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Modeling Predictive Maintenance for NuScales Condensate and Feedwater System Using EMRALD

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Changing the World's Energy Future

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Introduction

Small Modular Reactors are expected to have lower capital costs; however , smaller units may not correspond to lower operation and maintenance costs. There are two types of maintenance:

- Preventive maintenance includes periodic, planned and predictive maintenance; all for which are used to increase component reliability.
- Corrective maintenance are forced by component failure, which could also result in power derate or reactor trip (shutdown).

Reliability of a component depends on the failure rates of components.

- Failure rates $\lambda(t)$ are time-dependent and is generally characterized by the bathtub curve in three stages: the startup (early-life, 1), the useful-life (2), and the degradation stage (3), as shown in Figure 1.

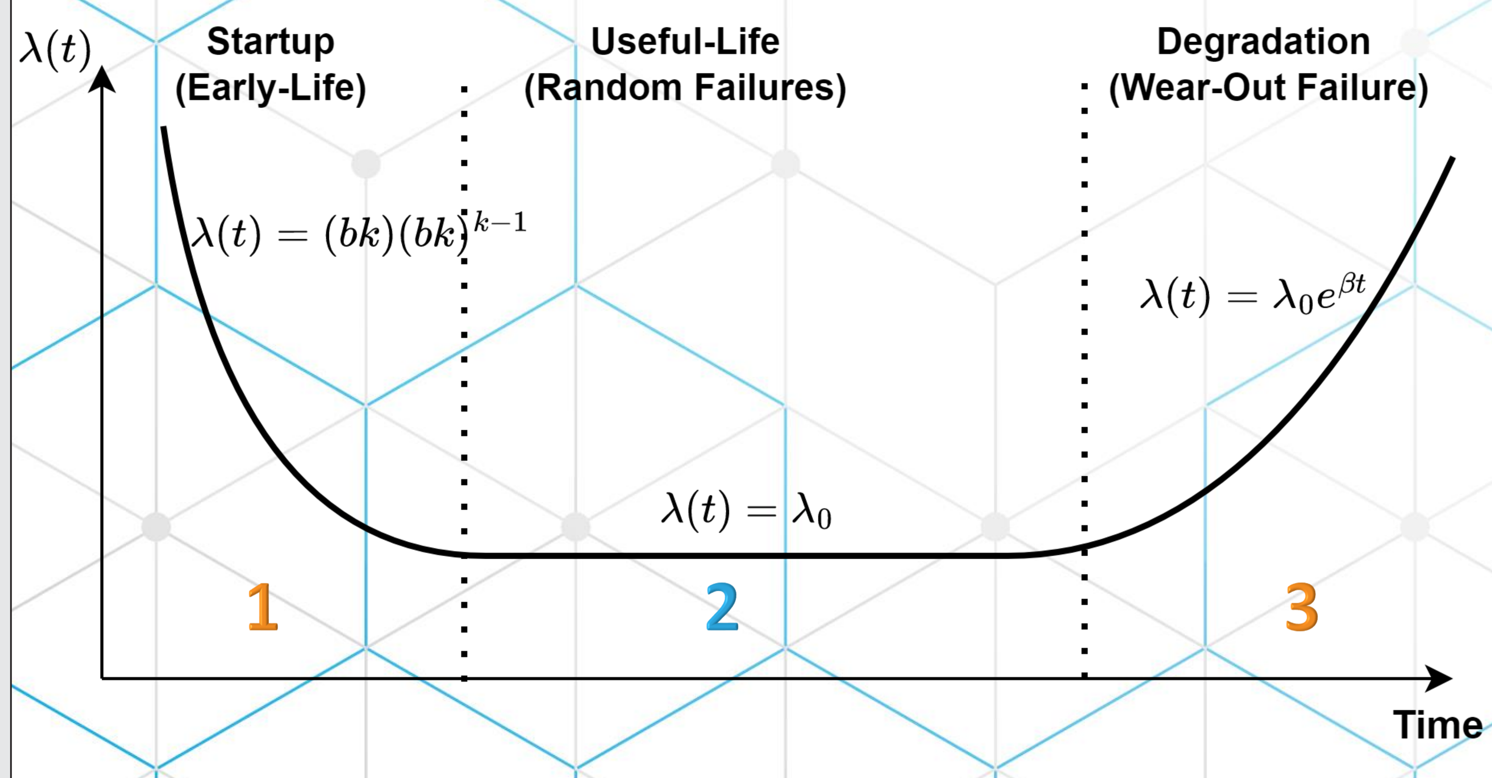

Figure 1. General bathtub curve describing component failure rate at different stages of its life-time

Motivation

The main objectives of this project are to increase the **availability** of the NuScale units and profits by:

- Developing a modeling method to capture degraded components and repair process for the condensate and feedwater system (CFWS) , shown in Figure 2.
- Estimate reduction in plant trips or forced power reduction through predictive maintenance procedures.

