PUBLIC SUBMISSION

SUNI Review Complete
Template=ADM-013
E-RIDS=ADM-03

ADD: John Lane, Mary Neely
Comment (7)
Publication Date: 4/21/2021
Citation: 86 FR 20744

As of: 5/25/21 1:08 PM
Received: May 21, 2021
Status: Pending_Post
Tracking No. koy-r38d-neok
Comments Due: May 21, 2021
Submission Type: Web

Docket: NRC-2021-0048
Role of Artificial Intelligence Tools in Nuclear Plant Operations

Comment On: NRC-2021-0048-0001
Role of Artificial Intelligence Tools in U.S. Commercial Nuclear Power Operations

Document: NRC-2021-0048-DRAFT-0006
Comment on FR Doc # 2021-08177

Submitter Information

Email: jonathan@bwailabs.com
Organization: Blue Wave AI Labs

General Comment

See attached file(s)

Attachments

NRC Comments

Blue Wave AI Labs

Response to Request for Comments

Role of Artificial Intelligence Tools in U.S. Commercial Nuclear Power Operations [NRC–2021–0048]

AI and ML are emerging, analytical tools, which, if used properly, show promise in their ability to improve reactor safety, yet offer economic savings. The NRC requests comments on issues listed below in this solicitation to enhance the NRC's understanding of the short- and long-term applications of AI and ML in nuclear power industry operations and management, as well as potential pitfalls and challenges associated with their application.

1. **What is the status of the nuclear power industry's development or use of AI/ML tools to improve aspects of nuclear plant design, operations or maintenance, or decommissioning? What tools are being used or developed, and when are they expected to be put into use?**

Response:

In our view, the nuclear industry is in the early adopter phase. In general, we see three areas that should be supported and encouraged to maximize the utility and adoption of AI/ML in the nuclear power sector:

i. Utilizing data from the existing fleet to improve safety/performance of the plants in the existing fleet.
ii. Utilizing data from the existing fleet to inform and guide plans for advanced reactor technologies and next generation reactor designs. One example: the current sensor sets installed in the existing fleet impose limitations on the degree that AI/ML can support online monitoring, SSC performance monitoring, condition-based maintenance programs, and so on. A full understanding of the current capabilities and limitations can inform designs for future I&C systems, OLM systems, and the like.
iii. Utilizing data from modeling & simulation of advanced/next-gen reactor designs to inform the design process.

Our company, Blue Wave AI Labs, is working with two early-adopter utilities using AI for *Fuel Cycle Management* and *Predictive Maintenance*. This work has been going on for the last three years.

Tools have been developed to predict Moisture Carryover (MCO) in boiling water reactors (BWRs). Excessive MCO causes both corrosive wear and increased exposure if allowed to get too high during the fuel cycle. New advanced fuel strategies have saved significant fuel costs, but as a side effect, exacerbated the MCO. The tool, *MCO.ai,* is used by core designers and cycle managers. Cycle managers use *MCO.ai*, to assess the impact of cycle-management actions, such as control-rod sequencing, on MCO. Core designers use *MCO.ai* to assess the impact of alternative fuel configurations on future fuel cycles as part of the fuel planning process.

In addition to its predictive capabilities, the neural networks model provides technical insights into operational and core design conditions that might exacerbate MCO levels. This model provides insightful information to engineers to reduce MCO levels through improved decision making. The use of this artificial intelligence has been integrated into the utilities core design and cycle management processes.

Another tool, *Eigenvalue.ai*, uses data from past fuel cycles to create an AI-based model of the BWR eigenvalue evolution for future fuel cycles. It is also used by core designers to evaluate alternative fuel scenarios as part of the planning process. One utility has saved an aggregate of over **$20,000,000** over the last two years using these tools.

2. **What areas of commercial nuclear reactor operation and management will benefit the most, and the least, from the implementation of AI/ML? Possible examples include, but are not limited to, inspection support, incident response, power generation, cybersecurity, predictive maintenance, safety/risk assessment, system and component performance monitoring, operational/maintenance efficiency, and shutdown management.**

Response:

Most of these areas can benefit significantly. Fuel-Cycle planning and risk management have already benefitted from AI-based tools that are providing significantly more visibility and predictability into reactor and component status. There is a DOE-sponsored program on predictive maintenance which is developing AI-based models of remaining useful life and failure prediction. This enables **safer and less expensive** operation because incipient fault modes can be identified early from real-time data and dealt with prior to catastrophic failure. AI-based models for components, such as Feedwater Heaters and LPRMs are presently being developed in partnership with a major utility.

One area not mentioned is Next Generation reactor design. Present work on this existing fleet will inform designers on measurement systems to put in place to support safe operation in the future.

3. **What are the potential benefits of incorporating AI/ML in terms of design or operational automation, preventive maintenance trending, and improved reactor operations staff productivity?**

Response:

Preventative maintenance trending will benefit from AI-based models in several ways:

1. Remaining useful life models are being developed using historical data. These models will allow condition-based replacement and maintenance as opposed to the present time-based methods Time-based methods often replace fit and reliable equipment based on a time schedule – possibly increasing the likelihood of failure. Conversely, premature failures are difficult to predict and prevent without accurate, dependable models that fully capture the past condition profile and failure modes. AI/ML can play a prominent role in development of these models.
2. These same models allow the creation of virtual sensors and virtual calibration tools. They are currently being developed for LPRMs.

