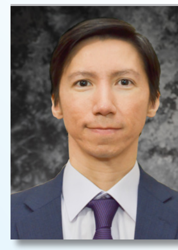
Risk and Cost Analysis of Utilizing FLEX Equipment for Efficient Maintenance in Nuclear Power Plants



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This article describes an innovative framework of reducing operation and maintenance (O&M) costs at nuclear power plants by utilizing the onsite FLEX equipment. FLEX strategies were postulated by the U.S. NRC in the wake of the Fukushima Daiichi accident to address beyond-design-basis accidents and improve plant flexibility. Onsite FLEX includes equipment such as portable pumps, generators, batteries, compressors, and other supporting equipment or tools stored in a dedicated and secure building designed to withstand external hazards. In the past few years, many nuclear power plants have invested in procuring and maintaining onsite FLEX assets that are unused for most of the time. Recently there have been active efforts to develop strategies through which nuclear power plants can take credit for this FLEX equipment. The LWRS program is conducting research on identifying areas where FLEX equipment can be utilized during normal plant operation and develop a framework that would aide in the reduction of O&M costs without impacting plant safety. The research explores two areas that have the potential to utilize portable FLEX equipment: (1) technical specification-required shutdown due to component failure; and (2) scheduled maintenance during a refueling outage.

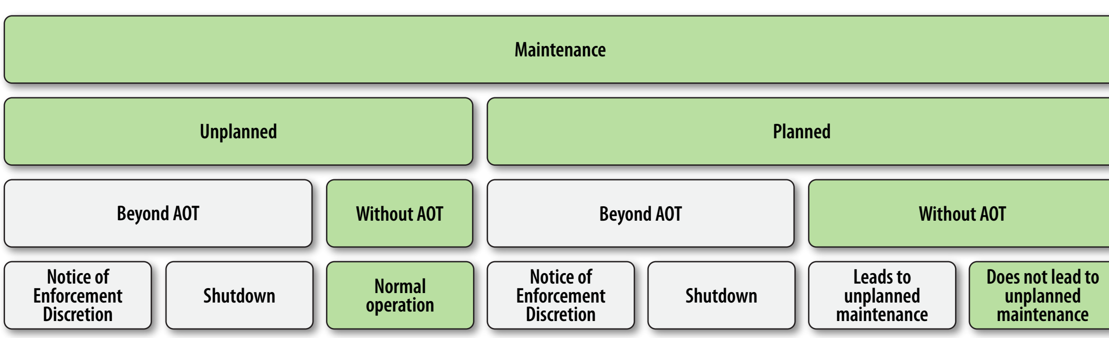
A risk- and cost-analysis framework has been developed for technical specification-required shutdowns due to component failure. The NRC's licensee event report (LER) database shows that commercial nuclear power plants in the U.S. reported 86 technical specification required shutdowns since 2010. When a component failure or unavailability leads to a technical specification-required shutdown, the nuclear power plants have additional costs, both direct costs in terms of revenue loss arising from the loss of generation and indirect costs in the form of reporting and inspection performed by the NRC.

The ongoing research has developed the following five-step framework to utilize FLEX equipment when a component failure could potentially lead to a technical specification-required shutdown.

Step 1. Identify the components, the failure or unavailability of which would result in a 10 CFR 50.73(a)(2)(i)A-reportability requirement, postulated by the NRC for technical specification-required shutdown to be reported in NRC's LER database.

Step 2. Identify the FLEX equipment that may be utilized as a standby to the failed component.

Figure 2. Possible maintenance scenarios.



Step 3. Develop a model that incorporates the FLEX equipment in an existing plant Probabilistic Risk Assessment (PRA) model.

Step 4. Perform calculations using the FLEX equipment model and the plant-specific PRA to study change in core damage frequency and change in risk-informed allowable outage time.

Step 5. Perform a cost-benefit analysis to determine the economic feasibility of implementing the FLEX equipment in the suggested manner.

Figure 2 shows the possible scenarios that may occur during maintenance activities [1]. Maintenance may be planned or unplanned due to unpredicted faults discovered during routine testing or online monitoring. Both scenarios may require a completion time exceeding allowable outage time (AOT). When this happens, licensees either file a notice of enforcement discretion to the NRC or shut down the plant. Both options incur costs or a loss of revenue. These O&M costs may be averted by extending AOT using FLEX equipment. Furthermore, the extended AOT may permit maintenance activities to be conducted thoroughly, with better resulting quality. Figure 3 illustrates the AOT extension framework when a component failure increases the plant's Core Damage Frequency (CDF) from CDF1 to CDF2. Taking credit of FLEX equipment reduces the CDF to CDF3 while also enabling extension in AOT.

An example of a cost analysis employs the premise that using FLEX equipment can maintain or reduce CDF such that an NRC inspection is avoided. This is based on recent NRC estimates that the hourly cost of a staff professional to conduct an inspection or conduct testing at a nuclear power plant facility is $275/hour [2]. Given the inspection event possibilities [3], inspection costs could range from a low of $36,000 per event to $667,000. In July 2018, the Energy Information Administration reports the average retail sales price of electricity across all user types was ¢11.02/kWh [4]. This equates to $110.2/MWh. Suppose a nuclear power plant is shut down for a 24-hour period. The amount of the opportunity cost and the foregone revenue depends on the size of the facility. At this rate, in terms of $/MWh, a plant with a capacity of 800 MWe loses $2.1 million per day. For a plant that is 1,000 MWe, it rises to $2.6 million per day and reaches $3.7 million per day for a plant that is 1,400 MWe. Adding the opportunity cost to the direct cost results in significant cost savings that might be avoided through the implementation of FLEX equipment to avoid technical specification-required shutdown.

This ongoing research is currently in Step 3 of incorporating a portable FLEX pump in the plant PRA model in a candidate system PRA model of a participating U.S. utility. The modeling efforts of Step 3 and the calculations of change in CDF (Step 4) are expected to be completed in May 2019. The comprehensive cost-benefit analysis and the economic feasibility study (Step 5) is expected to be completed in July 2019. Implementing the framework developed in this work would enable commercial nuclear power plants to reduce the economic impact of component failures, avoid unscheduled plant shut downs, perform efficient maintenance, and maximize generation.

References

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2. NRC, "Average cost per professional staff-hour," N.R. Commission, Editor, 2018.
3. Ball, J., Handbook for quick cost estimates: A method for developing quick approximate estimates of costs for generic actions for nuclear power plants. Argonne: Argonne National Laboratory, 1986.
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Figure 3. AOT extension in compliance with allowed risk acceptance guideline.