UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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MEMORANDUM FOR: W. M. Morrison, Assistant Director for General Engineering Standards, Division of Engineering Standards, OSD

FROM: Faust Rosa, Chief, Power Systems Branch, DSS

THRU: V. Benaroya, Acting Assistant Director for Plant Systems, DSS

SUBJECT: REGULATORY GUIDE 1.XX, "LIGHTNING PROTECTION FOR NUCLEAR POWER PLANTS DATED 8/25/78 (RS-705-4)

References:

1. Memorandum from E. G. Case to Robert B. Minogue dated August 8, 1977; Concurrence in OSD Task Initiation Form for Task No. RS 705-4, Development of Regulatory Guide on Lightning Protection.

2. Memorandum from Faust Rosa to R. J. Mattson dated April 5, 1978, ACRS Subcommittee Meeting 4/5/78 on the Proposed Regulatory Guide on Lightning Protection.

3. Memorandum from Faust Rosa to R. J. Mattson dated April 27, 1978, Status of PSB Review and Comments on Draft Reg Guide 1.XX, "Lightning Protection for Nuclear Power Plants", dated 3/9/78.

4. Memorandum from Faust Rosa to R. J. Mattson dated May 17, 1978, Draft Reg Guide 1.XX, "Lightning Protection for Nuclear Power Plants", dated 3/9/78, and its Value/Impact Assessment (SD Task RS 705-4).

5. Memorandum from W. M. Morrison to R. L. Tedesco dated August 11, 1978, Summary of Meeting with OSD on Lightning Protection - August 1, 1978.

I have reviewed the subject draft guide as requested by your memorandum to me dated August 25, 1978, and have the following comments:

The subject draft does not reflect most of the major comments which I have made on prior drafts of this guide (references 1 through 5).

Rather than reiterate my prior comments, I have written a complete Regulatory Position (Enclosure 1) which embodies those prior comments, and which I believe will better provide the necessary lightning protection for nuclear power plants with greater cost effectiveness to the industry. This proposed position is also consistent with the thrust of the H. R. Denton memorandum to the Commission on lightning protection dated August 16, 1978. Enclosure 2 is a comparison of my proposed position with the position of the subject draft guide.

I recommend adoption of this proposed position. I also recommend that the discussion section of the guide and the value impact statement be revised to accurately reflect the proposed position including the basic philosophy and engineering principles embodied therein.

Should this recommendation not be accepted, I request that my proposed position be included as an alternate position in the value/impact assessment when the guide and value/impact assessment are issued for public comments. The information in enclosure 2 is intended to aid your staff in writing a value impact comparison of the alternative approaches. My management has informed me that this course of action is consistent with the new procedures for public comment on draft prior to consideration by the Regulatory Requirements Review Committee.

Also, please note that my proposed position C.2 fulfills the commitment (unresolved item 2 of Reference 4) I made during our meeting on August 1, 1978.

Faust Rosa, Chief
Power Systems Branch
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cc: w/enclosure

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Enclosure 1

Proposed Regulatory Position for
RG 1.XX "Lightning Protection for
Nuclear Power Plants"
F. Rosa - 9/20/78

C. Regulatory Position

Conformance with the principles and requirements of the following standards (as applicable) provide acceptable methods for complying with General Design Criteria 2 and 18 of Appendix A and with Appendix B to 10 CFR Part 50 with respect to the design, qualification, construction, installation and testing of systems and components providing protection against lightning for light-water-cooled nuclear power plants, subject to the following:

NFPA (National Fire Protection Association) No. 78-1975; Lightning Protection Code, Part II - Protection of Buildings and Miscellaneous Property, and Part III - Protection of Structures Containing Flammable Liquids and Gasses;

ANSI C62.1-1975, American National Standard - Surge Arresters for Alternating - Current Power Circuits; and

ANSI C62.2-1969, American National Standard Guide for Application of Valve-Type Lightning Arresters for Alternating - Current Systems;

1. Protection of Structures

Lightning protection should be provided against direct strokes to structures and exposed equipment installations including containment, auxiliary buildings, off-gas stacks, fuel tanks, meteorological towers and other components important for maintaining the safety of the plant. The systems and equipment that provide this protection shall conform with the principles and requirements of NFPA No. 78-1975, subject to the following: Sections 2101(d), 2102(c) through (i) and 2122(b) shall be replaced by the following: Aluminum shall not be used as a conductor or structural support member.

