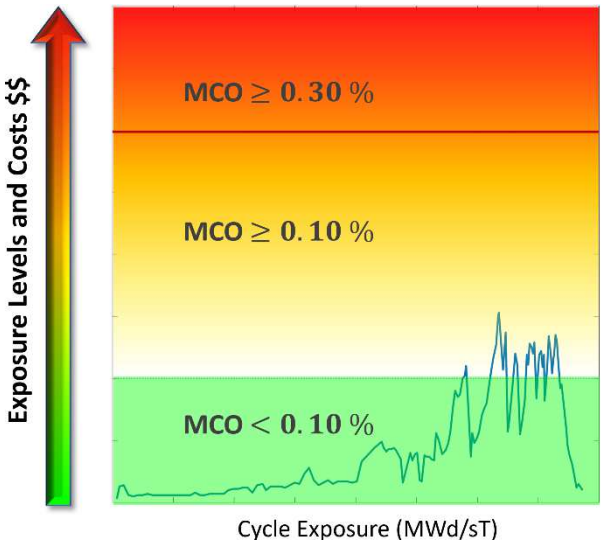
Excess moisture in the steam is problematic for many reasons, most importantly due to its ability to carry impurities dissolved in the water throughout the entire plant. MCO can increase erosion of the internal surfaces of the main steam isolation valves (MSIVs) and at the turbine, potentially causing costly repairs. Perhaps even more troublesome, soluble Cobalt-60 is carried over with the steam which increases plant dose rates and the collective radiation exposure of plant personnel. Beyond this, a small reduction in electrical output occurs with high MCO.



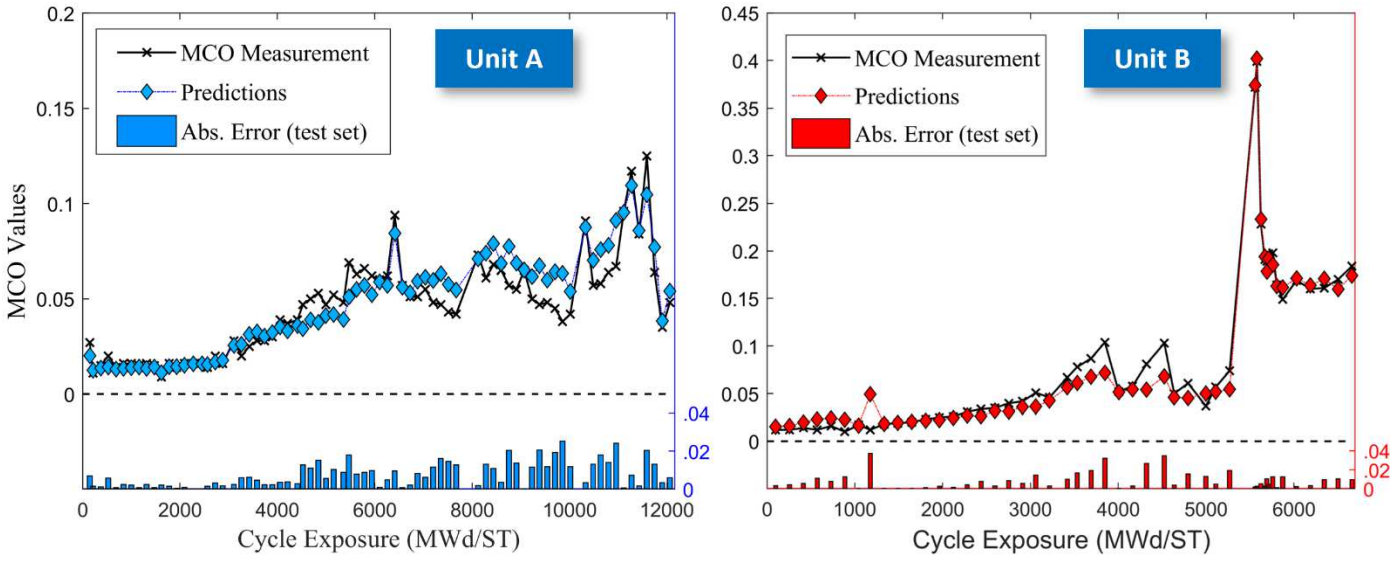
Up until recently, there has been no reliable method to forecast future MCO levels prior to or during a new fuel cycle. Consequently, the primary method to mitigate high MCO is to design the core with a larger-than-required reload batch size, thereby introducing potentially unnecessarily high reload fuel costs.

New Methodology

Blue Wave AI Labs is pioneering MCO prediction capability with the creation of **MCO.ai** to address these deficiencies and peer inside the 'black box' of MCO to meet the demands of current and future core designs. Our proprietary physics-constrained approach uses artificial intelligence (AI) coupled with machine learning (ML) to leverage historical fuel cycle data, outputs from core simulators, and past MCO measurements. By using AI and ML, we construct a neural representation of MCO dynamics, yielding high value results in the form of powerful predictive capability. Through feature engineering, and a physical understanding of the underlying mechanisms, we transform the



Relationship of high MCO to cumulative radiation exposure and costs at a generic BWR generating station with a functional design performance specification (FDPS) of 0.10%



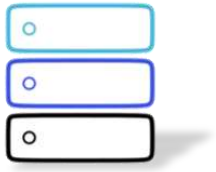
datasets into a "canonical set" of key drivers of MCO. This enables the development of high-fidelity models with parameters that core designers and operators can control, giving the models not only predictive power but, just as important, corrective power.

High Value Results

The predictive capability of MCO.ai is illustrated above for two BWR units. Since the time the model was first deployed at these units in 2018, the average prediction error is ± 0.018 percent MCO. The exceptional level of performance at this generating station is now limited only by the resolution imposed from the MCO measurement uncertainty. Comparable levels of accuracy have been obtained at multiple other BWRs that have adopted this enabling technology.

Features

MCO.ai is a robust state-of-the-art SaaS application for the nuclear power industry that provides unparalleled accuracy for MCO 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 MCO 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 mitigate MCO levels during design or manage MCO during operation
- Store and archive historical cycle data, design files, and MCO projection reports.

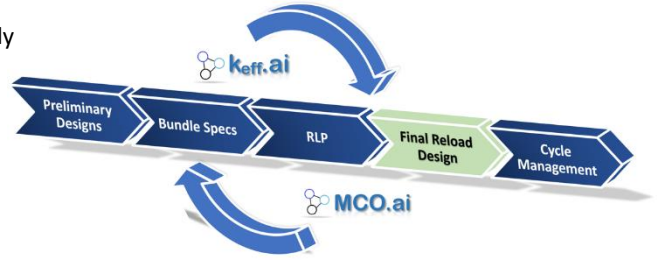
Data Requirements

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.

Requirements for MCO.ai

- MCO.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 MCO.ai.
- MCO.ai is 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.



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