### AMP 220 lightning protection, Grounding Grid, and surge arresters NOT SUBJECT TO ENVIRONMENTAL QUALIFICATION REQUIREMENTS (VERSION 2021)

### Programme Description

The main objective of this AMP is to provide the basis to establish a programme for early detection and appropriate monitoring of ageing effects on lightning protection and earth-termination systems, and medium voltage (MV) and high voltage (HV) surge arresters in order to ensure adequate performance over the entire service life.

Lightning Protection and Grounding Systems

Lightning protection and earth-termination system consists of passive components manufactured using copper, aluminium or steel.

The lightning protection system is built up of strike receptors, lightning arrestors, down conductors and connections to the earthing system. Arrangements to create a Faradays cage with the help of wall panels and/or reinforcement mesh also exist to reduce the effect of lightning strikes.

The earth-termination system is built up of un-insulated copper wires buried in the earth arranged in a grid covering the whole site; wires may also be positioned out in the sea. The earth-termination system normally is connected to one or more copper buses (as a protective equipotential bonding) per building.

Incoming power line earth wires, transformers and generator neutral point, as well as conductive parts originating from outside the building are connected to the protective equipotential bonding and earth-termination system.

MV and HV Surge Arresters

High voltage power systems are exposed to over-voltages which may exceed the dielectric strength of the equipment on the system. These over-voltages may be caused by lightning strokes, switching operations, abnormal load flow conditions, and line-to-ground and phase to-phase faults. Depending on the source of the overvoltage, the magnitude and duration can vary over a wide range. The power system equipment can effectively be protected from the high magnitude over-voltages through the proper selection and installation of surge arresters [1].

Surge arresters are clamping devices and are commonly used in use in medium and high voltage transmission lines, switchyards, and feeder circuits.

Design Construction and types of surge arresters:

Surge arresters are subject to two voltage levels: the system operating voltage and the high magnitude transient voltage. Elements of the arrester that primarily contend with these voltages are the gap and valve blocks. When conditions on the distribution system are normal, the gap element permits a minute grading current to pass to ground. Because of the relatively higher resistance across the gap, no voltage exists across the valve blocks.

Silicon carbide arresters contain series gaps that protect valve elements from continuous power frequency voltage and long-time overvoltage excursions (such as those caused by ferroresonant conditions). The series gap is the insulating means during normal voltage conditions. Besides keeping voltage across the valve elements below sparkover values, the gap performs an important secondary function of interrupting the power-frequency current that follows the transient current discharged by the arrester by not re-striking on subsequent half-cycles of power-frequency voltage after the first follow-current zero. A silicon carbide surge arrester is a clamping device. The metal-oxide surge arrester is a relatively recent innovation (i.e. mid-1970s), so most lightning arresters in nuclear power plant switchyards and feeder circuits are the gapped silicon carbide type. However, they are likely to be replaced by the metal-oxide arrester because of its dominance in the commercial market.

Metal-oxide surge arresters are typically constructed without series or shunt gaps (but there are innovations with them); they rely, instead, on their valve elements to withstand the line voltage during normal operation. The valve elements start to conduct sharply at a precise voltage level and cease when the voltage drops below this level. A series gap is usually not required to insulate a metal-oxide arrester from ground because the arrester's valve elements permit only low leakage currents at operating voltages; nor is a series gap needed to interrupt power follow current that does not exist as long as the applied voltage is below the conduction voltage. This arrester maintains its protective characteristics provided it is not required to dissipate more energy than it can tolerate. The conduction voltage depends on temperature, decreasing as the temperature increases.

### Evaluation and Technical Basis

1. ***Scope of the ageing management programme based on understanding ageing:***

Lightning Protection and Grounding Systems.

