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REGULATORY GUIDE

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SIZING OF LARGE LEAD-ACID STORAGE BATTERIES

A. INTRODUCTION

Purpose

This regulatory guide (RG) describes methods and procedures that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for use in complying with NRC regulations on sizing of large lead-acid storage batteries for nuclear power plants. This revision of RG 1.212, "Sizing of Large Lead-Acid Storage Batteries," endorses (with certain clarifying regulatory positions described in Section C of this guide) the Institute of Electrical and Electronics Engineers (IEEE) Standard (Std.) 485-2010, "IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications" (Ref. 1).

Applicable Rules and Regulations

The methods and procedures described in IEEE Std. 485 2010 as clarified by this RG support the requirements in sections 50.55a, "Codes and Standards," and 50.63(a)(2), "Loss of All Alternating Current Power," in Title 10 of the *Code of Federal Regulations* (10 CFR) and General Design Criteria (GDC) 1, "Quality Standards and Records," and GDC 17, "Electric Power Systems," as set forth in Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities" (Ref. 2).

- 10 CFR 50.55a(a)(1) requires, in part, that structures, systems, and components be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed.

- 10 CFR 50.63(a)(2) requires, in part, that the reactor core and associated coolant, control, and protection systems, including station batteries and any other necessary support systems, must provide sufficient capacity and capability to ensure that the core is cooled and appropriate containment integrity is maintained in the event of a station blackout for the specified duration.

- Appendix A to 10 CFR Part 50, GDC 1, requires, in part, that structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed.

Written suggestions on this guide or development of new guides may be submitted through the NRC's public Web site under the Regulatory Guides document collection of the NRC Library at http://www.nrc.gov/reading-rm/doc-collections/reg-guides/contactus.html.

Electronic copies of this regulatory guide, previous versions of this guide, and other recently issued guides are available through the NRC's public Web site under the Regulatory Guides document collection of the NRC Library at http://www.nrc.gov/reading-rm/doc-collections/. The regulatory guide is also available through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, under ADAMS Accession No. ML15170A003. The regulatory analysis may be found in ADAMS under Accession No. ML14031A264.

- Appendix A to 10 CFR Part 50, GDC 17, requires, in part, that an onsite electric power system and an offsite electric power system shall be provided to permit functioning of structures, systems, and components important to safety.

Purpose of Regulatory Guides

The NRC issues RGs to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants. RGs are not substitutes for regulations and compliance with them is not required. Methods and solutions that differ from those set forth in RGs will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

Paperwork Reduction Act

This RG contains information collection requirements covered by 10 CFR Part 50 that the Office of Management and Budget (OMB) approved under OMB control number 3150-0011. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

B. DISCUSSION

Reason for Revision

This revision of the RG (revision 1) endorses, with certain clarifications, IEEE Std. 485-2010. The initial version of this RG endorsed, with certain clarifications, IEEE Std. 485 1997. In 2010, the IEEE revised Std. 485 to refine the methods for defining direct current (dc) load guidance and sizing large lead acid batteries to ensure consistent performance. The revised IEEE standard provides a succinct document for the sizing of batteries with additional informative annexes. The NRC staff determined that, based on the revised IEEE standard, a revision to this RG is needed to support applications for new reactor licenses, design certifications, and license amendments.

Background

This RG provides guidance to applicants and licensees for defining the dc load and size of lead-acid batteries needed to supply the defined load for full-float stationary battery applications to support nuclear power plant operations. It endorses, with certain clarifications, IEEE Std. 485-2010. IEEE Std. 485-2010 describes the recommended methods for defining the dc load and for sizing lead-acid batteries to supply dc power to applications during the full range of operating and emergency conditions.

