Delivering the Nuclear Promise
Top Innovative Practice

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Implementation of System Media-Actuated MSIVs to Improve Plant Reliability and Reduce Maintenance Costs for Vogtle Units 1 and 2

2023 Top Innovative Practice Winner[1]

Summary

Main steam isolation valves (MSIVs) for operating commercial reactors are large, fast-acting valves responsible for isolating steam systems in the event of a design basis accident (DBA). Due to the fast closure times required for MSIVs to perform their safety function and the large size of the valve, the valve actuators are mechanically complex. At Plant Vogtle (Units 1 and 2), malfunctions associated with MSIVs have resulted in thirteen unplanned outages and/or reactor trips since both units began commercial operation in the late 1980s. Seven of these unplanned outages have occurred in the last 20 years. In addition to unplanned outages, maintenance associated with fast-acting MSIVs is expensive and often requires specialty vendors to perform the required routine maintenance evolutions.

The majority of the operating PWR fleet has one MSIV per steam line. However, Plant Vogtle in the Southern Nuclear fleet has two MSIVs per steam line. This leads to double the single point vulnerabilities (SPVs), double the maintenance costs, and double the probability of an unplanned outage resulting from an MSIV malfunction for Vogtle as compared to the current operating fleet.

Approximately 40 units in the U.S. fleet utilize fast-acting electrohydraulic isolation valves as a part of the main steam or feedwater systems. There is evidence that these valve types have had negative impacts on maintenance and plant capacity factors resulting from numerous unplanned outages and complex and expensive maintenance evolutions.

To improve these maintenance costs and overall plant reliability, Plant Vogtle has implemented an innovative valve actuator technology referred to as system media actuators (SMAs).

Innovation

Recently, new valve technologies have emerged that utilize SMAs. These SMA valves rely on the working fluid of the system (steam pressure, in this case) to open and close the valves. By relying on system media (working fluid) static and dynamic pressures, the overall complexity of the MSIV can be significantly reduced. This includes reductions in moving parts (pneumatic assist, nitrogen accumulators, etc.) that lead to SPVs, entry

[1] Winning entries of from NEI's Top Innovative Practices (TIP) awards are republished as DNP Efficiency Opportunities to ensure the broadest possible dissemination of these operating plant innovations.

into Technical Specification Limiting Conditions for Operation (LCO), and unplanned outages and high maintenance costs.

Vogtle Units 1 and 2 recently implemented (Spring 2023 and Spring 2022, respectively) a conversion of their MSIVs to the SMA valve type. Implementation of the SMA MSIVs at Plant Vogtle Units 1 and 2 is expected to result in a reduction of around 560 (considering sub-components) SPVs. This represents a marked improvement in plant equipment and operational reliability.

In addition to implementation of the SMA MSIVs, Plant Vogtle submitted a license amendment request (LAR) to eliminate one MSIV per steam line. A review of industry submittals indicated that this had not been done before in the U.S. fleet, making this a first of a kind (FOAK) LAR. The NRC approved the license amendment in September 2022. A reduction in MSIVs at Plant Vogtle from eight to four doubled the cost savings and improvements in equipment and plant operational reliability.

To further reduce costs associated with this design change the risk classification of the main steam system was evaluated in accordance with 10 CFR 50.69. The results of this risk categorization allowed the components of the MSIV to be categorized as RISC-3 which facilitated a maximization of cost-savings associated with commercial dedication procurement of the new MSIV SMAs and corresponding system components.

Safety

The safety analysis performed to support this design change showed no adverse consequences to safety margins. It is important to note that changing the valve actuator did not require prior NRC approval. The SMAs alone did not impact the plant analyses of record. Only the change associated with eliminating one MSIV per steam line required NRC approval (due to the need to change the plant Technical Specifications). The safety analyses submitted for NRC review and approval were required to address NSAL-06-15, "Single Failure Scenario for Steam Generator Tube Rupture Analysis"[2].

Cost Savings

A review of work packages for Plant Vogtle MSIVs determined that switching to SMAs would result in approximately $266K in cost savings per unit per cycle. This value assumes one valve rebuild per refueling cycle and assumes plants with only one valve per loop. For plants seeking subsequent license renewal (SLR) this would reduce maintenance costs by approximately $3.5M per unit over a span of 20 years. For the 40 operating PWRs and BWRs that utilize electrohydraulic-actuated MSIVs or MFIVs[3] in the US fleet, this equates to approximately $140M in maintenance cost savings industry-wide over a span of 20 years.