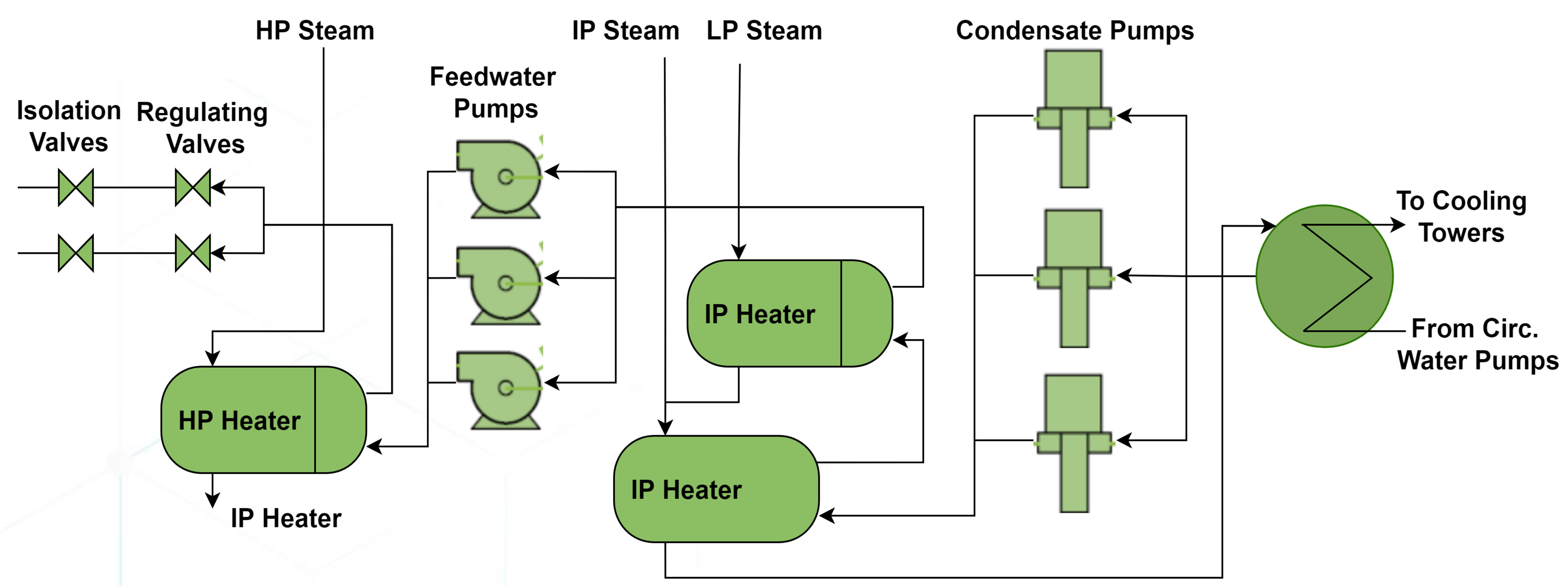

Figure 2. NuScale's Condensate and Feedwater System containing condenser, six pumps, three heaters, and eight valves (Check, regulating, and isolation).

Methodology

- Utilizing EMRALD to develop three-stage failure rate contrary to a constant failure rate found in industry. Figure 3 shows a four-state simplified diagram using the three-stage failure rate to component trip for each component.
- Use historical failure rates to estimate failure rate equations for different reliability stages of the components and associated probability density functions associated with each stage.
- Determine components in the system for monitoring by analyzing fault tree of reactor trip.

