U.S. NUCLEAR REGULATORY COMMISSION

REGULATORY GUIDE RG 1.204, Revision 1

Issue Date: January 2024
Technical Lead: Roy Hardin

GUIDELINES FOR LIGHTNING PROTECTION FOR PRODUCTION AND UTILIZATION FACILITIES

A. INTRODUCTION

Purpose

This regulatory guide (RG) endorses, with clarifications, the methods described in the Institute of Electrical and Electronics Engineers (IEEE) Standard (Std.) 665-1995 (R2001), "IEEE Guide for Generating Station Grounding"[1] (Ref. 1); IEEE Std. 666-2007, "IEEE Design Guide for Electric Power Service Systems for Generating Stations," (Ref. 2); IEEE Std. 1050-2004, "IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations," (Ref. 3); and IEEE Std. C62.23-2017, "IEEE Application Guide for Surge Protection of Electric Generating Plants," (Ref. 4) as an acceptable process for demonstrating compliance with the applicable U.S. Nuclear Regulatory Commission (NRC) regulations for adequate lightning protection of safety-related systems, structures, and components (SSCs) in production and utilization facilities.

Applicability

This RG applies to licensees and applicants subject to Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, "Domestic Licensing of Production and Utilization Facilities" (Ref. 7) and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants" (Ref. 8). With respect to 10 CFR Part 50, this RG applies to holders of or an applicant for an operating license. With respect to 10 CFR Part 52, this RG applies to applicants and holders of combined licenses, standard design certifications, standard design approvals, and manufacturing licenses. This RG does not apply to

1 Withdrawn IEEE Std 665-1995 (R2001), IEEE Guide for Generator Station Grounding, is considered by NRC staff to remain technically relevant and applicable. Staff's technical determination, plus information provided in the 2016 IEEE Project Authorization Request (PAR) P665 to develop an updated version of IEEE-665, provides the basis for staff to consider the withdrawn IEEE-665 – (R2001) guidance acceptable for continued use in RG 1.204."

Written suggestions regarding this guide may be submitted through the NRC's public Web site in the NRC Library at https://www.nrc.gov/reading-rm/doc-collections/reg-guides/index.html., under Document Collections, in Regulatory Guides, at https://www.nrc.gov/reading-rm/doc-collections/reg-guides/contactus.html, and will be considered in future updates and enhancements to the "Regulatory Guide" series. During the development process of new guides suggestions should be submitted within the comment period for immediate consideration. Suggestions received outside of the comment period will be considered if practical to do so or may be considered for future updates.

Electronic copies of this RG, previous versions of RGs, and other recently issued guides are also available through the NRC's public web site in the NRC Library at https://www.nrc.gov/reading-rm/doc-collections/reg-guides/index.html/under Document Collections, in Regulatory Guides. This RG 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 Number (No.) ML23241A957. The regulatory analysis is associated with a rulemaking and may be found in ADAMS under Accession No. ML22208A234. The associated draft guide DG-1409, Revision 1, may be found in ADAMS under Accession No. ML22208A232, and the staff responses to the public comments on DG-1409 may be found under ADAMS Accession No. ML23241A965.

production and utilization facilities that have submitted certifications as required by 10 CFR 50.82(a)(1) and by 52.110(a).

Applicable Regulations

- 10 CFR Part 50 provides regulations for licensing production and utilization facilities.
    - 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection against Natural Phenomena," requires, in part, that SSCs important to safety be designed to withstand the effects of natural phenomena without loss of capability to perform their safety functions. The design bases for these SSCs must reflect (1) appropriate consideration of the most severe natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for limited accuracy, quantity, and period of time in which the historical data have been accumulated; (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena; and (3) the importance of the safety functions to be performed.
- 10 CFR Part 52 governs the issuance of early site permits, standard design certifications, combined licenses, standard design approvals, and manufacturing licenses for nuclear power facilities. Part 52 specifies, among other things, that contents of some applications must satisfy the requirements of 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants."

