Development and Validation of a Lifecycle-based Prognostics Architecture with Test Bed Validation

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ABSTRACT

As nuclear power plants are licensed beyond their initial design lifetime, it is important to understand their degradation; monitor structures, systems, and components for degradation; detect and quantify their degradation, and perform prognosis of their future state. Prognostics is the methodology of predicting the remaining useful life (RUL) defined as the amount of time, in terms of operating hours, cycles, or other measures the component will continue to meet its design specification. This research project will develop lifecycle-based prognostic algorithms and validate them in several representative tests beds. For prognostics to be useful, the methods should provide probability of failure distribution estimates from beginning of component life (BOL) to end of component life (EOL). We term this "**Lifecycle Prognostics".** When a component is put into service, the only information available may be past failure times. At this time the predicted failure distribution can be estimated with reliability analysis methods such as Weibull Analysis, we tem this Type I Prognostics. As the component operates, it begins to consume its available life. This life consumption may be a function of system stresses and the failure distribution should be updated, we term this Type II Prognostics. When degradation becomes apparent through measured parameters, this information can be used to again improve the failure distribution estimate. We term this Type III Prognostics. Current research focuses on developing methods for the three types of prognostics. This research project will develop a framework using Bayesian methods to transition between prognostic model types and update failure distribution estimates as new information becomes available. The proposed research has four closely related objectives which will result in validated lifecycle prognostic methods: 1. Develop methods to formulate and integrate models from the three prognostics categories into a single prognostic system to estimate RUL over the life of the component: Lifecycle Prognostics. 2. Develop techniques to estimate uncertainty and produce a failure distribution output from each of the prognostic model types. 3. Integrate the models and methods developed in objective 1 into a toolset to provide a formal method for prognostics development that can be used for prognostics in general, whether it is for active or for passive components or systems (electronics, materials, equipment, etc.) 4. Validate the methods on a range of test beds. Several test beds that were constructed to alidate the process and empirical monitoring (PEM) algorithms will be made available for use in validating the prognostic algorithms. The techniques developed in this project will be standardized as tools which can be used to improve plant safety and reliability, optimize maintenance scheduling, and provide information to more accurately estimate plant risk. These tasks are vital for improved Light Water Reactor Sustainability.