INTRODUCTION

- Nuclear power plants need to operate not only safely, but also economically.
- Instrumentation and Control (I&C) systems in Nuclear Power Plants (NPPs) play an important role in reducing operational related costs.
- How to perform the test and maintenance for I&C systems with lowest cost while maintaining reliability and safety?
- A risk-informed test and maintenance framework based on Probabilistic Safety Assessment (PSA) and Reliability-Centered Maintenance (RCM) is presented.

The flowchart of the proposed test and maintenance framework is as follows:

1. Build a Fault Tree Model
2. Probabilistic Safety Assessment
3. Obtain Joint Failure Importance
4. Perform Reliability Allocation
5. Embed the Reliability Allocation into Reliability-Centered Maintenance

PROPOSED TEST AND MAINTENANCE FRAMEWORK

The PSA Process is shown in Fig. 3.

- Event-Tree Development
- Accident Sequence Quantification
- Analysis of Physical Processes
- Analysis of Radionuclide Release and Transport
- Analysis of Environmental Transport and Consequences
- Level 1 Scope Products
- Level 2 Scope Products
- Level 3 Scope Products

Figure 3: Probabilistic Safety Assessment: an Overall View

A Joint Failure Importance (JFI) measures how much change in the importance measure of a component will be when another component in the same system has changed its state.

\[ JFI_{ij}(q) = \frac{\partial^2 Q(q)}{\partial q_i \partial q_j} \]

where, 
\[ Q(q) \] is the system unavailability; and
\[ q_i \] and \[ q_j \] are the unavailability of component \( i \) and \( j \), respectively.

A fault tree example for the Shutdown System Number One in (SDS1) in Canadian Deuterium-Uranium (CANDU) NPPs is shown below:

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Figure 2: Fault Tree for SDS1 in CANDU NPPs

RELIABILITY-CENTERED MAINTENANCE

- Reliability Centered Maintenance consists the following twelve steps:
  1. Study Preparation
  2. System Selection and Definition
  3. Functional Failure Analysis
  4. Critical Item Selection
  5. Data Collection and Analysis
  6. Failure Mode Evaluation and Criticality Analysis (FMECA)
  7. Selection of Maintenance Actions
  8. Determination of Maintenance Intervals
  9. Preventive Maintenance Comparison Analysis
  10. Treatment of Non-Critical Items
  11. Implementation
  12. In-Service Data Collection and Updating.

The risk information from a PSA study is utilized for maintenance decision-making.

- Joint Failure Importance (JFI) is proposed to facilitate the reliability allocation.
- Reliability allocation is incorporated into the framework of Reliability-Centered Maintenance.
- The proposed risk-informed test and maintenance framework can reduce operational costs for I&C systems, while maintaining the same level of plant reliability and safety.

CONCLUSIONS

- Nuclear power plants need to operate not only safely, but also economically.
- Instrumentation and Control (I&C) systems in Nuclear Power Plants (NPPs) play an important role in reducing operational related costs.
- How to perform the test and maintenance for I&C systems with lowest cost while maintaining reliability and safety?
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Figure 1: A Risk-Informed Test and Maintenance Framework for I&C Systems

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