Related Guidance

- RG 1.180, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems," (Ref. 9) which describes methods and procedures considered acceptable for demonstrating compliance with the NRC's regulations on design, installation, and testing to address the effects of electromagnetic and radio-frequency interference (EMI/RFI), power surges, and electrostatic discharge on safety-related instrumentation and control systems.
- NUREG-1537, Parts 1 and 2, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," issued February 1996 (Ref. 10), contains format and content guidance for non-power reactor applicants and licensees, as well as a standard review plan and acceptance criteria for NRC staff.
- Final Interim Staff Guidance Implementing NUREG-1537, Parts 1 and 2, for Licensing Radioisotope Production Facilities and Aqueous Homogeneous Reactors, issued October 2012 (Ref. 11), contains format and content guidance for non-power aqueous homogeneous reactor and radioisotope production facility applicants and licensees, as well as a standard review plan and acceptance criteria for NRC staff.
- "Endorsement of Appendix A to Oak Ridge National Laboratory Report, 'Proposed Guidance For Preparing and Reviewing A Molten Salt Non-Power Reactor Application,' as Guidance for Preparing Applications for the Licensing of Non-Power Liquid Fueled Molten Salt Reactors," dated November 18, 2020, (Ref. 12) which endorses with clarifications, "Proposed Guidance for Preparing and Reviewing a Molten Salt Non-Power Reactor Application" (ORNL/TM-2020/1478) to support the review of non-power molten salt reactors (Ref. 13).

Purpose of Regulatory Guides

The NRC issues RGs to describe methods that are acceptable to the staff for implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific issues or postulated events, and to describe information that the staff needs in its review of applications for permits and licenses. Regulatory guides are not NRC regulations and compliance with them is not required. Methods and solutions that differ from those set forth in RGs are acceptable if supported by a basis for the issuance or continuance of a permit or license by the Commission.

Paperwork Reduction Act

This RG provides voluntary guidance for implementing the mandatory information collections in 10 CFR Parts 50 and 52 that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et. seq.). These information collections were approved by the Office of Management and Budget (OMB), approval numbers 3150-0011 and 3150-0151. Send comments regarding this information collection to the FOIA, Library, and Information Collections Branch (T6-A10M), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by e-mail to Infocollects.Resource@nrc.gov and to the OMB reviewer at: OMB Office of Information and Regulatory Affairs (3150-0011 and 3150-0151), Attn: Desk Officer for the Nuclear Regulatory Commission, 725 17th Street, NW Washington, DC 20503.

Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the document requesting or requiring the collection displays a currently valid OMB control number.

B. DISCUSSION

Reason for Revision

Revision 0 of RG 1.204 was issued in November 2005 to endorse IEEE Std. 665-1995 (Ref. 1); IEEE Std. 666-1991 (Ref. 14); IEEE Std. 1050-1996 (Ref. 15); and IEEE Std. C62.23-1995 (Ref. 16). The IEEE guidance documents 1050, 666 and C62.23 were revised in 2004, 2007 and 2017, respectively. This revision updates the RG to endorse IEEE Std. 665-1995; IEEE Std. 1050-2004; IEEE Std. 666-2007; and IEEE Std. C62.23-2017, with certain clarifications.

Background

Experience shows that lightning can pose operational threats to production and utilization facilities. Therefore, protection is essential to avoid malfunctions and upsets that, in turn, can lead to reactor trips. Nuclear power plants and other facilities should have a well-designed and properly installed lightning protection system (LPS) to safeguard their SSCs from lightning strikes and the resulting secondary effects. To protect against the effects of lightning strikes, the LPS should incorporate strike termination devices, discharge down conductors, and a grounding system. To protect against the secondary effects of lightning strikes, such as potentially disruptive surges and EMI/RFI that can propagate to internal structures and cause damage to safety-related systems, the LPS should also incorporate appropriate individual equipment grounding systems and surge protection devices (SPDs).

The NRC staff has reviewed IEEE Std. 665-1995, IEEE Std. 666-2007, IEEE Std. 1050-2004, and IEEE Std. C62.23-2017 and determined that, with certain clarifications, they are acceptable guidance for lightning protection for production and utilization facilities.

IEEE Std. 665-1995 (R2001) describes facility grounding practices and serves as the primary source of guidance on lightning protection for structures at power generating stations. As such, this guidance identifies the grounding practices that the electric utility industry has generally accepted as contributing to effective grounding systems for personnel safety and equipment protection in generating stations. This document also provides guidance for the design of generating station grounding systems and grounding practices applied to generating station indoor and outdoor structures and equipment.

