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Role of Artificial Intelligence Tools in Nuclear Plant Operations

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Role of Artificial Intelligence Tools in U.S. Commercial Nuclear Power Operations

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General Comment

See attached file(s)

Attachments

05-21-21_NRC_NEI Comments Regarding Role of Artificial Intelligence Tools in U.S. Commercial Nuclear Power Operations

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Subject: NEI Comments Regarding Role of Artificial Intelligence Tools in U.S. Commercial Nuclear Power Operations (Docket ID NRC–2021–0048)

Project Number: 689

On behalf of our members, the Nuclear Energy Institute (NEI)[1] is providing the attached response to the April 21, 2021 Federal Register request for information on the role of artificial intelligence tools in U.S. commercial nuclear power operations.

If you have any questions, please contact me at jcb@nei.org.

Sincerely,

John Butler

Attachment

c: John Lane, NRR, NRC

[1] The Nuclear Energy Institute (NEI) is responsible for establishing unified policy on behalf of its members relating to matters affecting the nuclear energy industry, including the regulatory aspects of generic operational and technical issues. NEI's members include entities licensed to operate commercial nuclear power plants in the United States, nuclear plant designers, major architect and engineering firms, fuel cycle facilities, nuclear materials licensees, and other organizations involved in the nuclear energy industry.

Docket ID NRC-2021-0048

Role of Artificial Intelligence Tools in U.S. Commercial Nuclear Power Operations

IV. Requested Information and Comments

The responses to the eleven (11) questions provided below were developed from a limited set of input from operating plant licensees and should not be viewed as fully representative of the operating nuclear plant fleet.

1. What is status of the commercial nuclear power industry 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? When are the tools currently under development expected to be put into use?

   Industry use of AI/ML tools varies from company to company but also within each company from organization to organization, with some in the mature stage and actively being used in the organization, while others are still in the development stage. Use varies across organizations, with some using internally developed solutions and others relying upon external vendors. Most are collaborating with EPRI in their AI/ML projects.

   Plant performance monitoring and oversight is an active area of AI/ML use to measure and analyze performance change across multiple functional areas. Natural language processing (NLP) based tools are used on textual reports to identify critical issues and trends. Some engineering groups are actively developing AI/ML applications focused on equipment condition-based maintenance and monitoring (CBM) tools including remaining useful life. AI/ML tools can be incorporated into helping work order planning, with future work management applications expected in work screening, scheduling, and prioritization. Procurement and supply chain can use AI tools for material and parts ordering optimization. One licensee is using artificial intelligence (AI) in a limited business process, not directly related to nuclear plant design, operations or maintenance or decommissioning. The business process of classifying condition reports (CR) uses IBM Watson (an AI product) to make the initial classification. There is still a human review and approval of the classifications. This licensee is exploring using the same product to automate CR classification in the near future. This licensee has also discussed using AI in simple work order creation, work order planning, scheduling and predictive maintenance but does not have any immediate plans or approved projects to start those initiatives.

   AI/ML tools can also be used to support nuclear operations and maintenance. In the area of engineering and equipment reliability, there are different tools used to help monitor equipment performance. ML can use system and component data to analyze for trends and correlations. Alarms can be generated with parameter drift outside of established trends. Neural network-based analytics can use natural language processing to enhance the review of thousands of equipment issue reports to help facilitate the identification of potential maintenance rule functional failures. Also, neural network-based analytics that use natural language processing and a scoring system can be used to review work order as found condition codes, completion remarks, cost data and maintenance frequencies to suggest changes in maintenance strategies.

In the area of nuclear fuels, ML tools can be used to predict BWR moisture carryover, hot eigenvalues (core reactivity), and off-line to on-line thermal limits. Additional ML tools are in development for local power range monitor remaining useful lifetime predictions and Deep Reinforcement Learning reactor core design optimization.

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.

