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Application of Machine Learning-Based Enhanced Fault Detection and Predictive Maintenance for Nuclear Reactor Cooling Efficiency

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This study discusses the application of artificial intelligence (AI) and machine learning (ML) to address critical challenges in nuclear reactor safety and efficiency, with a focus on fault detection, predictive maintenance, and the optimization of secondary cooling systems. The paper presents an innovative hybrid machine-learning approach for monitoring reactor performance, detecting anomalies, and predicting maintenance needs by combining support vector machines (SVM), K-nearest neighbors (KNN), SARIMA, and LSTM time-series models. Using real-time sensor data, this model enhances fault detection accuracy, supports better decision-making, and reduces operational risks.

Applied to a pressurized water reactor (PWR) model, the approach yielded exceptional results, improving fault classification precision and reliability. The hybrid model achieved a 15% increase in fault detection accuracy and reduced unplanned downtime by 25% compared to traditional methods. This work is unique in integrating advanced machine learning techniques with real-time reactor data to optimize cooling system efficiency, contributing to both operational safety and energy sustainability.

By combining AI-driven predictive maintenance and operational optimization, this research contributes to the development of more reliable and sustainable nuclear reactor systems, improving reactor safety and supporting their long-term viability in the global energy mix.

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