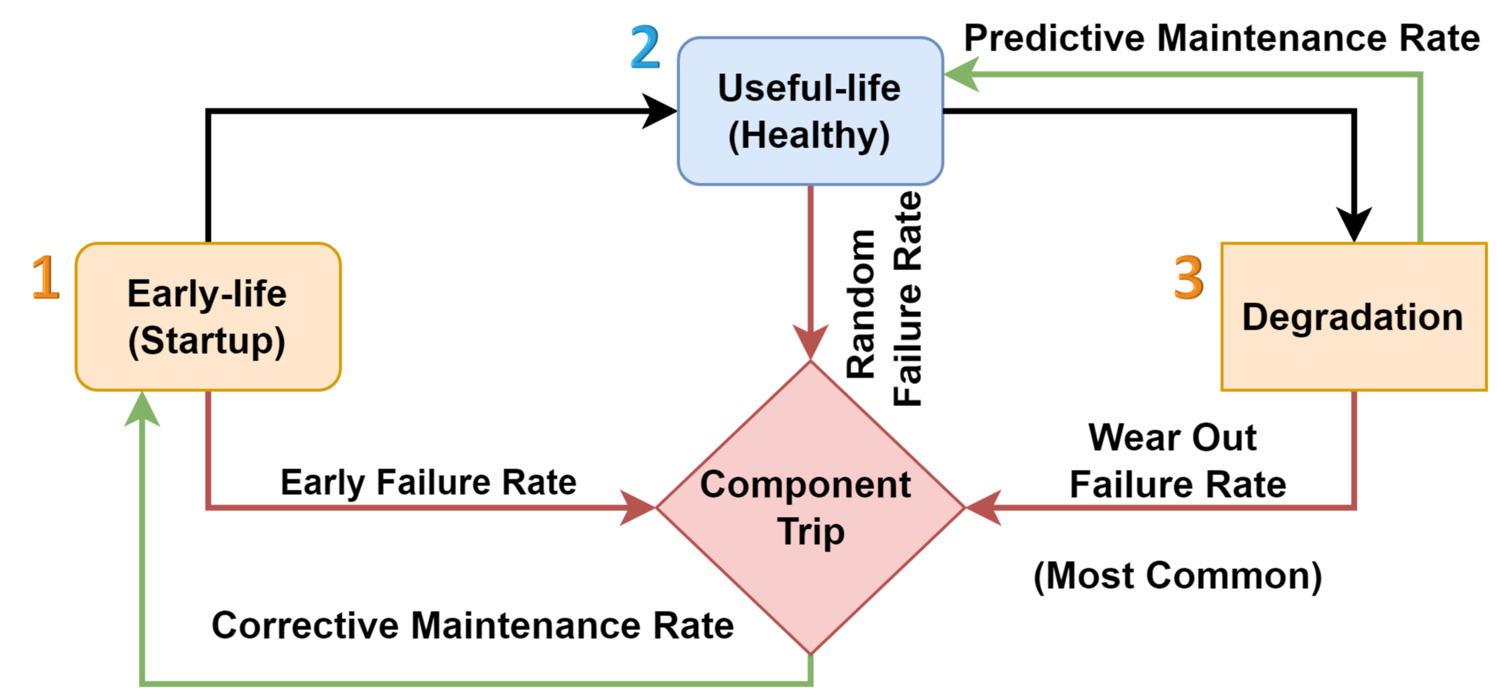

Figure 3. Transition diagram of the 4-state model of a component following the bathtub curve. This model represents a simplified version of EMRALD component diagrams.

Preliminary Results

- Using a conservative estimate, condenser and feedwater were the main reason for reactor power derate and trip at a rate of 0.08 with mean time of 466 days without any maintenance. Nearly 80% of the failures occurred during degradation stage.
- Valve failures was the least occurring with almost no recorded.

Conclusion & Future Goals

Condenser and feedwater heaters were the most failed components due to leakage and inadequate heat transfer. Due to time limitation, similar assumptions were used for all the components. Future work includes:

- Obtain data to explore different approaches for estimating failure rate during degradation for different components.
- Evaluate reduction in outage time in planned outages relative to unplanned outages applying equipment monitoring.

Impacts and Benefits

- Develop maintenance by design for NuScale plants.
- Decrease outage time of the plant by maximizing remaining useful life of essential systems.

[1] : Instrumentation, Controls, and Data Science – C220
[2] : Reliability, Risk, and Resilience Sciences – C230

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