While there is a potential benefit to almost all parts of the nuclear organization, there will be a significant benefit in power generation through system and component performance monitoring by preventing equipment failures and events that result in plant shutdowns or power reductions. A 360° view of plant status can be achieved from a combined output of AI/ML tools on predictive maintenance, plant performance, and knowledge management of work management data. Predictive maintenance and achieving increased maintenance efficiency thru AI focused on work process improvements are also benefits. Use of AI/ML in trending plant equipment performance can pick up on adverse trends earlier and alert operators and engineers. With current technology, these alerts might become a burden to operators, but when coupled to a monitoring and diagnostic center, they can be useful as an input into operation’s critical parameter monitoring and planning maintenance.

One area of focus has been on identifying potential processes that could reduce required man hours with the use of AI. Any process that can become more efficient using AI could benefit from its use.

It is straight forward and cost effective to apply AI/ML to equipment issue report (IR) reviews and preventative maintenance feedback to understand trends and identify improvements. Using these tools can significantly reduce administrative burden.

The use of computer vision techniques will aid inspection analysis of videos and photographs and help identify issues. AI/ML would reduce the time taken to review while providing similar or more accurate analysis of changes and issues.

Cybersecurity techniques can be enhanced with AI/ML in identification of intrusion analysis and active attacks. For example, reinforcement learning could recognize the expected system behaviors so that differences in system performance would be noted quickly and flagged.

3. What are predictive potential benefits to commercial nuclear power operations of incorporating AI/ML in terms of (a) design or operational automation, (b) preventive maintenance trending, and (c) improved reactor operations staff productivity?

Potential benefits include improved safety and human performance, reduced dose, prevention of potential events and improved productivity.

Preventive maintenance has a significant benefit in ensuring equipment reliability and early detection of incipient failure which will avoid equipment failure, reduce challenges to operations staff having to respond to failures, and possible plant power reductions or shutdown. Use of AI/ML can improve preventative maintenance trending by incorporating many sources of information, such as live streaming plant process computer data, issue reports, maintenance feedback and similar parts/processes/systems/environment to identify gaps and opportunities.

Automation of equipment reliability health and trending supports improved long-range asset management planning. Preventive maintenance trending and its support for condition-based maintenance strategies allows for optimizing allocation of resources to work on equipment when it is needed, i.e., work on the right equipment at the right time.

Staff productivity is achieved in using AI/ML to handle massive sensor-based and textual data and to intelligently produce actionable insights which would otherwise require many man hours and significant expertise to produce. Reduction in staff time to perform repeatable tasks such as operator rounds, inspections and scheduling of preventative maintenance are all possibilities.

4. What AI/ML methods are either currently being used or will be in the near future in commercial nuclear plant management and operations? Example 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.

The following are some of the areas/methods of use:

- Deep learning models from image detection and natural language processing to generative adversarial networks for anomaly detections are being used to solve various plant problems.
- ML methods for forecasting, optimizing, clustering, and regression analysis are also widely used as appropriate to the respective problem.
- Data mining, content analytics tools, and decision tree applications are used in a variety of applications.
- Optical character recognition is used to understand handwritten or typed text in images to review large amounts of information quickly.
- Use of IBM Watson virtual assistant for its CR classification process.
- Use of trained artificial neural networks and natural language processing in equipment reliability process. The results are reviewed by an engineer to determine if an adverse trend or opportunity exists.
- Use of artificial neural networks (Supervised Learning) and Deep Reinforcement Learning.

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?

Using industry collaboration with organizations like EPRI and NEI, best practices can be shared industry wide to ensure that technical and regulatory challenges are addressed with robust and common approaches while also reducing the regulatory review process on a plethora of techniques.

The major challenge is that the number of techniques and how they are best applied means that multiple methods and algorithms are needed for the different aspects of nuclear plant operation and analysis. Therefore, a diverse team of developers and data scientists would be needed, within a utility, to drive an overall AI/ML program and this highlights the importance of industry wide efforts in this area to implement best practices and techniques.

