ELECTRIC POWER RESEARCH INSTITUTE

Quick Insight Brief: Leveraging Artificial Intelligence for Nondestructive Evaluation

With the power to substantially transform nearly every form of industry—just like electricity did in the last century—artificial intelligence (AI) has been branded as "the new electricity." Its impact on nondestructive evaluation (NDE) is a case in point. The purpose of this Quick Insight brief is to discuss areas where AI can impact NDE in the nuclear sector and inform the industry about current EPRI research activities on AI for NDE.

RESEARCH QUESTIONS

To help the nuclear industry understand the potential use cases of AI for NDE, this brief addresses the following questions:

- How can AI be used for NDE in the nuclear sector?
- What is needed in order for AI solutions for NDE to be developed?

KEY POINTS

- NDE in the nuclear industry can leverage AI in three key areas: automated analysis of NDE inspection results, analysis of real-time NDE monitoring, and informing inspection planning through assessment of NDE history.
- AI technologies can provide a powerful tool to aid the nuclear industry in performing many of its customary NDE inspections, by further improving reliability and reducing the time needed for NDE inspection data analysis.
- Collaboration among all stakeholders is essential for the nuclear industry to realize the potential benefits of AI.

LEVERAGING AI FOR NDE

AI can be applied in three broad functions associated with NDE as used by the nuclear industry: analyzing or assessing the results of routine NDE inspections, enabling real-time monitoring of systems or components, and extracting lessons from inspection history to inform inspection planning.

Automated Analysis of NDE Inspection Results

Using AI to analyze NDE inspection results can make it possible to apply advanced automated analysis techniques to detect or characterize target conditions, such as flaws or equipment faults. As a result, inspection reliability increases and the analysis time is reduced, while at the same time human error is minimized.

EPRI is engaged in several research projects involving each of the main NDE sciences. Some representative examples follow.

Ultrasonic Inspection: Ultrasonic testing (UT) is the most common volumetric inspection method used in the nuclear industry, and it is an integral part of any in-service inspection (ISI) program. The reliability of such inspections is key to ensuring the safe operation of power plants. With a vision of increasing inspection reliability, the NDE program at EPRI is leading efforts to develop auto-analysis capabilities for challenging UT inspections. These include inspections of dissimilar metal welds and reactor vessel upper head (RVUH) penetration welds, a demanding task requiring highly skilled data analysts to review a significant amount of data.

Eddy Current Inspection: Automated analysis of eddy current inspections is already available for steam generator tubing. These inspection procedures are specific to steam generators and do not extend to inspections of balance-of-plant (BOP) components such as heat exchanger (HX) tubing. Although current inspection techniques for BOP applications are satisfactory for detecting damage, inspectors are challenged when characterizing certain types of operating conditions. This limitation in defect characterization can lead to the unnecessary plugging of tubes and consequent loss of performance, or unexpected leaks.

EPRI's NDE program is leveraging machine learning (ML) techniques to characterize the depth of inside-diameter defects in HX tubing. Preliminary results show at least a two-fold improvement in accuracy when compared to traditional practices.

Visual Inspection: EPRI's several efforts around machine vision (MV) apply AI techniques to image data. These include automated analysis of remote visual inspection of four-face fuel assemblies, reactor vessel internals, and containment buildings. In the latter case, such tools could enable utilities to maximize the benefits found in deploying unmanned aerial systems for remote visual inspections. In general, the objective of these efforts is to automatically detect the applicable damage types in the recorded images, either in real-time or in post-processing.

Figure 1 presents an example of the output of the concrete damage localization model under development (see technical brief 3002018419). The results of the initial model on a limited dataset show that this approach is feasible and if implemented can provide added value to the nuclear industry through increased reliability and efficiency. EPRI continues to improve these models and is developing tools to implement and deploy them.

