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Light Water Reactor Sustainability (LWRS) FY 2018 CINR Webinar: RC-5, 6 & 7

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Light Water Reactor Sustainability (LWRS) Program

LWRS Program Goal

- Develop fundamental scientific basis to allow continued long-term safe operation of existing LWRs (beyond 60 years) and their long-term economic viability

LWRS program is developing technologies and other solutions to

- Enable long term economical operation of existing nuclear power plants
- Improve reliability
- Sustain safety

Nine Mile Point ~ Courtesy Constellation Energy

LWRS focus areas

- Materials Aging and Degradation
- Advanced Instrumentation and Controls
- Risk-Informed Safety Margin Characterization
- Reactor Safety Technologies
- Systems Analysis and Emerging Issues

Technical Focus Areas Summary

- **Nuclear Materials Aging and Degradation**
  - Understand and predict long-term environmental degradation behavior of materials in nuclear power plants, including detecting and characterizing aging degradation
- **Advanced Instrumentation, Information, and Control Systems Technologies**
  - Address long-term aging and obsolescence of existing instrumentation and control technologies through a strategy for long-term modernization
- **Risk-Informed Safety Margin Characterization**
  - Develop significantly improved risk methods and safety analysis tools and apply these tools to analyze the safety margin of aging plants in order to enhance reliability and improve economics
- **Reactor Safety Technology**
  - Address emerging safety concerns in response to the Fukushima accident
  - Develop technologies to enhance the accident tolerance of current and future reactors
- **Systems Analysis and Emerging Issues**
  - Address high impact emerging issues such as flexible operations and water usage issues (the potential backfit of cooling towers)

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Advanced Instrumentation, Information, and Control Systems

- ***Address long-term aging and reliability concerns of existing II&C technologies:***
  - *Establish a strategy to implement long-term modernization of II&C systems.*
  - *Develop, test, and deploy advanced technologies.*
  - *Promulgate technologies, lessons learned, and foster industry standardization.*
  - *Develop advanced condition monitoring technologies to monitor, detect, and characterize aging and degradation processes.*

Adv. II&C RC-5 – Background

- **Potential for big data to improve nuclear power plant performance.**
  - Data on plant performance from component level sensors
  - Information from work flow and work related activities and plans
  - Cost and schedule information, technical specifications, material conditions
- **Fusing this information together has always been a challenge**
  - Legacy systems that do not exchange with one another
    - Operations systems operate separately from work management, planning, scheduling, costing, etc.
    - Information in different units, on different scales, difficult to reconcile
- **Big Data Science and Data Analytics Offer New Opportunities**
  - Fusing data from disparate, heterogeneous sources to obtain insights
  - Potential to apply insights to improve operational efficiencies and safety

Adv. II&C RC-5 – Proposed Research

- **Data Science and Big Data Analytics to Improve Nuclear Power Plant Efficiency**
- **Seeking research proposals to enhance operational efficiency and productivity of current light water reactors using data science, especially big data analytics.**
- **Proposals should address novel approaches to integrate and analyze heterogeneous data streams to extract insights and significantly impact the operational efficiencies in managing and protecting physical assets and plant components**
- **Interested in transformation of large volumes of heterogeneous data into useful information including data visualization.**
- **The outcomes of research are expected to provide input to a more agile and modular big data analytic framework that can be leveraged by nuclear power plant owner operators and their suppliers.**

Risk-Informed Safety Margin Characterization (RISMC)

Margins Analysis Techniques

- Develop techniques to conduct margins analysis, including methodology for carrying out simulation-based studies of safety margin
- Use advanced probabilistic risk assessment (PRA) to optimize plant safety and performance via highly-integrated simulation

Simulation components of the RISMC Toolkit

- RELAP-7 Thermal-hydraulics
  - Thermal-hydraulics systems code that simulates plant-level fluid behavior
- RAVEN (Risk Analysis Virtual Environment)
  - Risk analysis and scenario generator
  - Provides probabilistic input on plant state to RELAP-7 (including operator actions, component states, etc.)
  - Integrates output from RELAP-7 with other considerations (e.g., probabilistic and procedures information) to determine component states
- Component Aging (Grizzly)
  - Component aging and damage evolution that is modeled in separate modules which are able to couple to RELAP-7 and RAVEN
- External Hazards (flooding and seismic)