4. **What AI/ML methods are either currently being used or will be in the near future in nuclear plant management and operations? Examples of possible AI/ML methods include, but are not limited to, artificial neural networks, decision trees, random forests, support vector machines, clustering algorithms, dimensionality reduction algorithms, data mining and content analytics tools, Gaussian processes, Bayesian methods, natural language processing, and image digitization.**

Response:

All the listed methods are currently in use in one way or another. Additionally, the use of Convolutional Neural Networks (CNNs) has yielded breakthrough progress in eigenvalue prediction for BWR's. Clustering algorithms and other unsupervised learning techniques such as **k-means** and **DBSCAN** have been particularly useful in feature selection and dimensionality reduction. **Pearson's** analysis also sheds light on how complementary systems interact by showing correlations between reactor variables that heretofore were not obvious. **Transfer Learning** is proving to very valuable in using data from many similar systems to construct generalizable models which can be applied to data-sparse situations.

Image digitization and image recognition is being used to identify cracks on the interior of the pressure vessel. **Reinforcement Learning** is being used for core loading and fuel cycle optimization.

5. **What are the advantages or disadvantages of a high-level, top-down strategic goal for developing and implementing AI/ML across a wide spectrum of general applications versus an ad-hoc, case-by-case targeted approach?**

Response:

There needs to be a top-down approach in support and funding for AI-based work in the nuclear power arena. Other countries are investing far more to grow and nurture the development of AI expertise and AI-inspired tools to enhance nuclear power generation. A quick literature search will illustrate this point. A vast majority of publications originate in China.

The specific programs are more naturally purpose and problem specific. Our approach has been to work with Utilities to identify the absolute most critical problems in terms of economic or safety impact and work on those. Different facilities will present their own set of related but locally condition-specific problems due to different maintenance and management practices at different stations.

6. **With respect to AI/ML, what phase of technology adoption is the nuclear power industry currently experiencing and why? The current technology adoption model characterizes phases into categories such as the innovator phase, the early adopter phase, the early majority phase, the late majority phase, and the laggard phase.**

Response:

The nuclear industry is in the early adopter phase although an argument could be made it is in the innovator phase. While application of AI and Machine Learning to Nuclear Power Generation is relatively nascent, the utilities have been quick to put new, proven innovations into practice.

7. **What challenges are involved in balancing the costs associated with the development and application of AI/ML tools against plant operational and engineering benefits when integrating AI/ML into operational decision-making and workflow management?**

Response:

Compared to the cost of developing and maintaining AI-based tools, the benefits have been outsized. Thus far, in our experience, AI based tools have prevented unplanned shutdowns and saved tens of fresh fuel bundles per reload on three refueling programs. The savings have been in the tens of millions and development cost in the half to one-million-dollar range.

8. **What is the general level of AI/ML expertise in the commercial nuclear power industry (e.g., expert, well-versed/skilled, or beginner)?**

Response:

For the most part, the commercial nuclear power industry is at the beginner stage. There are pockets as expertise, mostly individuals with some Machine Learning training. At the organizational level there are few if any AI programs underway. This makes sense as it is hard to build this capability from scratch with no extant infrastructure to guide the building of such a program internal to the utility. They are relying on external organizations with AI expertise to undertake programs—thus reducing their risk and reaping quicker benefits. The National Labs, especially Idaho National Labs have excellent program in AI and Machine Learning which support some of the utilities, as well.

9. **How will AI/ML effect the commercial nuclear power industry in terms of efficiency, costs, and competitive positioning in comparison to other power generation sources?**

Response:

The nuclear industry has collected vast amounts of data over many years of operation. This should not be underestimated as an asset capable of delivering tremendous value. Aggressive use of modern machine learning techniques, applied across all aspects of operations, does have the potential to lower operating costs by 20%-30%. To achieve these cost reductions, AI needs to be applied to operation and fuel programs in a greater capacity as it is today, but additionally the use of drones and robots for inspection and repair in hazardous parts of the facility could reduce human labor costs significantly. Other power generation sectors are ahead of the nuclear sector in this regard.

10. **Does AI/ML have the potential to improve the efficiency and/or effectiveness of nuclear regulatory oversight or otherwise affect regulatory costs associated with safety oversight? If so, in what ways?**

Response:

AI trained monitoring software could replace some portions of human surveillance. These systems could monitor data and written reports and detect problems/compliance issues before they occur.

11. **AI/ML typically necessitates the creation, transfer, and evaluation of very large amounts of data. What concerns, if any, exist regarding data security in relation to proprietary nuclear plant operating experience and design information that may be stored in remote, off-site networks?**

Response:

Utilities have very sophisticated risk management programs for data and software. Data is encrypted both at rest and in transit. They require frequented penetration tests and remediation efforts for any vulnerabilities uncovered by the tests. It is unlikely that significant insight could be gleaned from the purloined data unless the hackers had access to the application software that generated the data.