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Achieving a Level of Autonomy for Autonomous Operation of Microreactors: Reliability Considerations

Vivek Agarwal

Instrumentation, Control, and Data Science/Idaho National Laboratory, Idaho Falls, USA.
E-mail:vivek.agarwal@inl.gov

Modular and microreactors, along with other advanced reactor technologies, are important contributors to the future of nuclear energy and net-zero vision. Though designs for these reactor types are diverse, they share a common goal: to ensure that future reactor technologies have (1) low operating costs; (2) high reliability; (3) remote, autonomous, or semi-autonomous operations; and (4) the flexibility to support expanded applications and markets. To achieve this, it is important to embrace advancements in modeling and simulation (physics-based), sensors, and artificial intelligence to make informed decisions. This work serves to propose updated levels of automation for nuclear reactor operations, because of considering long-term economic and commercial ambitions of the advanced reactor developer community. As in other fields such as road-going vehicles and aviation, reactor technologies can benefit from modern automation through the resulting reduction in operations and maintenance costs, while still maintaining the current industry standards regarding safety, resilience, reliability, overall performance, and the capacity for root-cause analysis. The current guidelines on automation levels, as published by the U.S. Nuclear Regulatory Commission in Section 9 of NUREG-0700, reflect design principles that implicitly limit the potential of automation innovation for reactor operations, particularly regarding advanced reactors intended to operate in remote locations or be used for off-grid applications. Motivated by the operational paradigms anticipated for future reactor designs, this work would present a six-level approach [1] that aligns with contemporary automation concepts as well as automation level definitions from other non-nuclear safety–critical industries. These levels build upon the current guidelines to enable next-generation nuclear reactor technologies to become increasingly economically competitive and commercially viable relative to competing power generation sources. The work critically examines the identified challenges, knowledge gaps, and enabling technologies to achieve advanced levels of automation.

Keywords: Autonomous operation, levels of automation, predictive controls, digital twin, reliability.

References

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