RSMIC RC-6 – Background

- **Evaluation of Potential Improvements to Risk and Economics Resulting from Accident Tolerant Plant Designs**
- **Concept of "accident tolerance" has been ingrained in the LWR design and operation for decades**
  - Regulatory Guide 1.155: Station Blackout notes "…for complying with the Commission regulation that requires nuclear power plants to be capable of coping with a station blackout for a specified duration."
  - The method provides an informed way to select a minimum acceptable station blackout coping duration capability from 2 to 16 hours
- **Focus of this research is to evaluate current LWRs for design enhancements including**
  - Accident-tolerant fuel
  - Accident-tolerant core structures
  - Incorporation of and credit for backup safety systems such as FLEX and new passive cooling systems
  - Improved operational control
  - Accident-tolerant instrumentation

RISMC RC-6 – Proposed Research

- **The research will evaluate plant scenarios using RISMC simulation tools to determine potential applicability of the different coping times using risk-informed approaches**
- **This analysis will focus on determination of "response surface" of coping time versus potential economic savings**
  - Goal is to leverage RISMC methods and tools + 10CFR 50.69 to provide flexibility to reduce cost and improve plant operations & safety margins
- **The research will use infrastructure developed within LWRS Program to consider coping time issues on both fuel/cladding and plant/system-level integrity issues**
- **Once risk implications are identified, these will be evaluated against 10CFR 50.69 to understand potential regulatory relaxations that are possible in order to improve economics of the plant**

RISC 1	RISC 2
Safety Related High Safety Significance	Non Safety Related High Safety Significance
Safety Related **Low Safety Significance**	Non Safety Related Low Safety Significance
RISC 3	RISC 4

RISC = Risk Informed Safety Class

Reactor Safety Technologies (RST)

- **The Reactor Safety Technologies (RST) Pathway provides scientific and technical insights, data, analyses and methods that can support industry efforts to enhance nuclear reactor safety in beyond design basis events**
- **RST activities evolved from a coordinated global effort to assist in the analysis of the Fukushima accident progression and response into the following areas**
  - Fukushima Forensics and Examination Plans: Provides insights into the accident progression at Fukushima through data collection, visual examination of in-situ conditions of the damaged units as well as collection and analysis of samples within the reactor systems and structural components from the damaged reactors
  - Severe Accident Analyses: Analyses using existing computer models and their ability to provide information and insights into severe accident progression that aid in the development of Severe Accident Management Guidance (SAMGs)
  - Accident Tolerant Components: Analysis or experimental efforts for hardware-related issues with the potential to prevent core degradation or mitigate the effects of beyond-design basis events

RST RC-7 – Background

- **Although R&D on severe accidents is important for developing mitigation strategies, an equally important question is whether there are innovative concepts for increasing the ability of existing plants to passively respond to Beyond Design-Based Events (BDBEs)**
- **Within the LWRS Program, two approaches are currently being considered to achieve this objective:**
  1. Accident Tolerant Fuel (ATF) coupled with extended emergency core cooling equipment (e.g., reactor core isolation cooling (RCIC) pump for BWRs and aux feedwater pump for PWRs) to delay or prevent core damage, and
  2. Novel ways for using existing structures and equipment within containment to augment long-term containment heat sink. One example would be exterior flooding of the drywell head in Mark I and II containments.

RST RC-7 – Proposed Research

- **Innovative Methods for Increasing Passive Safety Response for Existing Plants**
- **Seeking proposals that explore Innovative Methods for Increasing Passive Safety Response for Existing Plants**
- **Desirable elements of this work include: i) definition and analytical demonstration of novel methods for increasing containment heat sink, ii) evaluations of ATF coupled with extended performance of emergency core cooling equipment, and iii) use of system level codes to demonstrate the synergistic effects of these two concepts on preventing or delaying core damage.**
- **Goal is to develop and demonstrate a concept for achieving a 72-hour coping period for an existing plant using existing equipment.**