IEEE Std. 485-2010 is an updated national consensus standard that adds new recommendations and guidance, as well as informative annexes for both vented and valve-regulated lead-acid batteries for stationary applications. The standard was developed by the IEEE Power Engineering Society Stationary Batteries Committee and approved by the IEEE Standards Association Standards Board on November 8, 2010. The standard is applicable to vented and valve-regulated lead-acid batteries, and also describes some factors relating to cell selection. However, consideration of battery types other than lead-acid is beyond the scope of this RG. Additionally, installation, maintenance, qualification, testing procedures, and design of the dc system and sizing of the battery charger(s) are also beyond the scope of the IEEE standard and this RG.

It is important to recognize that IEEE Std. 485-2010 states it can be used as a standalone document. However, the NRC staff has found that using IEEE 485-2010 in conjunction with the following IEEE standards provides the user with a general guide to the design, installation, and maintenance of vented lead acid batteries in nuclear power plants.

- IEEE Std. 450, "IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications" (Ref. 3) (endorsed, with clarifications, in RG 1.129, "Maintenance, Testing, and Replacement of Vented Lead-Acid Storage Batteries for Nuclear Power Plants" [Ref. 4])

- IEEE Std. 484, "IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications" (Ref. 5) (endorsed, with clarifications, in RG 1.128, "Installation Design and Installation of Vented Lead-Acid Storage Batteries for Nuclear Power Plants" [Ref. 6])

Additionally, section 2, "Normative References," of IEEE Std. 485-2010 stipulates that, if IEEE Std. 485-2010 is to be used in conjunction with other IEEE standards, it should be supplemented with the following IEEE standards:

- IEEE Std. 308, "IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations," (Ref. 7) which the NRC endorses, with clarifications, in RG 1.32, "Criteria for Power Systems for Nuclear Power Plants" (Ref. 8).

- IEEE Std. 344, "IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations," (Ref. 9) which the NRC endorses, with clarifications, in RG 1.100, "Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants" (Ref. 10).

- IEEE Std. 384, "IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits," (Ref. 11) which the NRC endorses, with clarifications, in RG 1.75, "Physical Independence of Electric Systems" (Ref. 12).

- IEEE Std. 535, "IEEE Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations," (Ref. 13) which the NRC endorses, with clarifications, in RG 1.158, "Qualification of Safety-Related Lead Storage Batteries for Nuclear Power Plants" (Ref. 14).

The sizing methodology provided in IEEE Std. 485-2010 is very similar to that provided by IEEE Std. 485-1997. The approach consists of defining the load that the batteries will be required to support and using the guidance in the IEEE standard to determine the best battery for the application. To this end, IEEE Std. 485-2010 provides guidance on general considerations that should be included in defining the duty cycle; load classifications, including continuous, non-continuous, and momentary loads; and the construction of a duty-cycle diagram. In calculating the number of cells and minimum voltage section, IEEE Std. 485-2010 cautions the user that the charging voltage needs to be recalculated and verified for adequacy if the numbers of cells are rounded off. It also provides a discussion on how to ensure all voltage drops are considered when calculating the allowable minimum voltage.

IEEE Std. 485-2010 discusses defining loads and other considerations but notes that for sizing purposes the loads can be treated as constant power or constant current. The annexes A, C, D, E, F, G, and J are informative and should be reviewed by applicants and licensees to assist them with the battery design.

IEEE Std. 485-2010, Section 4.3 "Duty Cycle Diagram" states that the total time span of the duty cycle is determined by the requirements of the installation. This duty cycle time depends on the type of nuclear power plant design – active or passive. The duty cycle time is typically discussed in a plant safety analysis report. For the active plants, the battery duty cycle should cover both design basis accidents (DBAs) and station blackout (SBO) scenarios (with a permitted load shedding scheme). For design basis accidents, since an emergency diesel generator (EDG) is assumed to be available within approximately 10 seconds to recharge the battery, some nuclear plants have sized the vital batteries considering a duty cycle of less than 2 hours duration. However, an EDG may be out of service at the time of accident concurrent with the loss of offsite power. It may take up to 2 hours to switch the associated battery charger to an alternate power source. Therefore, for active plant designs, the vital batteries should be sized for the worst case duty cycle, consisting of either a minimum of 2 hours for the DBAs or the analyzed SBO duration (with a permitted DC load shedding scheme). This guidance does not apply to the EDG's own battery if provided separately (which is exclusively sized based on starting requirement of the EDG, such as field flash).