The cost of unplanned outages varies from region to region and depends on other electrical production costs. For Plant Vogtle SNC estimated that if electrohydraulic-actuated valves result in two unplanned outages of an average duration of 11 days (needed for heat up and cooldown to allow for maintenance on the valves), that a change to SMAs would yield a reduction of approximately $22M in replacement power costs over a 20-year period. This yields industry-wide cost savings of approximately $1.3B over the same 20-year period.

In total a plant could expect cost savings from reduced maintenance costs and reductions in replacement power costs on the order of $25.5M over a 20-year period and the U.S. industry could yield a total cost savings on the order of $1.5B.

It is important to note that the cost savings considered here do not assume dual isolation valves per loop (i.e., the Vogtle configuration). It was determined that Plant Vogtle is the only operating unit that utilizes this

[2] Westinghouse Nuclear Safety Advisory Letter (NSAL)-06-15

[3] Main feedwater isolation valves.

configuration. As a result, the cost savings for Plant Vogtle would be approximately double that provided above for a single unit.

Lastly, if implementation of SMAs would alleviate one unplanned outage at an affected unit, the cost-savings of that plus the maintenance cost reductions less the cost of implementation would yield an approximate total cost savings of $2M over the life of the plant (based on replacement of four valves at a 4-loop PWR).

Productivity/Efficiency

The major productivity/efficiency improvement is associated with the SMA MSIV design. The design of the valve as illustrated in Figures 1-4 is significantly simpler than what it replaced. This leads to significant reductions in required maintenance work orders and in overall valve maintenance durations as the number of moving and mechanical parts of the valve is substantially reduced. This simplicity in design and resulting reduction in maintenance activities yield the cost savings and improved reliability observed at the few plants that have implemented these SMAs (Callaway/Wolf Creek).

Transferability

The SMA technology is transferable to almost every PWR and BWR in operation (that utilize electrohydraulic actuators). In addition to SNC, only Callaway and Wolf Creek have implemented this change.

The following distinctions associated with "transferability" are important to consider:

1. In the "Cost Savings" Section of this form, the cost savings numbers are associated with the rebuild costs of plants with electrohydraulic actuated valves. Typically, these valve types are used in feedwater and main steam isolation valves (BWRs and PWRs).

    a. The savings in maintenance cost cited is associated with elimination of one rebuild of an electrohydraulic-actuated valve per refueling cycle. Plants with these valve types typically rebuild one valve per cycle.

    b. The power replacement costs assume two plant trips in a 20-year period associated with the less reliable electrohydraulic actuators. The limited INPO event reports reviewed as a part of preparation of this form indicate an average unplanned outage duration of approximately 11 days.

2. To provide additional assurance of the "transferability" of this technology, a list of plants using fast-close electrohydraulic-actuated valves was compiled along with associated INPO event reports where malfunctions of these valves led to a plant trip. The search identified numerous reactor trips so it is clear that this innovation may help other units reduce the likelihood of unplanned scrams.

As part of its focus on Equipment Reliability (ER), SNC has committed to a practice of "eliminate vs mitigate" for single point vulnerabilities. Successful implementation of the new actuators on both units has resulted in elimination of over 500 SPV subcomponents. The success of the project has been shared with the industry at multiple users' groups including the PWROG, ISTOG[4], Curtis-Wright's RAPID conference, and the ANS Utility Working Group Conference. Lessons learned from the utilization of 10 CFR 50.69[5], Alternative Treatments, to reduce lead time and project costs were presented to the PWROG Risk Management Committee and the BWROG 50.69 subcommittee in 2022.

Team Members

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- Scott Pellet, Lead Engineer, SNC
- Mackie Sinkler, Maintenance Supervisor, SNC

[4] Inservice Testing Owners Group. Information available at https://istog.net.

[5] Title 10, Code of Federal Regulations, Part 50.69, "Risk-informed categorization and treatment of structures, systems and components for nuclear power reactors".

