Maintenance Analysis of Lightning Protection Technology for Medium Wave Broadcasting Stations (Postprint)

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Abstract

Medium wave relay stations, as transmission facilities for sending signal electromagnetic waves, primarily provide audio-visual relay services for broadcasting and play an important role in people's lives. However, in their actual operation, they also need to overcome objective factors to ensure the continuity and stability of information transmission. Lightning is an important factor that damages and interferes with medium wave relay stations, seriously threatening the safe and effective broadcasting. This problem cannot be fundamentally solved to date and can only be addressed by renovating existing facilities and equipment through diverse methods to achieve ideal lightning protection effects. This paper analyzes and explores the lightning protection technology maintenance of medium wave relay stations.

Full Text

Analysis of Lightning Protection Technology Maintenance for Medium-Wave Relay Stations

Abstract: Medium-wave relay stations serve as critical transmission facilities for electromagnetic broadcast signals, providing essential audio-visual relay services that play an important role in daily life. However, their operation must overcome objective environmental factors to ensure continuous and stable information transmission. Lightning represents a significant destructive and interfering influence on medium-wave relay stations, seriously threatening safe and effective broadcast operations. This problem has yet to be fundamentally resolved and can only be addressed through diverse methods of renovating existing facilities and equipment to achieve ideal lightning protection effects. This paper analyzes lightning protection technology maintenance for medium-wave relay stations.

Keywords: medium-wave relay station; lightning protection technology; maintenance

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1. Types of Lightning Damage to Medium-Wave Relay Stations

Lightning damage to medium-wave relay stations can be categorized into six primary types. First, electromagnetic pulse damage occurs when lightning strikes ground protrusions, buildings, signal poles, or other structures, generating electromagnetic pulses that create overvoltage or overcurrent within the station's signal system, severely damaging signal equipment. Second, direct lightning strikes, though rare for relay stations, can directly impact transmission circuits, towers, building structures, or other equipment. The microelectronic components in modern signal systems are particularly vulnerable to direct strikes, which can cause catastrophic damage or even complete station paralysis. Third, shock wave damage results from high-voltage shock waves penetrating equipment, power supply systems, or high-voltage lines. The excessive voltage levels overwhelm signal system equipment, causing damage and disrupting normal transmission operations [2]. Fourth, backflash damage occurs when lightning strikes the transmission tower, raising the potential of the nearby grounding grid and creating a large potential difference between equipment enclosures and power supplies. This can cause current to flow through enclosures into power supplies, damaging equipment. Fifth, lightning surge damage affects relay stations during operation when lightning surges, combined with numerous microelectronic components in signal equipment, destroy both signal devices and communication lines upon intrusion. Sixth, electromagnetic induction damage arises during lightning discharge, where induced electromagnetic fields 侵入 outdoor transmission signal lines and power lines, easily destroying series-connected electronic devices.

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2. Analysis of Lightning Protection Technology Problems

Two major issues plague lightning protection systems. First, grounding grid damage frequently occurs during station operation, primarily because farmers working the land beneath transmission towers inadvertently sever underground copper conductors. This severely compromises the grounding system's effectiveness and reduces station stability. When the grounding grid is damaged, the relay system automatically reduces copper foil charge capacity during live broadcasts, creating electric shock hazards that threaten lives and property. Second, four-level discharge devices—including graphite discharge spheres, transmitter internal discharge spheres, and metal discharge spheres—suffer from excessive clearance gaps, resulting in poor lightning protection performance. This necessitates strict adherence to installation specifications and proper gap adjustment [3]. Given the station's structure and operational characteristics, which make it a natural lightning attractor, practical design approaches must ensure effective discharge protection after lightning strikes. Notably, under normal temperature and pressure conditions, discharge sphere spacing should be 1mm per 1kV, though climatic factors often require adjustment to 1mm per 500V. For live broadcast discharge spheres operating at approximately 316V, spheres should remain insulated with optimal spacing of 2–3mm. When lightning voltage across graphite discharge spheres exceeds 1000–1500V, spacing should be maintained at 5mm, while copper discharge spheres inside transmitters require 1mm spacing to achieve saturated conduction or normal conduction states, maximizing discharge effectiveness during lightning strikes on medium-wave transmission towers.