Harmonization with International Standards

The International Atomic Energy Agency (IAEA) has established a series of safety guides and standards constituting a high level of safety for protecting people and the environment. IAEA safety guides present international good practices and increasingly reflect best practices to help users striving to achieve high levels of safety. Pertinent to this RG is IAEA Safety Guide NS-G-1.8, "Design of Emergency Power Systems for Nuclear Power Plants" (Ref. 15), which addresses design provisions for the inspection, testing, and maintenance of the emergency power systems (such as battery equipment in sections 5.1 through 5.8) as part of the overall periodic testing and maintenance of specific equipment in nuclear power plants. Additionally, Requirement 68, "Emergency Power Supply" of IAEA Safety Standard SSR-2/1, "Safety of Nuclear Power Plants: Design" (Ref. 16) contains a requirement that emergency power supplies be sized to provide sufficient emergency power. This RG incorporates similar capacity, design, and preoperational testing guidelines and is consistent with the basic safety principles provided in both IAEA documents.

Documents Discussed in Staff Regulatory Guidance

This RG endorses, in part, the use of one or more codes or standards developed by external organizations, and other third-party guidance documents. These codes, standards, and third-party guidance documents may contain references to other codes, standards, or third-party guidance documents ("secondary references"). If a secondary reference is incorporated by reference into NRC regulations as a requirement, then licensees and applicants must comply with that standard as set forth in the regulation. If the secondary reference is endorsed in an RG as an acceptable approach for meeting an NRC requirement, then the standard constitutes a method acceptable to the NRC staff for meeting that regulatory requirement as described in the specific RG. If the secondary reference is neither incorporated by reference into NRC regulations nor endorsed in an RG, then the secondary reference is neither a legally-binding requirement nor a "generic" NRC-approved acceptable approach for meeting an NRC requirement. However, licensees and applicants may consider and use the information in the secondary reference, if appropriately justified and consistent with current regulatory practice and applicable NRC requirements.

C. STAFF REGULATORY GUIDANCE

The staff finds that IEEE Std. 485-2010 provides methods acceptable to the NRC staff for complying with the design requirements for stationary battery applications in full-float operation for nuclear power plants, subject to the following staff regulatory guidance positions:

1. Annex A to IEEE Std. 485-2010 is informative and provides sample sizing demonstrations. Unless otherwise stated in a separate regulatory position, endorsement of the IEEE Std. 485-2010 does not include endorsement of this annex.

2. Annex B to IEEE Std. 485-2010 is endorsed as an accepted method of converting constant power and constant resistance loads to constant current loads for purposes of battery-sizing calculations.

3. Annex C to IEEE Std. 485-2010 is informative and provides a method for estimating battery terminal voltage at various points in the battery duty cycle using manufacturer's typical discharge characteristics. Unless otherwise stated in a separate regulatory position, endorsement of the IEEE Std. 485-2010 does not include endorsement of this annex.

4. Annex D to IEEE Std. 485-2010 is informative and provides a method for considering other cell types when selecting a battery for its intended application. Unless otherwise stated in a separate regulatory position, endorsement of the IEEE Std. 485-2010 does not include endorsement of this annex.

5. Annex E to IEEE Std. 485-2010 is informative and provides a method for sizing a battery properly for a constant power application and also to convert from constant power loads to constant current. Unless otherwise stated in a separate regulatory position, endorsement of the IEEE Std. 485-2010 does not include endorsement of this annex.

6. Annex F to IEEE Std. 485-2010 is informative and provides a method for describing the construction and use of battery discharge characteristics curve. Unless otherwise stated in a separate regulatory position, endorsement of the IEEE Std. 485-2010 does not include endorsement of this annex.

