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Neural networks and AI-decision making for a more flexible nuclear industry

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1. Introduction

In today's world, artificial intelligence (AI) is at the cutting edge of technological innovation. Using it is key to improving almost every process in modern society. For nuclear power plants (NPPs), AI-driven decision-making and Neural networks (NNs) offer a gateway to optimizing operations, enhancing overall efficiency, and improving safety and reliability. This study presents potential applications of our previously developed methodology, highlighting key opportunities for their implementation in nuclear power plants.

Figure 1. NNs and AI – The future of nuclear power

B. BALANCING OF ELECTRICITY AND HEAT GENERATION

Using NPPs for industrial applications opens the door to innovative approaches for balancing electricity and heat generation while providing ancillary services to the grid. Practical implementation will require meeting heat demand while also providing ancillary services for the power grid, which can be performed by NNs and AI.

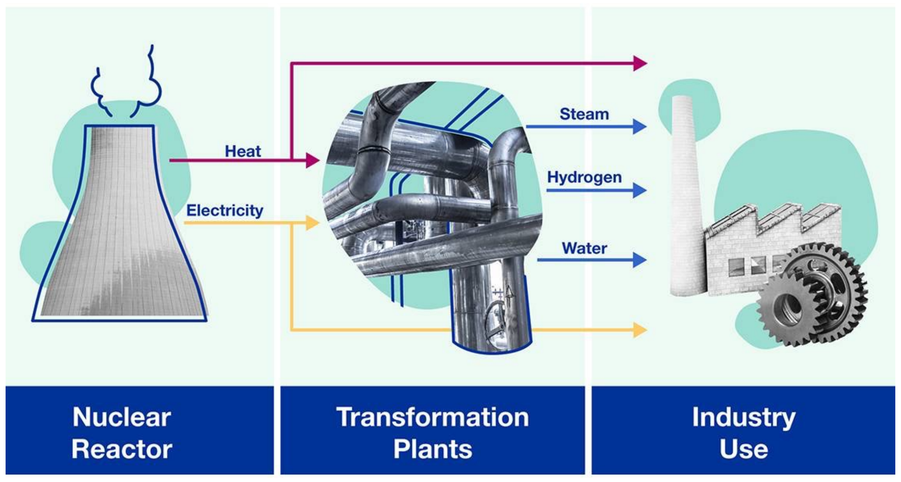

Figure 4. NPPs for industrial purposes [2].

2. Methodology

Figure 2 shows our methodology, which is composed of the dataset (variable selection, data validation and preparation). The next block involves the NNs: in our approach, we specify the NN type, along with the layers and hyperparameters. The final block focuses on validation of results. For more details about methodology see [1], as well as additional information visit dedicated page related to this study (www.ullmann.zcu.cz/FISA.html), or scan QR code above.

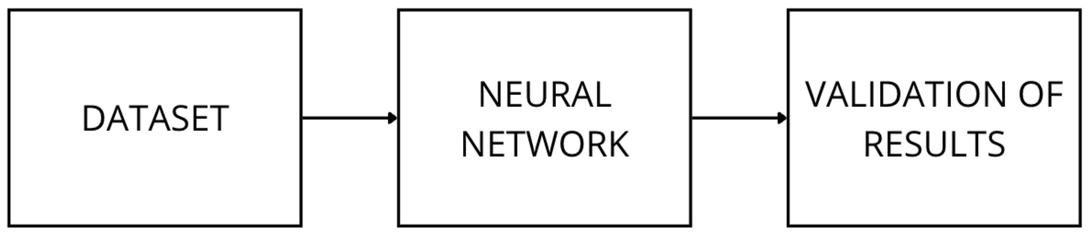

Figure 2. Methodology [1]

3. Applications of NNs and AI-decision making

A. POWER REGULATION (GRID STABILITY)

There is significant potential for utilizing NNs in the power grid for ancillary services and power regulation, especially by leveraging data from transmission system grid operators. As renewables expand, power regulation in a decarbonized grid will depend on NPPs. Predictions and simulations based on NNs are valuable for both NPPs operator and transmission system grid operators. Figure 3 shows our NN t+15 min prediction (details in [1]).