The list below provides degradation mechanisms/ageing effects generally associated with lightning protection and earth-termination system:

|  |  |  |
| --- | --- | --- |
| **Material** | **Degradation  mechanism** | **Ageing effect** |
| Welded copper connections | Fatigue | Loss of electrical function, loss of mechanical function due to fatigue |
| Copper (for other than welded copper connections) / Aluminium / Steel | Corrosion | Increased resistance of connection due to corrosion  Loss of electrical function, loss of mechanical function due to corrosion, |
| Fatigue | Loss of electrical function, loss of mechanical function due to fatigue. |

MV and HV Surge Arresters

The list below provides degradation mechanisms/ageing effects generally associated with MV and HV surge arresters:

|  |  |  |
| --- | --- | --- |
| **Surge Arrester type** | **Degradation mechanism** | **Ageing effect** |
| Metal-Oxide Surge Arresters | Surge / Voltage Spike | Cracking, loss of material properties:   * The arrester’s temperature is raised above the thermal stability limit, and the energy absorbed by the arrester exceeds heat dissipated by the arrester housing. * A small hole is made from melting of the ZnO material when there is excessive current concentration. * Non uniform current distribution can cause non-uniform heating within the ceramic material and if the thermal stress exceeds the strength of the metal oxide, the arrester block may crack.   For each failure mode the outcome is the same: an electrical short circuit leading to operation of protection. |
| Gapped Silicon-Carbide Surge Arresters | Surge / Voltage Spike | Cracking, loss of material properties:   * Changes in the grain structure of the material leading to short circuit and operation of protection.   Increased resistance of connection:   * Loss of housing tightness; spark gap wear; or degraded element resistance from wear |

1. ***Preventive actions to minimize and control ageing degradation:***

Lightning Protection and Grounding Systems

Preventive actions to minimize ageing degradation can consist of using cathodic and/or anodic protection devices.

Preventive actions to prevent damage to the equipment may be suggested such as the following:

* At the time of the design, the possible routes for corrosion of the system may be analysed and corrective action proposed to ensure the functions of the earth network without replacement, for the service life of the installation. An analysis may be carried out to ensure the ability of the earth network to perform its function in time, without any significant loss of mass and for the service life specified.
* The connection in the earth or to structures is welded. Note: Welded copper connections have no proven structural corrosion.
* Mechanical constraints, such as the passage of railway lines or roads, likely to damage the buried system may be identified and taken into account for the design of structures and appropriate protection
* Preliminary inspection is performed in order to secure that excavation work is preceded by identification of hidden cables and conductors in order to prevent damages on the grounding grid.
* Down conductors from the lightning protection system are protected in order to prevent physical impact. It is important that the protection is designed in such a way that it does not affect the protective function of the down conductor or obstruct the possibility to inspect the installation.
* Procedures are established to secure that exposed un-insulated copper wires connected to the earth-termination system are verified and their condition is assessed and documented.

Global ohmic resistance measurement of the earth terminal system is not possible because of its size. Therefore, resistance measurements during the equipotential bonding continuity test are performed as required by the lightning protection and protection for safety standards [2-4].

MV and HV Surge Arresters

Preventive actions to minimize ageing degradation can consist of implementing and using leakage current device and infrared thermographic camera for overheating detection.

Preventive actions to prevent damage to the equipment may be suggested such as the following [5]:

* Inspection of porcelain for cracks (if applicable);
* Cleaning arrestors;
* Torque electrical connections .

1. ***Detection of ageing effects:***

Lightning Protection and Grounding Systems

Low ohmic resistance measurements of all connections attached to the protective equipotential bonding are performed periodically or, in the event of civil works being undertaken in the area, when the opportunity arises.

Control of the earth-termination system is performed periodically (according to corrosion risk analysis) via earth pits.

Visual inspections of all accessible parts of the systems are carried out periodically. In addition, consideration should be given to using divers to access and inspect submerged grounding systems, particularly in turbulent areas e.g. canals or drainage system, where fatigue failures are more likely to occur.

IEC 62305 (Parts 3-4) [4] describe in more detail the maintenance and inspection of lightning protection systems. Part 4 provides information on the Lightning Electromagnetic impulse (LEMP) protection system for electrical and electronic systems within a structure. It recommends the earthing system should be a Type B arrangement i.e. a fully connected ring earth electrode that is sited around the periphery of the structure and is in contact with the surrounding soil for a minimum 80% of its total length.

MV and HV Surge Arresters

Although some countries rely solely on non-invasive thermographic or PD surveys, and visual inspections of accessible parts on a routine basis, there is evidence of others carrying out more invasive electrical checks including:

On line monitoring of leakage currents to ground (µA), to allow trending and comparisons between phases.

DC Insulation Resistance (IR) measurements

Power Factor (PF), AC Dielectric Losses test (TD), and Dielectric Spectroscopy testing (DS)

1. ***Monitoring and trending of ageing effects:***

Results from measurement of attribute 3 are trended.

