Delivering the Nuclear Promise
Top Innovative Practice

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State-of-the-Art Digital Uninterruptable Power Supplies for PWR & BWR Units
2023 Top Innovative Practice Winner[1]

Summary

Streamlining the regulatory process to enable the industry adoption of digital technologies has taken decades. PSEG tackled this challenge with the replacement of obsolete uninterruptable power supplies (UPS) with state-of-the-art digital designs in safety-related applications across all three of its nuclear units. The new AMETEK-Solidstate Controls (AMETEK-SCI[2])-designed digital processing UPS inverters are part of a multi-unit project to address legacy Cyberex analog units. This is the first application in the nuclear fleet for this design in safety-related systems in both PWR and BWR units and first implementation using NRC's 10 CFR 50.59 process.[3]

Innovation

Digital systems offer many advantages over legacy analog systems. For example, the digital UPS design provides data logs that show machine operational history and traceability if an event takes place and are useful for trending, advanced operational corrective maintenance purposes and diagnostics. Nevertheless, the industry remained uncertain about pursuing digital upgrades via the 10 CFR 50.59 process. Industry experience raised questions about the applicable regulatory guidance for evaluating digital upgrades. In one case, a utility was given a non-cited violation for using the 10 CFR 50.59 process to change safety-related circuit cards containing a central processing unit. The Nuclear Regulatory Commission (NRC) asserted that the licensee should have submitted a License Amendment Request (LAR) for that change based on Interim Staff Guidance (ISG)-06.[4] The NRC's biggest concern was properly evaluating common cause failures such that a latent software design error could not impact all trains of equipment.

The desire to use a 10 CFR 50.59 evaluation in lieu of submitting a LAR to the NRC prompted the PSEG project team to engage with industry stakeholders and partners, such as the Nuclear Energy Institute (NEI) Digital Instrumentation and Controls Working Group, NEI, and the NRC. These parties worked together for nearly a decade to reach the end result.

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[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.
[2] Ametek Solidstate Controls, Columbus, Ohio, information available at https://www.solidstatecontrolsinc.com/.
[3] Code of Federal Regulations, Title 10, Part 50.59, "Changes, Tests and Experiments", available at https://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0059.html
[4] "Digital Instrumentation and Controls, Licensing Process", Interim Staff Guidance (ISG)-06, December 2018, USNRC, ADAMS Accession Number ML18269A259.

The working group leveraged NEI as the conduit to the regulator and on many occasions NEI engaged the NRC through workshops to help resolve questions about the NRC's positions. After nearly five years of such effort, PSEG was able to use the guidance in the NRC RIS 2002-22, Supplement 1[5], to perform a qualitative assessment and a 10 CFR 50.59 evaluation. This allowed PSEG to install the new safety-related inverters without prior NRC approval, significantly reducing regulatory uncertainty.

The Hope Creek and Salem stations have now installed the digital UPS systems in non-safety-related machines. The first safety-related units were installed at Hope Creek during the Fall 2022 refueling outage. This started the sequence for the replacement of eight UPS machines in safety-related applications for the station. Salem is currently targeted to install their first safety-related machine in the Spring 2023 Unit 2 refueling outage, which will be the first safety-related digital UPS machine installed at the station.[6]

The project has optimized savings by applying common process design developments, manufacturing, testing, maintenance, consolidations of machines and lessons learned across two projects. Also, stakeholders and project team members are common across the three PSEG nuclear units, thus resulting in reduced operational costs. The collective savings of the efforts and collaboration are significant.

The project was initiated to enhance equipment reliability associated with both the safety- and non-safety-related inverters. Experts on the NEI Digital I&C Working Group were contacted to understand the changing regulatory framework and requirements for a safety-related digital system. Industry subject matter experts at EPRI were consulted to build safety-related digital programs at PSEG and AMETEK to satisfy the stringent software safety requirements. PSEG interfaced with the industry and the NRC as design work proceeded.

The actual safety-related UPS machines were pre-staged and wired ahead of installation in a lab environment. This enabled personnel to verify operating procedures, do Modification Acceptance Testing (MAT) dry runs and provide training familiarization opportunities for the crews that would perform the MAT and in-service testing. This allowed the teams to become proficient with the equipment in a safe environment ahead of the actual installations and to verify machine operation prior to installation.

Safety

Nuclear Safety – Obsolete & Unavailable Materials:

Current performance and operation of the aged Cyberex analog equipment and unavailability of replacement parts posed risks to Technical Specification compliance (i.e., out-of-service times) and plant operations. These were the primary drivers behind pursuing the new design and its installation across the site.

Project strategies and improvements helped ensure the potential impacts to nuclear safety were thoroughly addressed. This was evident in the depth of digital reviews, cyber security checks and validations, and audits of these reviews, checks and validations. Independent quality checks, factory operational testing, site acceptance testing, startup testing for operational validation and visual inspections were all enhancements to normal process requirements. Pretesting equipment in a lab setting with actual power logistics was set up at PSEG's Learning Development Center and enabled a full range of testing. All three power sources were replicated ahead of installation. In addition, the testing enabled full operational testing in a lab environment for maintenance and operations personnel ahead of the installation testing for familiarization.

[5] Regulatory Issue Summary (RIS)-02-22, Supplement 1, "Clarification on Endorsement of Nuclear Energy Institute Guidance in Designing Digital Upgrades in Instrumentation and Control Systems", May 31, 2018, USNRC, ADAMS Accession Number ML18143B633.
[6] Statements about units installed or planned to be installed were current as of the date of the company's TIP submittal.

