Print Edition of the Optimized Lightning Protection System for TV/FM Relay Stations

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Abstract

This paper describes the application of common grounding devices, low-voltage distribution systems, signal systems, equipotential bonding design and construction, and lightning vector control grounding technology in the lightning protection system renovation at Yongzhou Dahua Mountain TV/FM Relay Station.

Full Text

Optimization and Retrofitting of Lightning Protection Systems for TV/FM Relay Stations

Abstract: This paper presents the optimization and retrofitting of the lightning protection system at the Yongzhou Dahua Mountain TV/FM Relay Station, focusing on the implementation of shared grounding devices, low-voltage distribution system protection, signal system protection, equipotential bonding design, and the application of lightning current vector control grounding technology.

Keywords: Lightning protection; Grounding; SPD; Vector control grounding technology

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The Dahua Mountain Relay Station currently operates two sets of terrestrial wireless digital television systems, transmitting 12 central and 10 provincial/municipal wireless digital TV signals, along with 6 radio channels and 4 analog television channels. Located in Qiyang County, Yongzhou City at coordinates 111°52 12 E, 26°41 9 N, and an altitude of approximately 601 meters, the station features a new 85-meter transmission tower—the tallest metal structure in the surrounding area—making it highly susceptible to lightning strikes. Lightning has consistently been a critical factor affecting broadcasting transmission stations. Since its establishment in 1985, the station's lightning protection and grounding system has never undergone comprehensive systematic retrofitting. Due to its advanced age, the ground resistance has increased and protective performance has degraded, resulting in multiple lightning strikes that damaged transmission equipment last year.

1. System Retrofitting Content

Lightning primarily manifests as direct strikes and induced surges, with induced surges mainly taking the form of electrostatic induction, electromagnetic induction, and lightning pulses. To effectively prevent equipment damage from lightning strikes and eliminate safety broadcast accidents, our station conducted systematic optimization and retrofitting in accordance with national standards and industry regulations.

The system retrofitting encompasses five main aspects: (1) shared grounding device retrofitting; (2) low-voltage distribution system lightning protection facilities; (3) signal system lightning protection facilities; (4) equipotential grounding facilities retrofitting; and (5) application of lightning current vector control grounding technology. For the shared grounding device, we employed 40$×4mmcopperstripsashorizontalgroundingconductorsand500×400×60mmhigh−efficiencygroundingmodulesburiedatadepthof0.5meters.Verticalgroundingelectrodesconsistingof25×1500 cladsteelrodsand50×2500mmelectrolyticiongroundingrodswereinstalledevery5meters.Additionally,450×30 mm high-efficiency grounding modules and long-acting corrosion-resistant resistance-reducing agents were placed every 10 meters to improve the dielectric coefficient around the grounding electrodes and increase their equivalent capacitance, forming the outdoor grounding busbar (as shown in [Figure 1: see original paper]).

2.2 Retrofitting of Lightning Protection Facilities for Transmission Room Power Supply Lines

Due to the long overhead transmission distance of high-voltage power supply lines to the mountain and their installation through hilly terrain, the probability of lightning strikes is extremely high. Lightning intruding through high-voltage lines into transformers and the equipment room accounts for over 80% of lightning-related incidents. Therefore, overvoltage protection of power supply lines is the top priority for lightning protection at mountain stations.

The retrofitting includes two main measures: (1) Installation of shielding facilities for power supply lines. The low-voltage power supply lines entering the equipment room are installed underground. (2) Installation of surge protective devices (SPDs) for the low-voltage distribution system. We designed and installed a three-level SPD system to reduce overvoltage damage to equipment introduced through power supply lines. Level I: Install voltage-switching type

SPDs at the transformer low-voltage outlet and diesel generator inlet, with impulse current capacity of 25 kA (10/350 μs), response time <25 ns, protection level of 2.5 kV, and a 63 A circuit breaker, primarily for protection against direct lightning conducted along transmission lines. Level II: Install voltage-limiting type SPDs at the equipment room distribution cabinet inlet, with impulse current capacity of 80 kA (8/20 μs), response time <25 ns, and protection level of 1.3 kV, mainly for induced lightning protection. Level III: Install voltage-limiting type SPDs at transmitter cabinet power inlets, air conditioner power inlets, and AC/DC inverter cabinet inlets, with impulse current capacity of 20 kA (8/20 μs), response time <25 ns, protection level of 1.0 kV, and rated voltage of 380 V, providing final protection for transmitters and other equipment (as shown in [Figure 2: see original paper]).