2. Protection of Switchyard Equipment Against Direct Strokes

Overhead ground wire shielding, augmented by air terminals and masts as necessary, should be provided to protect all switchyard components of the power system (including overhead line power circuits from the switchyard to other plant structures) against direct lightning strokes. The complete shielding system including the overhead components, interconnecting conductors and grounding system should be designed and installed in accordance with established conservative design principles and practices of the electric utility industry; and the ground resistance should not exceed one ohm. In addition, the design should provide a shielding effectiveness such that shielding failure stroke current (I_{max}, the current in a lightning strike which bypasses the shielding and strikes a live component directly) will not exceed 15,000 amperes as defined by the relation

$$*r_{s\ max} = \frac{h + y}{2(1 - \sin \theta_s)} = 7.1\ I_{max}^{0.75}$$

where the maximum strike distance ($r_{s\ max}$) is a function of shield wire height (h), live component height (y), and shield angle (θ_s). All dimensions are in meters, I_{max} in KA.

3. Protection of Transmission Lines Against Direct Strokes

Overhead ground wire shielding should be provided to protect all transmission lines terminating in the switchyard against direct lightning strokes. This shielding system should be provided over the entire length of the line, however, it should definetly be provided for a minimum distance of one-half mile from the switchyard terminus of the lines. The complete shielding system including overhead ground wire, tower components, interconnecting conductors, and tower grounding system should be designed and installed in accordance with established conservative design principles and practices of the electric utility industry. The overhead ground wires should be carried into the switchyard and tied to the switchyard ground system. In addition, for each transmission line for a minimum of one-half mile from the switchyard, the design should provide a shielding effectiveness such that shielding failure stroke current (I_{max}) will not exceed 15,000 amperes, as defined in Position C.2 above.

*Details for determination of shielding effectiveness using this method are contained in a paper by G. W. Brown, Lightning Performance - I Shielding Failures Simplified, IEEE Transactions on Power Apparatus and Systems, Vol. PAS-97, No. 1, January/February 1978. Note: This paper specifically addresses transmission line shielding but the methodology is readily applicable to switchyard shielding.

4. Surge Protection for Switchyard Terminal Equipment

Station type surge (lightning) arresters should be installed on both the high and low voltage sides of all unit, and start-up or station service transformers in accordance with the following provisions:

a. The arresters should conform to all the applicable requirements of ANSI C62.1-1975 including design, construction and qualification testing with the following exception: In Section 7.5.1, High Current Short-Duration Test, the test surge current wave-shape should be at least 8 x 20 μsec (instead of the less conservative options also permitted by the standard).

b. The arresters should be provided with a discharge counter and a leakage grading current meter to facilitate surveillance and assessment of the functional capability of the installed arrester.

c. The arresters should be selected and applied in accordance with conservative application of the principles and methodology contained in ANSI C62.2-1969, including the following:

(1) Insulation coordination should be performed at a discharge current of 20,000 amperes minimum. (See Sections 3.2.1 and 3.2.2 of ANSI C62.2).

(2) The protective ratio (margin) for impulse coordination should be 1.2 minimum; for switching surge coordination it should be 1.15 minimum. (See Section 3.5.1 of ANSI C62.2).

5. Surge Protection for Class 1E Switchgear

Station type surge arresters should be provided for all Class 1E switchgear components that are connected to exposed overhead lines either directly or through a short length of cable. These arresters should conform to the following:

a. The arresters should be selected and applied in conformance with Positions C.4.a, C.4.b and C.4.c above.

b. The arresters should be installed in the circuit upstream of the feeder breaker; and the physical arrangement should be such as to preclude damage to the switchgear in event of arrester failure.

6. Periodic Surveillance of Lightning Protection Systems

Periodic surveillance of lightning protection systems and components addressed in Positions C.1 through C.5 should be performed, consistent with other planned periodic surveillance programs for outdoor electrical installations. As a minimum this periodic surveillance should include:

a. Visual inspection, augmented by conductor continuity tests and ground resistance measurements as deemed necessary, to ascertain the functional capability of the systems providing protection against direct strikes to structures, switchyard components and transmission lines.

b. Visual inspection of the surge arrester installation to determine if there is evidence of physical damage, surface contamination, or other deterioration in the arrester or its line and ground connections which could result in failure of surge protection. The visual inspection should be augmented by conductor continuity tests and ground resistance measurements as deemed necessary to ascertain the functional capability of the surge arrester installations.

c. A check of the surge arrester discharge counter reading and leakage grading current reading for each arrester. A permanent record of these data should be maintained and an assessment of arrester functional capability should be determined by comparison with previous readings and with the recommendations of the manufacturer in this regard. If the functional capability of an arrester is deemed to be marginal, it should be replaced in accordance with established maintenance procedures for this type of equipment.