7. Annex G to IEEE Std. 485-2010 is informative and provides a method for addressing random loads and their application in battery sizing process. Unless otherwise stated in a separate regulatory position, endorsement of the IEEE Std. 485-2010 does not include endorsement of this annex.

8. Annex H to IEEE Std. 485-2010 is endorsed as an accepted method for determining the capacity variation for long-duration discharges solely for the vented lead-acid batteries.

9. Annex I to IEEE Std. 485-2010 is a full-size worksheet for Sizing Lead-Acid Batteries for Stationary Applications, and is endorsed as an accepted method for sizing the lead-acid batteries.

10. Annex J to IEEE Std. 485-2010 is informative and provides the bibliography. Unless otherwise stated in a separate regulatory position, endorsement of the IEEE Std. 485-2010 does not include endorsement of this annex.

11. The battery duty cycle span should be discussed in the plant safety analysis report. For the active plant designs, the battery duty cycle should cover both DBAs and SBO scenarios (with a

permitted load shedding scheme). The minimum duty cycle for active plant designs for DBAs should be two hours.

D. IMPLEMENTATION

The purpose of this section is to provide information on how applicants and licensees[1] may use this guide and information regarding the NRC's plans for using this RG. In addition, it describes how the NRC staff complies with 10 CFR 50.109, "Backfitting" and any applicable finality provisions in 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

Use by Applicants and Licensees

Applicants and licensees may voluntarily[2] use the guidance in this document to demonstrate compliance with the underlying NRC regulations. Methods or solutions that differ from those described in this RG may be deemed acceptable if they provide sufficient basis and information for the NRC staff to verify that the proposed alternative demonstrates compliance with the appropriate NRC regulations. Current licensees may continue to use guidance the NRC found acceptable for complying with the identified regulations as long as their current licensing basis remains unchanged.

Licensees may use the information in this RG for actions that do not require NRC review and approval such as changes to a facility design under 10 CFR 50.59, "Changes, Tests, and Experiments." Licensees may use the information in this RG or applicable parts to resolve regulatory or inspection issues.

Use by NRC Staff

The NRC staff does not intend or approve any imposition or backfitting of the guidance in this RG. The NRC staff does not expect any existing licensee to use or commit to using the guidance in this RG, unless the licensee makes a change to its licensing basis. The NRC staff does not expect or plan to request licensees to voluntarily adopt this RG to resolve a generic regulatory issue. The NRC staff does not expect or plan to initiate NRC regulatory action that would require the use of this RG. Examples of such unplanned NRC regulatory actions include issuance of an order requiring the use of the RG, requests for information under 10 CFR 50.54(f) as to whether a licensee intends to commit to use of this RG, generic communication, or issuance of a rule requiring the use of this RG without further backfit consideration.

During regulatory discussions on plant-specific operational issues, the staff may discuss with licensees various actions consistent with staff positions in this RG, as one acceptable means of meeting the underlying NRC regulatory requirement. Such discussions would not ordinarily be considered backfitting even if prior versions of this RG are part of the licensing basis of the facility. However, unless this RG is part of the licensing basis for a facility, the staff may not represent to the licensee that the licensee's failure to comply with the positions in this RG constitutes a violation.

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1 In this section, "licensees" refers to licensees of nuclear power plants under 10 CFR Parts 50 and 52; and the term "applicants," refers to applicants for licenses and permits for (or relating to) nuclear power plants under 10 CFR Parts 50 and 52, and applicants for standard design approvals and standard design certifications under 10 CFR Part 52.

2 In this section, "voluntary" and "voluntarily" mean that the licensee is seeking the action of its own accord, without the force of a legally binding requirement or an NRC representation of further licensing or enforcement action.

