Stationary Battery Installation, Maintenance and Replacement in Operating Nuclear Plants

Surendra (Sal) K. Salgia
Senior Staff Engineer
Exelon Generation
Warrenville, IL 60555

Abstract
There are special requirements for the selection, installation, maintenance, and replacement of stationary batteries in operating nuclear plants due to regulatory commitments. Mistakes are sometimes made as a result of a lack of knowledge, a lack of familiarity with regulatory commitments, and improper training. Human performance plays an important role in understanding the risk to plant operation, safety, and consequences. This paper will discuss the regulatory and other requirements that are unique to the safe operation of nuclear plants.

Introduction
Currently there are around 99 operating nuclear units and 4 new under construction in the United States. Each unit has anywhere from 2 to 8 strings of 125/250 Volt battery banks and 2 to 4 strings of 24/48 Volt battery banks. Batteries play a very important role during normal plant operation and especially during a loss of onsite and offsite power for continued operation of circuit breakers, switchgears, valves, emergency pumps, computers and instrumentation as was evident from the Fukushima event. The majority of stationary batteries used in nuclear units are vented lead-acid (VLA) type. There are two classifications of stationary batteries:

- Critical batteries which supply DC power to critical equipment associated with the safe operation and safe shut down of the nuclear plant during normal plant operation, accident conditions, and station black out (SBO) events. They also provide DC power to instruments that monitor critical plant parameters and radiation during both normal plant operation and post-accident conditions.
- Balance of Plant (BOP) batteries supply power to the rest of the auxiliaries in the plant

Critical batteries have higher classifications of preventive maintenance than BOP batteries. Critical batteries are also required to have qualification documents for environmental and seismic integrity.

Special Requirements

Nuclear Regulatory Commission (NRC)
A nuclear plant's operating license is based on commitments made to the NRC in an Updated Final Safety Analysis Report (UFSAR) and Technical Specifications (TS) listing the IEEE standards with the year of publications & Regulatory Guides for:

- Selection of a battery to support the duty cycle of 2 to 8 hours or longer during a loss of onsite and offsite power for safe shut down of the reactor and to monitor critical parameters
- Batteries and racks are selected and mounted to withstand environmental conditions and seismic events. The battery should be able to supply DC power during the expected temperature, humidity, and earthquake scenarios. Qualification of Class 1E (nuclear safety related) VLA storage batteries and racks are based on IEEE-535 for radiation exposure, aging, and seismic qualification.

- Maintenance and testing of batteries are performed at periodicities based on IEEE-450 which is endorsed by Regulatory Guide 1.129 and station Technical Specifications (NRC plant license requirements)
- The plant must also resolve any battery issues in a time interval known as a Limiting Condition of Operation (LCO) that is called out and committed to in the Technical Specifications. If the issue is not resolved within the specified time interval then the plant must commence the process of shutting the reactor down. This presents a significant challenge to operations.
- Replacement of batteries is critical at the end of their qualified life or sooner based on the health of the battery
- Maintenance and test results should meet the acceptance criteria otherwise it may be subjected to an LCO
- Batteries are subjected to NRC audit and inspection to assure design basis is maintained and maintenance and testing are performed as committed

North American Electric Reliability Corporation (NERC)

Some batteries are associated with the reliability of switchyard & grid operation and protection systems. These batteries are located both inside the plant and outside the plant in the switchyard.

- Batteries are maintained per NERC standard PRC-005
- Batteries are subjected to NERC audit

Nuclear Electric Insurance Limited (NEIL)

NEIL is a mutual insurance company which insures all nuclear plants in the United States as well as some facilities internationally.

- Battery maintenance, capacity testing, and replacement periodicity need to comply with the NEIL loss control manual for insurability
- Batteries are subjected to NEIL inspection and audit

Scheduling

- Testing and replacement of batteries is allowed mostly in a short window during refueling outages which occur at a periodicity of 18 to 24 months dependent on the plant. This could be a challenge based on the health of the battery.
- Installation is dependent on other ongoing activities during the outages; therefore a short window of installation, maintenance & testing is vital
- On-line replacement of the battery is only allowed as long as loads can be fed from another qualified reserve battery or power source. Some plants may not have a qualified reserve battery making on-line replacements more difficult.