Personnel Safety – Electrical & Physical:

The improved design implemented circuit card technology that replaced bulk size components. This advancement in electrical preventive maintenance is safer for personnel. The reduction in capacitor bank handling removes the shock hazard and the need to lift the heavy weight of the assembled banks.

Additionally, digital systems offer the flexibility to adjust system output voltage with a push button, which is helpful should there be a need to compensate for line loss out to the load. The previously installed analog designs required output voltage adjustments to be done manually by changing taps on a transformer or reconfiguring a control board. This required a technician to internally adjust the equipment with potential exposure to high voltages. Thus, the improved design and safer maintenance strategies enable increased personnel safety.

Equipment Safety - Tooling – Faraday Cage:

The project also used a Faraday cage[7] to contain the electromagnetic field (EMF) impacts while operating the Nelson stud mounting tooling[8]. The cage is portable and could be installed in tight areas, which enabled the stud gun to operate in normally EMF sensitive environments. This was a critical step in developing the mounting strategies of the machines. (See related discussion of EMF/RFI guidelines in "Equipment Design Savings" section below.)

Cost Savings[9]

Integration of a site-wide approach across three nuclear units enabled great cost savings in processing and programs. A unified approach on material purchases, design development, engineering support, installation tooling, techniques, schedules and common model training for maintenance and operation all contributed to cost savings.

PSEG has installed four non-safety-related UPS machines at Salem and will install eight safety-related machines over the next four years for a total of 12 UPS machines. The first safety-related UPS machine will be installed during the spring 2023 outage at Salem. In their design load review, the team identified additional savings by consolidating three UPS units into a single unit, thus saving $1 million in machine purchases.

The Hope Creek station has completed phases I and II of the project with a total of 12 non-safety-related machines installed and operational. Lessons learned were rolled into the project as it moved forward, and cost savings opportunities were shared. The station has installed two of the eight safety-related machines.

In aggregate the projects have a combined count of 32 machines. The strategy and application of sharing knowledge, lessons learned, common resources, template design changes, installation planning and scheduling and project plans has resulted in savings of hundreds of thousands of dollars.

Preventive maintenance costs associated with the new machines are expected to be lower, resulting in a combined savings of $6.4 million over an estimated 20-year operational life cycle.

Measurable savings to date are $8.6 million for the machine elimination, consolidations, and shifts in maintenance costs. Cost savings for the processes, programs and personnel savings have not been quantified but are substantial in terms of human performance, proficiency and knowledge gains.

[7] Generic information on Faraday cages is available at https://en.wikipedia.org/wiki/Faraday_cage. Faraday cages of various designs and configurations are available commercially.
[8] See, for example, https://www.stanleyengineeredfastening.com/en/brands/nelson.
[9] All numbers on units installed or planned to be installed were as of the date of the company's TIP submittal.

Equipment Design Savings – Partnership with AMETEK:

To meet current NRC guidelines on EMI/RFI[10], the new systems must have additional filtering and cable termination areas that add to the space required for installing the systems. The AMETEK digital system reduces the dimensions of the UPS/inverter so that the additional filtering and termination enclosures can still fit into the same space in which the existing analog systems are located. New analog systems with EMI/RFI filtering would not fit. Had the company wanted to replace the old analog system with the same design, it would have been necessary to relocate the UPS equipment or modify the current location to accommodate the EMI/RFI filters. This would have had a significant cost impact with no safety benefit. The company's partnership with AMETEK took this into account with the design criteria, impacts and potential expansions for costs that PSEG was able to address with the digital design. The ability to meet the original design constraints and locations for the new machines resulted in significant savings and helped PSEG meet the project's long-term goals.

Productivity/Efficiency

The project optimized savings by applying common process design developments, manufacturing, testing, maintenance, consolidation of machines and lessons learned across two projects. In addition, as mentioned previously, providing a lab environment for pre-installation testing and training helped to make installation smoother and more efficient.

The approach taken in this project enabled key organizations, including station maintenance, operations, engineering, and training, to perform unified training. While each unit may be designed with specifications for the installation applications in BWR and PWR plants, the common design of AMETEK's machines allowed for templated training modules for each department. This reduced training development and execution resources. Additionally, the AMETEK design prototype machines were retained and turned over to the training department for real-time training on actual modeled equipment. This saved training equipment expenses and led to more effective training. These units also will be used for troubleshooting, root cause evaluations, component warmups, and just-in-time readiness training for critical evolutions.

Transferability

The design of the nuclear digital process power (NDPP) unit can be shared among the nuclear industry as the program and design meet all the requirements for safety-related equipment. In addition, the program met all current cyber security, critical digital asset and safety-related requirements and could be implemented via the 10 CFR 50.59 process. AMETEK also developed and maintained a NUPIC-audited[11] and -supported program.

The lessons developed can be shared across the industry. As the leader in the design and installation of this system, PSEG can assist others going forward with similar projects. PSEG has also benefitted from the lessons learned from other digital installation projects.

Team Members

- Jonathan Paes and Shawn Madden, Project Managers
- Michael Richers, Design Manager
- Ben Gordon, Manager of Engineering AMETEK SCI
- Frank Calabrese, S&L Engineering Manager

[10] See, for example, NRC Regulatory Guide 1.180, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems", available at https://www.nrc.gov/docs/ML0036/ML003677639.pdf

[11] NUPIC is the Nuclear Procurement Issues Corporation, which focuses on significant industry challenges or issues which may influence procurement, planning and management activities.

Additional Information

Figure 1 – First Safety-Related NDPP Digital UPS at Hope Creek Station

Figure 2 – Faraday Cage for EMI/RFI Protection When Performing Base Mount Welding

Figure 3 – Inverter Test Lab Used for Pre-Testing and Acceptance Testing