If an existing licensee voluntarily seeks a license amendment or change and (1) the NRC staff's consideration of the request involves a regulatory issue directly relevant to this new or revised RG and (2) the specific subject matter of this RG is an essential consideration in the staff's determination of the acceptability of the licensee's request, then the staff may request that the licensee either follow the guidance in this RG or provide an equivalent alternative process that demonstrates compliance with the underlying NRC regulatory requirements. This is not considered backfitting as defined in 10 CFR 50.109(a)(1) or a violation of any of the issue finality provisions in 10 CFR Part 52.

Additionally, an existing applicant may be required to comply with new rules, orders, or guidance if 10 CFR 50.109(a)(3) applies.

If a licensee believes that the NRC is either using this RG or requesting or requiring the licensee to implement the methods or processes in this RG in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfit appeal with the NRC in accordance with the guidance in NUREG-1409, "Backfitting Guidelines," (Ref. 17) and the NRC Management Directive 8.4, "Management of Facility-Specific Backfitting and Information Collection" (Ref. 18).

REFERENCES[3]

1. Institute of Electrical and Electronics Engineers, (IEEE) Standard (Std.) 485-2010, "IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications," Piscataway, NJ, 2011[4].

2. *U.S. Code of Federal Regulations*, "Domestic Licensing of Production and Utilization Facilities," Part 50, Chapter I, Title 10, "Energy."

3. IEEE Std. 450, "IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications," Piscataway, NJ.

4. U.S. Nuclear Regulatory Commission (NRC), Regulatory Guide (RG) 1.129, "Maintenance, Testing, and Replacement of Vented Lead-Acid Storage Batteries for Nuclear Power Plants," Washington, DC.

5. IEEE Std. 484, "IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications," Piscataway, NJ.

6. NRC, RG 1.128, "Installation Design and Installation of Vented Lead-Acid Storage Batteries for Nuclear Power Plants," Washington, DC.

7. IEEE Std. 308, "IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations," Piscataway, NJ.

8. NRC, RG 1.32, "Criteria for Power Systems for Nuclear Power Generating Systems," Washington, DC.

9. IEEE Std. 344, "IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations," Piscataway, NJ.

10. NRC, RG 1.100, "Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants," Washington, DC.

11. IEEE Std. 384, "IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits," Piscataway, NJ.

12. NRC, RG 1.75, "Physical Independence of Electric Systems," Washington, DC.

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3 Publicly available NRC published documents are available electronically through the NRC Library on the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/ and through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html The documents can also be viewed online or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD. For problems with ADAMS, contact the PDR staff at 301-415-4737 or (800) 397-4209; fax (301) 415-3548; or e-mail pdr.resource@nrc.gov.

4 Copies of Institute of Electrical and Electronics Engineers (IEEE) documents may be purchased from the Institute of Electrical and Electronics Engineers Service Center, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855 or through the IEEE's public Web site at http://www.ieee.org/publications_standards/index.html.

13. IEEE Std. 535, "IEEE Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations," Piscataway, NJ.

14. NRC, RG 1.158, "Qualification of Safety-Related Lead Storage Batteries for Nuclear Power Plants," Washington, DC.

15. International Atomic Energy Agency (IAEA) Safety Guide NS-G-1.8, "Design of Emergency Power Systems for Nuclear Power Plants," IAEA, Vienna, Austria, 2004. [6]

16. IAEA, Safety Standard SSR-2/1, "Safety of Nuclear Power Plants: Design," IAEA, Vienna, Austria, 2012.

17. NRC, NUREG-1409, "Backfitting Guidelines," July 1990, Washington, DC. (ADAMS Accession No. ML032230247).

18. NRC, Management Directive 8.4, "Management of Facility-specific Backfitting and Information Collection," Washington, DC.

6 Copies of International Atomic Energy Agency (IAEA) documents may be obtained through their Web site: WWW.IAEA.Org/ or by writing the International Atomic Energy Agency P.O. Box 100 Wagramer Strasse 5, A-1400 Vienna, Austria. Telephone (+431) 2600-0, Fax (+431) 2600-7, or E-Mail at Official.Mail@IAEA.Org