ENCLOSURE 2

Comparison of Proposed Position (Enclosure 1)
With Position in RG 1.XX "Lightning
Protection for Nuclear Power
Plants" Dated 8/25/78

General

The proposed position is based on the following basic considerations:

1. Lightning protection for structures has been a human concern for centuries. The design principles and practices necessary for providing complete protection for all types of structures have been well established for some time, and are embodied in NFPA No. 78-1975, Lightning Protection Code - Parts II and III. Therefore, a Regulatory Guide endorsing this national standard (plus I&E follow to assure implementation) will be the most effective and efficient means of assuring that nuclear power plant structures are adequately protected against lightning.

2. Lightning protection for electric power systems and components has been a primary concern of the electric utility industry since its inception. The design principles and practices have evolved over the years based on empirical data derived from observations and measurements of the effects of lightning on actual power systems and components. These principles and practices and relevant data base are well established and extensively documented in the

literature and in National Standards. They are routinely implemented by the electric utility industry in a conservative manner, particularly at generating stations, switchyards and the bulk transmission network. Experience indicates that very effective lightning protection is being provided for all the on-site electrical systems; and there is no experience even remotely involving lightning induced common mode failures of redundant safety-related systems or components. Therefore, a Regulatory Guide endorsing the applicable national standards (ANSI C62.1-1975, ANSI C62.2-1969), and augmenting these standards as necessary to insure their conservative application and to include surveillance, will be the most effective and efficient means of assuring that the on-site electrical systems (safety and non-safety) of a nuclear plant are adequately protected against lightning.

3. The most direct, effective and least expensive lightning protection for outdoor electrical systems and components is provided by an overhead grounded shield (ground wire and/or mast) installation. The effectiveness of existing installations designed in accordance with current engineering practices and standards is confirmed by the fact that the maximum measured discharge current for station type surge arresters is 15KA. Therefore, the Regulatory Guide addressing lightning protection should simply include provisions for assuring the continued conservative application of current engineering practices to the design of these overhead grounded shield systems. These provisions should be quantifiable in terms of shielding effectiveness, i.e., shielding bypass stroke current magnitudes.

4. In view of item 3 above, a regulatory requirement for peak withstand current capability in excess of the 65KA specified by ANSI C62.1-1975 for station type arresters is unwarranted (R.G. 1.XX specifies 200 KA). The impact on the industry of a 200KA requirement would involve either (1) development of new arrester designs with this capability, or (2) using existing arresters with 65KA capability connected in parallel. As noted in our comments on the prior version of R.G. 1.XX, the cost of implementing either option is not insignificant. Also, although option 2 appears feasible and most capable of early implementation, it will require extensive full scale operational testing to verify expected performance. Finally, in our opinion, a requirement (200 KA) so out of line with present engineering principles and practices without valid justification could only have a detrimental effect on staff effectiveness and efficiency throughout the area of technical review of electric power systems.

5. The onsite electrical distribution system, because of its extensive branching, voltage transformations, and other electrical discontinuities, is inherently resistive to propagation of impulse voltages to the low voltage levels (110V) which serve sensitive solid state type of equipment. That is significant attenuation of voltage impulses is inherent in the design of electric power distribution systems. This is particularly true for the redundant Class 1E systems. Furthermore, electrical equipment at all voltage levels is designed, based on industry experience over many years, with impulse voltage withstand capability commensurate with its design voltage. Sensitive equipment, safety or non-safety related, is specifically designed for noise/pulse withstand capability. This is the most direct, most effective and least expensive method of voltage impulse protection for this type

of equipment. The most effective way of assuring that this protection is provided for this type of equipment is by appropriate environmental qualification. Provisions for accomplishing this are already embodied in IEEE Std. 323-1974.

Specific Comments

The following is a section summary comparison of the PSB proposed position, C. Regulatory Position, with respect to the R.G. 1.XX Part C "Regulatory Position".

Proposed Introductory Remarks

The introduction identifies and endorses three national standards that address lightning protection for structures and AC power systems.

R.G. 1.XX makes no such endorsement.

Proposed C.1.0 - Protection of Structures

This section identifies the structures at the plant site that should be protected and endorses NFPA No. 78-1975 with one exception for guidance on implementation. The exception being the prohibition of the use of aluminum as a conductor or support member.