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Additional Information

Figure 1 – Detailed Laser Scan of MSIV Valve Body

Figure 2 – MSIV Actuator Comparison – Legacy in Foreground vs. New SMA Actuator in Background

Figure 3 – MSIV Valve and Actuator Schematic

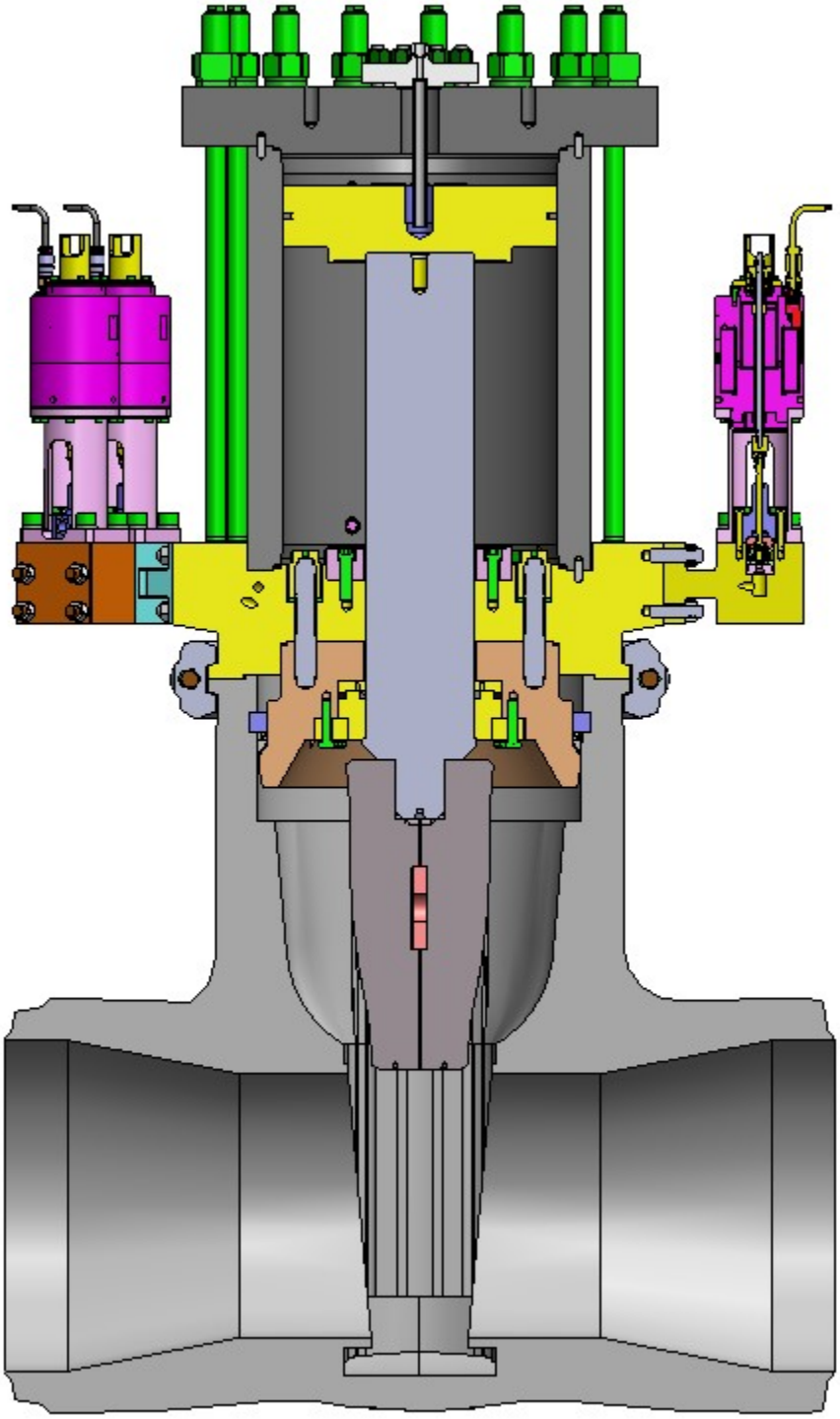

Figure 4 – New SMA MSIV Actuator Hot Functional Testing During Fabrication