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3. Lightning Protection Maintenance Measures for Medium-Wave Relay Stations

3.1 Strengthening Grounding Grid Renovation Grounding grid improvement focuses on two aspects. First, for lightning current dissipation, composite grounding networks should be added to the antenna tower structure based on the original grounding grid. This enhances lightning discharge speed, reduces grounding resistance, and provides effective current dispersion paths. Second, for resistance reduction, resistivity-reducing agents represent an important method, though several concerns exist: (1) grounding electrode corrosion, as agents can corrode electrodes and reduce effectiveness; (2) stability issues, where large amounts of inorganic salts provide short-term resistance reduction but cause rapid rebound; and (3) environmental pollution, as buried agents containing heavy metals contaminate soil. Therefore, comprehensive consideration of environmental impact, stability, and corrosion is necessary. An alternative approach involves mixing water-absorbing agents and conductive powder into the original grounding grid soil in specific proportions to improve resistivity and achieve effective resistance reduction.

3.2 Lightning Protection for Transmission Towers Medium-wave relay station transmission towers employ metal discharge spheres in a guyed-wire configuration, typically exceeding 100 meters in height. During lightning strikes, adjusting the discharge gap of these spheres channels current into the ground, or alternatively, installing graphite discharge devices in antenna tuning units dissipates residual current, effectively protecting the tower [4]. Direct lightning strikes on metal discharge spheres can create high impedance and short-circuit discharge phenomena. However, graphite discharge devices utilize the characteristics of graphite magnetic ring coils and special materials to maintain normal transmitter operation while providing effective protection. Magnetic ring installation enables lightning current dissipation and offers excellent protective effects. Using capacitive DC-blocking characteristics effectively prevents lightning DC current from entering transmitters. Additionally, coordinated operation between tower discharge spheres and graphite discharge devices helps prevent direct lightning damage to medium-wave transmitters.

3.3.1 Indoor Equipment Protection Three key measures protect indoor equipment. First, shielded cables should be used for all connections to outdoor signal system equipment, ensuring proper cable shield grounding. Second, lightning protection devices—including lightning wires, lightning nets, and lightning rods—must be appropriately installed in areas with dense outdoor signal system equipment to protect cables, towers, and signal devices from lightning strikes. Installation requires careful positioning, with ground wires maintaining safe distances from other equipment and cables to prevent chain lightning induction effects [5]. Third, grounding techniques must be properly implemented for towers, receiving equipment, and signal transmission towers during installation to prevent damage from lightning electromagnetic pulse shielding failures.

3.3.2 Outdoor Equipment Protection Four measures address outdoor equipment vulnerabilities. First, dedicated high-voltage lightning arresters should be installed on high-voltage power transmission signal lines to ensure stable and safe line transmission. Second, overvoltage protectors must be installed at power entry points of indoor electronic core cabinets to prevent microelectronic equipment damage from surge voltages, as lightning primarily 侵入 s through weak current equipment power lines. Third, shielding against interference is crucial because induced lightning creates radio, electrical, electromagnetic, and electrostatic interference that causes surge voltages in signal systems. Installing current protection devices in series at signal line entrances effectively suppresses overcurrent and prevents equipment damage. Fourth, equipotential bonding is essential. During lightning strikes, current flows through down conductors into the ground, creating radial potential distributions that can damage electronic equipment through high potential differences. Proper local equipotential bonding connections, using connection rods linked to branch rods, ensure balanced potentials and rapidly dissipate lightning current into the ground through low impedance, preventing signal equipment from being affected by radial potentials.

4. Conclusion

With socioeconomic development and scientific-technological advancement, medium-wave relay station systems and equipment have achieved significant improvements in informatization and electronicization, raising higher requirements for lightning protection. The effectiveness of lightning protection directly impacts program signal transmission, affecting social stability and daily life. Therefore, lightning protection work must be based on practical conditions, addressing lightning hazards by promptly eliminating potential lightning scenarios, strengthening grounding grid renovation, and implementing comprehensive lightning protection for transmission towers and indoor/outdoor equipment. These measures better prevent losses from lightning strikes, reduce lightning damage to relay stations, and effectively ensure normal station operation.

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Note: Figure translations are in progress. See original paper for figures.