R.G. 1.XX (Section C.4.0) references NFPA No. 78-1975 as a footnote.

Proposed C.2.0 - Protection of Switchyard Equipment Against Direct Strikes

This section endorses state-of-the-art methodology developed by G. W. Brown by which the maximum current in a lightning strike which bypasses the shielding can be controlled by design.

By introducting this methodology and requiring an upper limit for shielding bypass stroke current of 15KA, the 65KA peak withstand current capability now required by national standards for station type arresters provides better than a factor of 4 margin. This obviates the need to consider 200KA as required by R.G. 1.XX Sections C.1.0, C.2.5 and C.2.6. The PSB assessment of the impact of the 200KA rating is found in the preceeding general comments.

R.G. 1.XX does not directly and specifically address the subject of switchyard protection. This subject is indirectly covered under the R.G. 1.XX section on protection of structures. We also note the requirement for a nominal 40° core of protection (R.G. 1.XX Section C.4.3) is less conservative than implementation of the PSB proposed alternative methodology.

PSB C.3.0 - Protection of Transmission Lines Against Direct Strikes

This section applies the methodology of C.2.0 above to the transmission lines for a minimum distance of one-half mile from their switchyard terminus.

With the exception of the endorsement of the above methodology, R.G. 1.XX (Section C.3.0) is essentially the same as the PSB alternative.

Proposed C.4.0 - Surge Protection for Switchyard Terminal Equipment

This section endorses in detail ANSI C62.1-1975 and ANSI C62.2-1969, requires arresters to be provided with a discharge counter and a leakage grading current meter, requires insulation coordination at 20 KA minimum and defines the protective ratios (margin) for impulse and switching surge insulation coordination.

R.G. 1.XX (Sections C.1.0, C.2.5 and C.2.6) requires a discharge capability for station type arresters of 200KA as opposed to the referenced standards requirements of 65KA. (See our comments on the 200KA rating in the general comments above). Section C.2.8 endorses the qualification testing section of ANSI C62.1-1975. Section C.2.9 endorses the design tests of ANSI C62.1-1975 but requires the substitution of 200 KA for the discharge tests. Section C.2.10 endorses ANSI C62.2-1969 for insulation coordination for transformer but requires that for safety equipment connected to these transformers the voltage due to arrester discharge current of 200 KA should not exceed the safety equipment withstand capability. This appears to be another way of saying that insulation coordination should be performed at 200KA (as opposed to 20KA specified by ANSI C62.2-1969 as being conservative)thereby contradicting the prior endorsement of the standard.

Proposed C.5.0 - Surge Protection for Class 1E Switchgear

This section applies the same requirements of C.4.0 above to protection of Class 1E switchgear connected to exposed overhead lines either directly or through a short length of cable by requiring arresters to be installed upstream of the feeder breaker and physically arranged to preclude damage in the event of arrester failure.

R.G. 1.XX(Section C.2.6)has similar requirement at the 200KA level but does not address physical protection in the event of arrester failure nor does it distinguish requirements based upon whether or not overhead lines are part of the feeder circuits. (See the general comments section for further comments on the 200KA rating).

Proposed C.6.0 - Periodic Surveillance of Lightning Protection Systems

This section outlines an in-situ periodic surveillance and test program of visual inspection, continuity tests and resistance measurements for assuring functional capability of the protection systems. Also, a check of the surge arrester discharge counter reading and leakage grading current reading for each arrester is required. A permanent record of these data will be maintained and an assessment of arrester functional capability can be determined by comparison with previous readings and with the recommendations of the manufacturer in this regard. If the functional capability of an arrester is deemed to be marginal, it should be replaced in accordance with established maintenance procedures for this type of equipment. The above forms the basis for not requiring the periodic removal of arresters for laboratory testing.

R.G. 1.XX(Section C.2.1) requires removal from service and full scale testing of representative arresters at five year intervals. R.G. 1.XX does not address in-situ visual inspections, measuring of continuity and resistance, or checking of discharge counters and leakage grading current readings at any periodic interval.

Note: The remaining portions of R.G. 1.XX not discussed above were taken directly from the ANSI Standards (i.e. sections C.2.1, 2.2, 2.3, 2.4). When these sections taken directly from the ANSI Standards are coupled with the references discussed in the preceeding parts of this comparison (i.e. parts C.1.0 and C.4.0 above), we can see no reason why R.G. 1.XX does not fully endorse (with comments) the national standards itemized in the introductory remarks of our proposed alternative.