IEEE Std. 666-2007 describes grounding practices for neutral grounding and grounding methods for medium-voltage equipment. As such, this design guide is intended for application to generating station service systems that supply electric power to auxiliary equipment. It applies to all types of generating stations that produce electric power and is particularly applicable to stations in which the electric power service is required to perform continuously. Such a service system consists of a main auxiliary power distribution network that might supply many subsystems (including direct current systems and Class 1E power systems), much of which is medium-voltage (2.4-13.8 kV) equipment.

This guidance addresses recommendations for neutral grounding, as well as the grounding of generating station auxiliaries. It also covers grounding methods for both low-voltage (120-480 V) and medium-voltage power service systems. The low-voltage grounding methods parallel similar guidance in IEEE Std. 665. In addition, this guidance document covers surge protection of transformers, switchgear, and motors, paralleling similar guidance in IEEE Std. C62.23.

IEEE Std. 1050-2004 describes design and installation practices regarding grounding methods for instrumentation and control (I&C) equipment. As such, this guidance recommends grounding methods for I&C equipment to achieve a suitable level of protection for personnel and equipment, as well as suitable noise immunity for signal-ground references in generating stations. IEEE Std. 1050-2004 is

comprehensive, in that it covers both theoretical and practical aspects of grounding and noise minimization.

Surge protection measures are vital for protection of the power plant, ancillary facilities that could impact safety, the switchyard, the electrical distribution system, safety-related I&C systems, and communication systems from both direct lightning strikes and the resulting power surges. SPDs should be applied at the entry and egress points for signal-, communication-, and power-line conductors. They should also be applied to any equipment that is thought to be vulnerable to high-energy surges. The selection of SPDs typically depends on the location of the devices and the size(s) needed to prevent the energy from a lightning strike from impinging a facility or piece of equipment.

IEEE Std. C62.23-2017 describes surge protection application practices applicable to power generating stations. As such, this guidance consolidates many electric utility industry practices, accepted theories, existing standards/guides, definitions, and technical references as they specifically pertain to surge protection. This guidance document also provides information on proper surge protection techniques and interference reduction practices for communication, control, and protection circuits. The guidance covers the protection of transmission lines and switchyard equipment from direct lightning strikes (using overhead ground wires, tower footing resistance, counterpoise wires, and surge arresters on transmission lines); protection of distribution lines from direct lightning strikes, switching surges, and ferroresonance; and the selection of arrestors for distribution lines. The guidance covers the protection of both indoor and outdoor equipment (including transformers, motors, switchgear, etc.) from direct lightning strikes, incoming surges, internally generated surges, and ground potential rises. It also covers the protection of control and communication circuits and discusses the beneficial effects of shielding, grounding, and cable routing in the power plant buildings. In addition, the guidance covers the protection of remote ancillary facilities, dealing primarily with protection from direct lightning strikes and the surges induced on underground cables.

IEEE Std. 665-1995, IEEE Std. 666-2007, IEEE Std. 1050-2004, and IEEE Std. C62.23-2017 reference other IEEE guidance documents that contain useful information but are not endorsed in this RG; these secondary references are listed in Appendix A for clarity. Two other useful secondary references are National Fire Protection Association (NFPA) Standard 780, “Standard for the Installation of Lightning Protection Systems,” (Ref. 5) and Underwriters Laboratories (UL) Standard 96A, “Installation Requirements for Lightning Protection Systems,” (Ref. 6). While the NRC staff is not endorsing these two standards due to their exclusion of electric power generation facilities, staff notes that Annex B “Principles of Lightning Protection” and Annex D “Inspection and Maintenance of Lightning Protection Systems” in NFPA 780 provide useful information on testing and maintenance practices that licensees and applicants may wish to reference in developing their own testing and maintenance practices.

Consideration of International Standards

The International Atomic Energy Agency (IAEA) works with member states and other partners to promote the safe, secure, and peaceful use of nuclear technologies. The IAEA develops Safety Requirements and Safety Guides for protecting people and the environment from harmful effects of ionizing radiation. This system of safety fundamentals, safety requirements, safety guides, and other relevant reports, reflects an international perspective on what constitutes a high level of safety. To inform its development of this RG, the NRC considered IAEA Safety Requirements and Safety Guides pursuant to the Commission’s International Policy Statement (Ref. 17) and Management Directive and Handbook 6.6, “Regulatory Guides” (Ref. 18).