2.1 Construction of New Shared Grounding Device

According to the *Technical Specifications for Grounding of Radio and Television Engineering Processes*, the direct lightning grounding for the transmission tower, induced lightning grounding for the equipment room, operational grounding, and protective grounding must share a common grounding device, with power-frequency ground resistance not exceeding 1 Ω and lightning impulse ground resistance not exceeding 10 Ω [1]. Given our station's high altitude, frequent severe convective weather, and geological conditions dominated by rock or weathered stone, the grounding system construction faces significant challenges. To ensure excellent corrosion resistance, stable ground resistance values, and improved lightning current dissipation performance while effectively reducing direct lightning impulse ground resistance [2], we designed multiple discharge paths for tower lightning strikes. Multiple mesh grounding conductors were extended along the tower foundation, with six deep-well grounding devices (Ø150 mm × 30 m) installed. Each deep well contains a Ø150$×30000*mmcopperstripasaverticalgroundingelectrode*, *with*50×$2000 mm electrolytic ion grounding rods welded every 10 meters, all constructed using exothermic welding.

2.3.1 Lightning Protection for Signal Source Equipment

When the tower is struck by lightning, the massive lightning current dissipated to earth creates a strong transient magnetic field around the tower structure. Through electromagnetic induction, communication lines within this magnetic field induce high electromotive force, generating overvoltage that damages signal equipment ports. Since signal equipment ports operate at low voltages with very limited overvoltage and overcurrent withstand capability, they are extremely vulnerable to induced lightning damage.

Signal lines entering the equipment room primarily consist of antenna feeders, coaxial cables, and optical fibers, all installed overhead. The low-noise block downconverters (LNBs) of satellite receiving antennas have been damaged by lightning strikes multiple times, causing signal transmission interruptions. Therefore, signal source system retrofitting was implemented in two aspects: (1) Shielding facility renovation for outdoor cables. An equipotential bonding ring (40$×$4 mm hot-dip galvanized flat steel) was installed on the equipment room roof, with satellite antenna bases, feed tube bridges, and signal cable shielding facilities connected to the grounding bar. Coaxial cables from satellite antennas to the equipment room were installed in Ø50 mm hot-dip galvanized steel pipes with both ends grounded. Coiled cables on the building exterior were removed and rerouted according to lightning protection requirements. Independent dedicated down conductors were installed to connect the roof grounding bar to the new grounding grid. (2) Overvoltage protection for signal equipment ports. The strengthening members of optical fibers entering the equipment room are grounded, while appropriate signal line SPDs are installed at satellite receiver ports and network equipment ports.

2.3.2 Installation of Equipotential Bonding Facilities and Rational Cabling

Equipment room equipotential bonding facilities serve as the "bridge" connecting equipment and lightning protection facilities to the grounding system, representing a critical component of the lightning protection grounding system. If equipotential bonding facilities are inadequate or improperly installed, the lightning protection grounding device cannot perform its intended function. Therefore, equipotential bonding installation is crucial—the "last mile" of the entire lightning protection system. We implemented M-type equipotential bonding in the equipment room using 30$×$3 mm copper strips to create a bonding ring. All metal enclosures, cabinets, racks, metal conduits, shielded cable outer layers, equipment anti-static grounds, safety protection grounds, and SPD grounding terminals must be connected to this equipotential bonding network via the shortest possible paths.

2.4 Application of Lightning Current Vector Control Grounding Technology

Before a lightning strike occurs, the air terminal, down conductors, and entire grounding system remain at zero potential equal to earth, with no potential backflash between the grounding device and connected equipment. However, after a lightning strike, as the lightning current flows through down conductors and the entire grounding system, the voltage drop across different parts of the grounding device is unequal, creating voltage differences between various parts of the grounding system and causing potential backflash (or voltage 反击) between the grounding device and connected equipment.

Lightning current vector control grounding technology addresses this by providing a bypass path that forces lightning current to discharge only through designed channels, thereby protecting transmission facilities [3] (as shown in

[Figure 3: see original paper]). Based on the traditional integrated grounding grid, all grounding conductors in the equipment room are functionally divided into operational ground, lightning protection ground, and protective ground, with a "lightning current vector controller" connected in series between them. When lightning occurs, the vector controller activates, isolating the connection between the integrated grounding grid and the operational/protective ground lines, preventing lightning current on the grounding grid from backfiring into protected equipment through operational or protective ground lines.

Upon project completion, our station engaged a qualified testing organization for system acceptance. Grounding is critical to the effectiveness of the entire lightning protection system. We conducted tests at four tower bases, equipment room equipotential bonding points, and SPD grounding terminals for each transmitter. The tower grounding resistance measured 0.94 Ω, with all other test points meeting design requirements. Additionally, we tested all SPDs and found two units non-compliant, which were promptly replaced.

References

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