Risk and Consequence Evaluation

- For anyone to be in the proximity of critical batteries it is required and essential to maintain proper isolation
- Modification to batteries is not allowed without proper documentation and screenings known as mod packages and work orders
- Water leaks in the battery room could present a problem and contingencies should be in place to deal with them
- Typical deviations are:
    - Low individual cell voltages
    - High inter-cell connection resistances
    - Degraded capacity test results
- Risk and consequences for any failed or degraded equipment, its corrective actions, and contingencies are challenged by management for the safe operation of the plant
- With proper preventive maintenance and testing of batteries the risk of entering an LCO that could possibly shutdown the reactor is minimized

Optimum Preventive Maintenance

- Optimum PM intervals are required to minimize the risk to plant operation
- Excessive performance of PMs needs evaluation for any detrimental impact to the health of the battery and for the added cost of maintenance

Replacement of Full String

- Replacement of the battery with like for like is preferable because it does not require a modification and it is cost effective
- Replacement of the battery with a different make and model requires a full evaluation for its impact on plant parameters (floor loading, seismic, cable and conduit sizing, DC system analysis, etc.)
- Replacement of the battery with a different make and model may be considered if there have been issues with the existing battery, there is need of a larger battery, or for economic considerations

On-Line Replacement of Single or Multiple Cells and Availability of Spares

- Special seismic considerations are required during the removal or installation of a cell from the battery rack
- The site needs to have a seismic crash cart available for transporting the spare cells
- Availability of single cell load testers may be a challenge
- If unable to replace a single or multiple cells X, the site needs to verify the availability of N-X calculations for battery operation with jumpering of X number of cells
- Availability of critical spare cells and their in storage maintenance is a challenge

Communication with Regulators

- Sites are required to notify regulators for any serious issues with the health of the batteries or deviations to the commitments made in the Technical Specifications and UFSAR

Operating Experiences (OEs)

- The nuclear industry relies heavily on the lessons learned from internal and external OEs
- OEs are shared with the nuclear industry by the Institute of Nuclear Power Operations (INPO)
- Failure analysis is generally performed on premature failure of cells to evaluate the cause

Documentation

It is very important to retain all documentation of procurement, preventive maintenance, testing, modifications, work orders, etc. for audits, references and records.

Typical Issues with Stationary Batteries in Nuclear Plants

Most of the battery issues and degradation mechanisms are common for all the industries however some of the issues are unique to the nuclear industry, e.g.:

High Inter – Cell Connection Resistance:

- Maximum allowable resistance of inter cell connection committed to in the regulatory documents. Some of the sites have revised their acceptance criteria to include the maximum total inter cell connection resistance of the string for battery operation**.**

Test Interruptions:

- Interruptions to the service, performance, or modified performance test for critical batteries have limitations on how long they can occur. In a nuclear plant, a very short window is allowed to do this test; therefore it is very important to avoid interruptions by proper procedures, planning and availability of spare test equipment.

10 CFR Part 21 issues:

- Part 21 is an NRC regulation for the reporting of defects and noncompliance by a vendor. Any time a Part 21 notice is received reporting defects and noncompliance for the battery it gets reviewed for the extent of the condition on other batteries of the same make and model numbers and information provided in the notice. The purpose of the review is to assess the impact of defect or noncompliance on the remaining batteries in the plant.

Replacement of batteries:

- Service life of a qualified VLA battery is typically 20 years, however, based on operating experience a battery starts showing signs of degradation around 17 Years of age (85% of service life). With the special testing requirement for capacity after 85% service life of the battery per IEEE-450, and availability of installation windows only during outages requires proper planning and scheduling for replacement.

Human Performance:

- It is very important to avoid any human performance issues in the maintenance and testing of batteries for safe and reliable operation of a nuclear plant

Conclusion

Stationary battery installation, maintenance, and replacement in operating nuclear plants to ensure safe and reliable operation require the following and more:

- Familiarity of regulatory commitments made in UFSAR, Technical Specifications, other documents, industry standards (IEEE, Regulatory Guides, NERC, NEIL, etc.), plant procedures, and OEs
- Proper sizing of battery, cables & chargers, etc.
- Monitoring of battery room temperature
- Optimum preventive maintenance & testing, and corrective actions for the battery should be completed in a timely manner
- Performance of routine operator rounds to notice anything unusual with the battery and battery room conditions, and alarms on battery charger & DC distribution panels
- Health report on the battery to catch signs of early degradation
- Availability of N-X calculations for jumpering X number of cells and availability of its procedure
- Availability of sufficient number of spare cells and proper planning for replacement of the battery string
- Following safe work practices
- Retaining documentation and records of procurement, preventive maintenance history, testing, modifications, work orders, etc. for audits, and references

References

IEEE Standard 450 - IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead - Acid Batteries for Stationary Applications

IEEE Standard 535 – IEEE Standard for Qualification of Class 1E Vented Lead - Acid Storage Batteries for Nuclear Power Generating Stations

NEIL – Loss Control Manual

NERC Standard PRC-005 - Protection System, Automatic Reclosing, and Sudden Pressure Relaying Maintenance

Operating Experiences - Institute of Nuclear Power Operations (INPO)