This RG is consistent with the general principles of IAEA Specific Safety Guide No. SSG-34, “Design of Electrical Power Systems for Nuclear Power Plants,” issued March 2016 (Ref. 19), which

provides guidance for lightning protection of internal and external systems and components important for safe plant operation.

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 has itself been 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 has been endorsed in a 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 has neither been incorporated by reference into NRC regulations nor endorsed in a 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, consistent with current regulatory practice, and consistent with applicable NRC requirements.

C. STAFF REGULATORY GUIDANCE

The collective guidance in IEEE Std. 665-1995[2]; IEEE Std. 666-2007; IEEE Std.1050-2004; and IEEE C62.23-2017 provide an acceptable approach to the NRC staff for meeting the agency's regulatory requirements for adequate lightning protection of SSCs in production and utilization facilities with the clarifications below.

1. LPSs should be inspected following installation, and systems should be inspected on a regular, periodic basis throughout their lifetime. LPS systems should be inspected whenever any alterations or repairs are made to a protected structure, as well as following any known lightning transient to the system. An LPS should be visually inspected at least annually. In areas where severe climatic changes occur, it is advisable to inspect the LPS semiannually or following extreme changes in ambient temperature. An in-depth inspection of the LPS every 3–5 years to assess the effects of aging is also recommended.

2. Testing and maintenance procedures should be established for each LPS. The frequency of testing and maintenance will depend on weather-related degradation of protective features, frequency and severity of damage attributable to lightning transients, and required protection level. Also, an LPS testing and maintenance program should include (1) inspection of all conductors and system components, (2) tightening of all clamps and splicers, (3) measurement of the earth grounding resistance, (4) measurement of the resistance of ground terminals, (5) inspection or testing (or both) of SPDs to assess their effectiveness, (6) periodic testing and maintenance of earth grounding systems, (7) refastening and tightening of components and conductors as required, (8) inspection and testing when the LPS has been altered by additions to, or changes in, the structure, and (9) complete records.

2 IEEE Std. 665-1995 Section 5.7.4 should reference IEEE Std. 142-1991 Subclause 4.2.3 rather than IEEE Std. 142-1991 Subclause 4.2.4.

D. IMPLEMENTATION

The NRC staff may use this RG as a reference in its regulatory processes, such as licensing, inspection, or enforcement. However, the NRC staff does not intend to use the guidance in this RG to support NRC staff actions in a manner that would constitute backfitting as that term is defined in 10 CFR 50.109, "Backfitting," and as described in NRC Management Directive 8.4, "Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests," (Ref. 20), nor does the NRC staff intend to use the guidance to affect the issue finality of an approval under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." The staff also does not intend to use the guidance to support NRC staff actions in a manner that constitutes forward fitting as that term is defined and described in Management Directive 8.4. If a licensee believes that the NRC is using this RG in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfitting or forward fitting appeal with the NRC in accordance with the process in Management Directive 8.4.

REFERENCES [3]

1. Institute of Electrical and Electronics Engineers (IEEE) Standard (Std.) 665-1995 (R2001), "IEEE Guide for Generating Station Grounding," Piscataway, NJ.[4]

2. IEEE Std. 666-2007, "IEEE Design Guide for Electric Power Service Systems for Generating Stations," Piscataway, NJ.

3. IEEE Std. 1050-2004, "IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations," Piscataway, NJ.

4. IEEE Std. C62.23-2017, "IEEE Application Guide for Surge Protection of Electric Generating Plants," Piscataway, NJ.

5. National Fire Protection Association (NFPA) Standard 780-2023, "Standard for the Installation of Lightning Protection Systems," Washington, DC.[5]

6. Underwriters Laboratories (UL) Standard 96A-2023, "Installation Requirements for Lightning Protection Systems," Northbrook, IL.[6]

7. CFR, "Domestic Licensing of Production and Utilization Facilities," Part 50, Chapter 1, Title 10, "Energy."

8. CFR, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Part 52, Chapter 1, Title 10, "Energy."

9. U. S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.180, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems," Revision 2, December 2019, Washington, DC (ADAMS Accession No. ML19175A044)