The advantages of a top-down approach within a company include:

- Enables a holistic approach to choose one product that meets the needs of all possible AI use cases.
- Creating a standardized data and solution architecture that is conducive to using data for analysis.
- Creating a data governance and security system at enterprise level which allows for a safe use of innovative technology.
- Creating a pool of data science experts that can be used as a shared resource across the enterprise.
- Ability to easily share knowledge and utilize learned OE from AI/ML application use across departments.
- Allows for staffing of more data science expertise, shared resources and a support organization across the enterprise. Strategic implementation drives consistency across multiple applications, avoidance of effort duplication by various internal organizations/departments, proper resource planning.
- Minimizes spinoff software packages that are difficult to maintain and have heavy reliance of contract companies that are challenging to oversee and interface with by typical staff engineers with little AI/ML experience.

The disadvantages of a top-down approach within a company include:

- Implementation takes a long time and delays the quick time-to-market approach.
- Framework can be limiting to a constantly changing technology landscape and will require a longer time for the framework to adopt up-and-coming innovations.
- Potential loss of employee insights on how to innovate and where the true value propositions exist. Employees with the most passion for AI/ML tend to drive these initiatives most effectively therefore a top-down approach could hinder this.

6. With respect to AI/ML, what phase of technology adoption is the commercial 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.

The commercial nuclear power industry is in the early stages of applying digital transformation efforts such as AI/ML as compared to many other industries. Relative to the technology adoption curve model, the nuclear power industry population in general falls into the late majority phase group, with some areas considered as early adopter or innovator phase. The nuclear workforce and overall historical culture of nuclear in general is focused on using long standing, proven methods and desires to have new applications or tools proven to be reliable prior to adopting and utilizing broadly.

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

Some of the benefits from AI/ML are long term and can only be determined more precisely following implementation. The benefit tends to grow with maturity of application and requires upfront financial commitment for a long-term benefit. All uses of AI/ML do not inherently result in timely benefits. Implementing AI does have a considerable up-front cost to create the process. In identifying the benefits, licensees are challenged to estimate savings since the benefit is often a reduction in hours of many staff and not a direct elimination of staff.

Reductions in risks and improvements in preventative maintenance take years to see a return on investment and clear improvement in equipment reliability.

As with many innovation projects, success is not guaranteed. There is an acknowledgment that some innovation projects will not be successful and not be fully implemented. Therefore, the value proposition must be strong for an AI/ML application and a prudent prototype/pilot program conducted to prove success, demonstrate the benefits and improve stakeholder support.

A potential challenge is the readiness and culture of the organization to accept and adopt these innovative tools after development.

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

This is varied across the industry. In some utilities AI/ML has been a focus and staffing has been aligned to ensure expertise in AI/ML techniques. Other utilities may have employees with expertise and knowledge in AI/ML, but they are not known or are not assigned to these types of activities. Maintaining staff that are experts in the AI/ML techniques and that maintain awareness of the constantly changing landscape is a challenge. In some cases, outside entities (vendors and industry resources) provide the needed knowledge and experts to help in AI/ML solution development.

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?

AI/ML will support staff in operation and management at increasingly reliable levels, resulting in early detection of incipient failures; optimizing resources and the timing of maintenance. This will improve efficiency, lower costs, and position nuclear power more favorably with competing carbon free generation sources.

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?

    AI/ML is expected to improve the effectiveness associated with safety oversight based on improved equipment operation, fewer plant events, and improved performance indicators.

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, offsite networks?

    Cybersecurity, proprietary information concerns, export control information, data curation challenges and WiFi connectivity in the power plant are concerns with the use of AI/ML in nuclear power. Many of the AI/ML techniques require large data sets and rely on previous events to help identify issues and changes early. Utilizing industry wide data instead of a single utility or site could provide more robust AI/ML solutions and therefore appropriate data security and control would be required. Data stored in remote, offsite networks has the potential to be exposed to unauthorized persons if appropriate controls are not in place. Application of stringent processes, architectural design, protocols, and oversight are necessary to ensure data movement of any sort is thoroughly vetted and approved by cybersecurity and data architect personnel. Robust data security and governance protocols are required to ensure data security risks from these applications are minimized.