Design of Risk-informed Autonomous Operation for Advanced Reactor

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ABSTRACT:

The objective of this project is to develop and demonstrate artificial reasoning systems for operator decision support, aided by autonomous control technology, for advanced nuclear power reactors. A critical aspect of the operator decision support technology proposed here is the integration of prognostic calculations of plant state and risk-assessment of proposed actions relative to the current and postulated future plant states. To our knowledge, such integration has not been examined from the perspective of operator decision support. If successful, this technology will enable routine operator oversight of autonomous control actions while providing specific operator action options for more complex scenarios, optimizing plant availability and reliability while maintaining safety margins.

While related concepts have been examined in the past, the reliability of such technologies has not been high enough that potential adopters are sufficiently confident of their feasibility. Further, previous attempts have often focused on predefined sets of options for operators to choose from, with the assistance tool suggesting the best option from this list for maintaining system functionality. In the absence of adequate confidence that the system will reliably propose desirable actions—according to some set of metrics—for any scenario, others will remain reluctant to invest their resources in creating the needed applications. Our work goes beyond satisfactory, and aims for optimal action recommendations, but we do not view this as being required to justify our effort. The proposed work is expected to improve the knowledge base and specific lore to a convincing level of assurance, and through such progress to strengthen its foundation. The greatest need is demonstration of the feasibility of such operator support to the point that others can be confident in using the ideas demonstrated. Without such progress in supporting nuclear power plant (NPP) operations hopes of reducing operator errors and staff size will remain frustratingly difficult.

In our proposal, we use the experimental breeder reactor-II (EBR-II) as the advanced reactor example, which reflects greater system simplicity, and use of passive safety features such that task support for plant staff in the form of monitoring, prognostics, advice, and - at least initial stage autonomous control for some tasks - offers greater promise for advancement. Our goal is to advance such capabilities and to demonstrate their benefits and feasibility.The major elements of providing such capabilities include detection of system behavior anomalies as reflected in deviations of structures, systems and component (SSC) state variables from their expected values, assessing future conditional probabilities of SSC states as indicated by state variable deviations, identification of importance ranks of alternative feasible changes to SSC states-ranging from small control changes to shutdown and replacement via actuation of control actions by operators or automated systems, and finally-continued monitoring to determine whether desired SSC state changes result. We shall carry this work to the point of generating advice to operators and identification of control system input signals that could activate selective plant protection systems. We include efforts to demonstrate the reliability of the plant protection control software, and how it could be used to generate control signals based upon evolving sensor measurements.