1. ***Mitigating ageing effects:***

Possible preventive actions regarding ageing and damage are given in attribute 2.

1. ***Acceptance criteria:***

Lightning Protection and Grounding Systems

Any indication or relevant conditions of degradation detected are evaluated based on related standards [2-4] and guides such as SSG-34 [6].

MV and HV Surge Arresters

Any indication or relevant conditions of degradation detected are evaluated based on related standards [1, 7-9 and 11]

1. ***Corrective actions:***

An engineering evaluation is performed, and corrective action taken if unacceptable conditions are found.

1. ***Operating experience feedback and feedback of research and development results:***

This AMP addresses the industry-wide generic experience. Relevant plant-specific operating experience is considered in the development of the plant AMP to ensure the AMP is adequate for the plant. The plant implements a feedback process to periodically evaluate plant and industry-wide operating experience and research and development (R&D) results, and, as necessary, either modifies the plant AMP or takes additional actions (e.g. develop a new plant-specific AMP) to ensure the continued effectiveness of the ageing management.

Lightning Protection and Grounding Systems

No ageing OPEX has been identified, nevertheless industrial experience has shown that un-insulated copper wires buried in ground often are damaged when excavation work are performed on site.

At the time when this AMP was produced it was noted that Lund University in collaboration with Energiforsk were seeking to review and improve methodologies to detect degradation in earthing grids [12]-[14].

MV and HV Surge Arresters

Experience shows that SPDs are typically exchanged at the same time as the primary asset e.g. transformer or switchgear. However, it is noted that [11] recognises both time based and condition based replacement strategies.

1. ***Quality management:***

Site quality assurance procedures, review and approval processes, and administrative controls are implemented in accordance with the different national regulatory requirements, (e.g., 10 CFR 50, Appendix B [10]). The modification of lightning protection, earth-termination systems, and MV & HV surge arresters are carefully studied to ensure the lack of regression.

References

1. ELECTRIC POWER RESEARCH INSTITUTE, Transmission Line surge Arrester - White Paper, EPRI, Palo Alto, CA: 1010233, 2005
2. INTERNATIONAL ELECTROTECHNICAL COMMISSION, Low-voltage electrical installations – Part 4-41: Protection for safety –Protection against electric shock IEC 60364-4-41, Geneva, 2005.
3. NTERNATIONAL ELECTROTECHNICAL COMMISSION, Low-voltage electrical installations – Part 6: Verification, IEC 60364-6, Geneva, 2006
4. NTERNATIONAL ELECTROTECHNICAL COMMISSION, Protection against lightning, IEC 62305-1 to 4, Geneva, 2010.
5. ELECTRIC POWER RESEARCH INSTITUTE, Switchgear and bus maintenance, EPRI Palo Alto CA: 1013457, 2006
6. INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Standard Series No. SSG-34, Design of Electrical Power Systems for Nuclear Power Plants, VIENNA, 2016.
7. UNITED STATES NUCLEAR REGULATORY COMMISSION, Aging Assessment of Surge Protective Devices in Nuclear Power Plants, NUREG/CR-6340, BNL-NUREG-52463, US NRC, 1996
8. IEC 60099-4 ‘Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a. c. systems’, Edition 2.1, 2006–07
9. ABB, Over-voltage protection - Metal oxide surge arresters in medium voltage systems, ABB Application Guidelines, 5th revised edition, May 2011
10. UNITED STATES NUCLEAR REGULATORY COMMISSION, 10 CFR Part 50, Appendix B, Quality Assurance Criteria for Nuclear Power Plants, Office of the Federal Register, National Archives and Records Administration, USNRC, Latest edition.
11. ELECTRIC POWER RESEARCH INSTITUTE, Switchyard Equipment Application and Maintenance Guide, EPRI, Palo Alto, CA: 1026664, 2012
12. ENERGIFORSK, Grounding Grid Integrity, Pre-study, PETER ULRIKSEN, TORLEIF DAHLIN, Stockholm, 2017
13. InterNational Electrical Testing Association, Jeff Jowett Megger: Ground Grid Integrity, www.netaworld.org, Portage MI, 2008
14. IEEE Transactions on Industry Applications, A Novel Method for Fault Diagnosis of Grounding Grids, Volume: 51, Issue: 6, Nov.-Dec. 2015