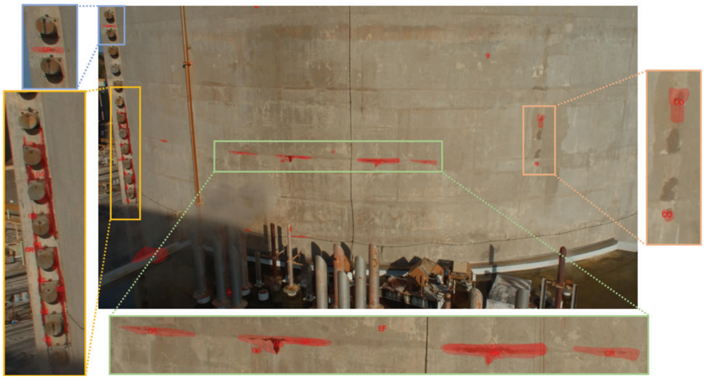

Figure 1. Example of the Concrete Damage Detection Model. Details show a crack detected between tendon caps (top right); grease stain detection around tendon caps (bottom left); crack and grease stain detections on the wall, with a miscalled efflorescence (bottom); and corrosion detection (bottom right).

Analysis of Real-Time NDE Monitoring

For some assets, continuous monitoring can be more cost-effective and efficient than routine inspections. To move toward continuous monitoring, the industry will need to ingest and process a large amount of streaming data. AI can provide the tools to analyze this data and perform real-time assessment of the evolving condition of the monitored component.

One such EPRI effort involves processing data from guided wave sensors to continuously monitor heat exchanger shells for flow-accelerated corrosion (FAC) damage. EPRI is also examining active flaw growth monitoring as well as tendon tension monitoring, which could replace expensive and hazardous periodic lift-off tests.

Informing Inspection Planning Through NDE Inspection History

Over the years, the nuclear industry has accumulated a large history of NDE inspections across many inspection programs. AI offers an opportunity to assess this rich operational experience holistically for trends or other insights relating to component aging and condition.

EPRI is engaged in efforts to mine industry inspection databases for trends. If carefully studied, they may provide information about suspect areas before remedial action is needed. One such project is developing capabilities to retrieve historical UT information; by adding the information to digital databases, data analytics evaluation techniques could then identify trends or leading damage indicators.

In another project, EPRI hopes to leverage ML to better inform FAC inspection programs in their entirety. For modeled locations, preliminary research (see technical brief 3002019731) has shown potential for ML techniques to provide more accurate predictions of wear rates. This effort continues and is being expanded to susceptible-not-modeled (SNM) locations that comprise more than half of a typical FAC program. In this case, the objective is to leverage ML to rank the locations in terms of susceptibility and risk in order to optimize FAC inspection schedules.

COLLABORATION: KEY FOR AI SUCCESS

AI technologies can be a powerful tool to aid the nuclear industry in performing many of its customary NDE inspections, improving both their reliability and efficiency. However, the development of such techniques typically requires a considerable amount of data to train and validate the AI models. EPRI is engaged in efforts to generate and leverage synthetic data to augment training datasets and improve model performance, but 1) they often require real seed data, and 2) synthesized data cannot be used in testing.

Therefore, the need for data remains one of the biggest challenges to making substantial progress. Because it is not likely that any one utility will have enough data to develop high-performing AI models for NDE applications, collaboration among all nuclear industry stakeholders is essential to realizing the potential benefits of AI. In recognition of this and of the potential positive impact that leveraging AI for NDE can have on the industry, EPRI has included NDE data in the EPRI10 as one of the 10 most impactful datasets in the industry, and is continuously engaged in collaborative efforts with all industry stakeholders to collect, anonymize, curate, and share relevant datasets.

Most of the projects discussed in this Quick Insight brief are examples of such a collaboration, as they have been derived from field data provided by EPRI's member utilities. As more data is collected to inform the models, the preliminary results discussed can be validated, the overall reliability of AI will improve, and the benefits of AI to the industry can be realized.

EPRI RESOURCES

If you would like to get involved with EPRI on AI for NDE or have ideas and feedback on the topic, please contact Thiago Seuaciuc-Osorio, Senior Technical Leader, at 704.595.2841 or tsosorio@epri.com.

To learn more about EPRI's AI initiative, visit ai.epri.com.

Nondestructive Evaluation

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3002021074

April 2021

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