10. NRC, NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Washington, DC, February 1996.

11. NRC, Interim Staff Guidance Implementing NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Part 1 and Part 2, Washington, DC, October 2012. (ML12156A069)

---

3 Publicly available NRC published documents are available electronically through the NRC Library on the NRC's public website 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. For problems with ADAMS, contact the Public Document Room staff at 301-415-4737 or (800) 397-4209, or email pdr.resource@nrc.gov. The NRC Public Document Room (PDR), where you may also examine and order copies of publicly available documents, is open by appointment. To make an appointment to visit the PDR, please send an email to PDR.Resource@nrc.gov or call 1-800-397-4209 or 301-415-4737, between 8 a.m. and 4 p.m. eastern time (ET), Monday through Friday, except Federal holidays.

4 IEEE publications may be purchased from the IEEE Service Center, which is located at 445 Hoes Lane, Piscataway, NJ 08855.

5 NFPA documents may be purchased from the NFPA Contact Center, which is located at 11 Tracy Drive, Avon, MA 02322.

6 UL documents may be purchased from the Comm 2000, which is located at 151 Eastern Avenue, Bensenville, IL 60106.

12. Endorsement of Appendix A to Oak Ridge National Laboratory Report, 'Proposed Guidance for Preparing and Reviewing a Molten Salt Non-Power Reactor Application,' as Guidance for Preparing Applications for the Licensing of Non-Power Liquid Fueled Molten Salt Reactors," dated November 18, 2020 (ML20251A008).

13. Oak Ridge National Laboratory, "Proposed Guidance for Preparing and Reviewing a Molten Salt Non-Power Reactor Application," (ORNL/TM-2020/1478) (ML20219A771).

14. IEEE Std. 666-1991, "IEEE Design Guide for Electrical Power Systems for Generating Stations," Piscataway, NJ.

15. IEEE Std. 1050-1996, "IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations," Piscataway, NJ.

16. IEEE Std. C62.23-1995, "IEEE Application Guide for Surge Protection of Electric Generating Plants," Piscataway, NJ.

17. NRC, "Nuclear Regulatory Commission International Policy Statement," Federal Register, Vol. 79, No. 132, July 10, 2014, pp. 39415-39418.

18. NRC, Management Directive (MD) 6.6, "Regulatory Guides," Washington, DC.

19. IAEA Specific Safety Guide No. SSG-34, "Design of Electrical Power Systems for Nuclear Power Plants," March 2016. [7]

20. NRC, MD 8.4, "Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests," Washington, D.C.

7 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.

SECONDARY REFERENCES IN ENDORSED DOCUMENTS

STANDARD NUMBER	STANDARD TITLE
IEEE Std. 80-2013	IEEE Guide for Safety in AC Substation Grounding (ANSI)
IEEE Std. 81-2012	IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System (ANSI)
IEEE Std. 142-2007	IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)
IEEE Std. 367-2012	IEEE Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage from a Power Fault (ANSI)
IEEE Std. 487-2015	IEEE Standard for the Electrical Protection of Communications Facilities Serving Electric Supply Locations – General Considerations (ANSI)
IEEE Std. 1100-2005	IEEE Recommended Practice for Powering and Grounding Electronic Equipment (IEEE Emerald Book) (ANSI)
IEEE Std. C37.101-2006	IEEE Guide for Generator Ground Protection (ANSI)
IEEE Std. C57.13.3-2014	IEEE Guide for the Grounding of Instrument Transformer Secondary Circuits and Cases (ANSI)
IEEE Std. C62.92.1-2016	IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part I-Introduction (ANSI)
IEEE Std. C62.92.2-2017	IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part II - Synchronous Generator Systems (ANSI)
IEEE Std. C62.92.3-2012	IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part III-Generator Auxiliary Systems (ANSI)
IEEE Std. C62.41.1-2002	IEEE Guide on the Surge Environment in Low-Voltage (1000 V and Less) AC Power Circuits (ANSI)
IEEE Std. C62.41.2-2002	IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits (ANSI)
IEEE Std. C62.45-2002	IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits (ANSI)