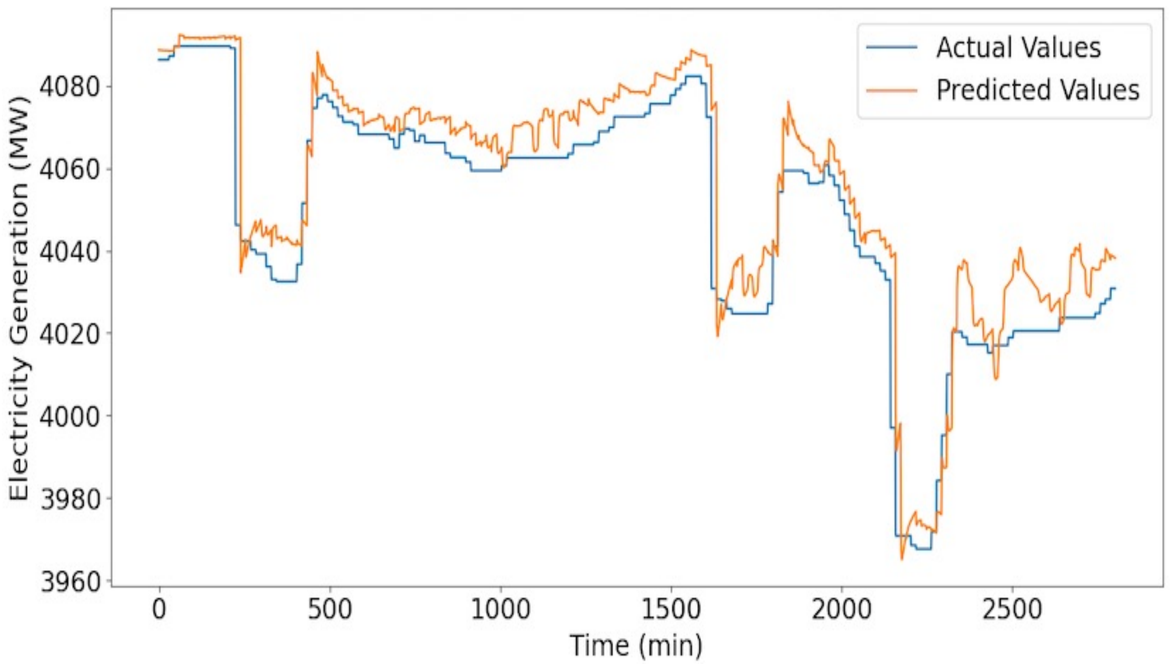

Figure 3. Electricity generation prediction using a NN [1]

C. NUCLEAR FUEL MANAGEMENT

NNs can predict fuel conditions and optimize the selection and arrangement of fuel assemblies for reactor reloads. AI can ensure efficient fuel utilization and enhance reactor operation.

D. PREDICTIVE MAINTENANCE

By monitoring operating variables during operation, we can use NNs and AI to detect deviations from operating parameters and order maintenance of the device - achieving greater overall plant reliability and safety.

E. OPTIMIZING TASK SCHEDULING IN PLANNED OUTAGES

During a NPP outage, a vast number of interconnected tasks and operations take place, making outage planning crucial for minimizing downtime. Utilizing AI-driven decision making and NNs for outage scheduling presents a significant opportunity to enhance efficiency and reduce outage duration.

4. Conclusions

This study presented potential applications of our developed methodology for using neural networks and AI in nuclear sector. These applications highlight areas where AI and NNs could enhance efficiency, safety, and operational flexibility. We have developed a methodology with the required tools that we can now use for these applications. Future work will focus on the direct implementation of NNs into one of these applications, depending on the availability of relevant data for training NNs. Neural networks represent a major opportunity for the nuclear sector, offering new ways to optimize operations, improve predictive maintenance, and enhance grid stability in a decarbonised energy mix, ultimately contributing to a more flexible, resilient, and efficient nuclear energy infrastructure. The real challenge ahead is to ensure that artificial intelligence and NNs become a reliable ally in the development of the current and next generation of nuclear power.

5. References

[1] J. Ullmann, J. Závorka, D. Mašata, J. Jiřičková, and R. Škoda, "Neural Network Optimization of Nuclear Energy Integration for Industrial Applications and Grid Stability," in Proceedings of the European Young Generation Forum (ENYGF'25), Zagreb, Croatia, June 2-6, 2025.
[2] A. Vargas, "The use of nuclear power beyond generating electricity: Non-electric applications," IAEA. [Online]. Available: https://www.iaea.org/newscenter/news/the-use-of-nuclear-power-beyond-generating-electricity-non-electric-applications. [Accessed: Mar. 19, 2025].