On Emergency Handling Methods and Preventive Measures After Lightning Strike Disasters at High-Altitude Radio and Television Broadcast Stations (Postprint)

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Abstract

Correctly assess the extent of damage and damage pathways of lightning disasters to radio and television transmission facilities, learn from emergency repair experience and preventive measures, thereby ensuring safe broadcasting of radio and television signals and the safety of radio and television facilities.

Full Text

Emergency Response and Preventive Measures for Lightning Disasters at Mountainous Radio and Television Transmission Stations

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Abstract

Correctly assessing the extent and path of lightning damage to radio and television transmission facilities, and drawing upon repair experiences and preventive measures, are essential for ensuring the safe broadcasting of radio and television signals and the security of broadcasting infrastructure.

Keywords: Transmission stations; Receivers; Transmitters; Lightning disasters; Emergency repair; Grounding resistance; Copper materials; Lessons learned

Mountainous TV and FM transmission stations are typically located at high altitudes due to their operating frequencies in the VHF spectrum. This special geographical positioning makes their towers, various RF cables, and high-voltage power supply lines primary targets for lightning strikes. The resulting damage to broadcasting facilities and consequent prolonged program interruptions are countless, making lightning disasters a major threat to safe broadcasting operations. How to quickly and effectively identify damaged equipment, perform repairs, and resume broadcasting after a lightning strike has become a critical means of reducing outage rates. The following account of our station's equipment repair and broadcasting recovery process after a lightning strike serves as a case study for discussion and reference, hoping to provide useful experience for colleagues at other stations.

The Lightning Incident and Initial Response

In the early morning of July 24, 2016, a severe lightning strike invaded our station through the 10kV power supply line. Due to aging lightning protection facilities at the transformer's high-voltage end, the discharge protector was instantly destroyed, preventing adequate dissipation of the lightning energy. The surge further penetrated through the transformer and low-voltage distribution cabinet into the transmission building, as well as offices and dormitories, damaging dozens of pieces of equipment. Immediately after the incident, our station organized emergency repair efforts. We first coordinated with the power utility to replace the high-voltage discharge protector, then inspected the transformer and low-voltage distribution system. After confirming normal operation, power supply was restored with stable voltage readings across all parameters.

Systematic Equipment Repair Process

Broadcasting Equipment: The "China Voice" FM transmitter had normal 380V power supply. Upon startup, the exciter and final power amplifier appeared normal with proper antenna feed indications, but the exciter showed no audio signal. Following the signal path forward, we discovered the satellite receiver display was abnormal with no signal strength indication. After replacing the receiver still yielded no signal, we proceeded to check upstream components and found that the satellite antenna's LNB had been damaged along with the receiver by the severe lightning surge. Replacing the LNB immediately restored the receiver input signal, and the transmitter resumed normal broadcasting. Concurrently, the "Rural Broadcasting" service, which sources its signal from the same "China Voice" receiver, also returned to operation.

Television Transmission Equipment: In the TV transmission room, we first inspected the CCTV-1 and CCTV-7 transmission equipment. The 380V power supply for both channels was normal. After starting the transmitters, all indicators for control systems, exciters, and antenna feed systems were normal, but no RF signal was output—the transmitters were operating under no-load modulation without effective signal broadcast. Following the principle of step-by-step forward checking, we examined the encrypted satellite receivers, which showed normal indications. Adhering to the principle of checking simpler components first, we quickly replaced the C-band LNBs, which restored normal ground station signals and brought both CCTV-1 and CCTV-7 transmitters back to normal operation. Within a short time, four sets of radio and television programs had resumed normal broadcasting.

The experience gained from repairing the "China Voice" and CCTV transmitters proved valuable for rapid recovery. Applying the same logic, we decisively replaced the C-band LNB for the CMMB equipment, which immediately restored its normal broadcasting.

Because our station's local TV and radio program transmission system differs from the previous systems, a different inspection approach was required. When we powered on the transmitter, only the 380V supply was normal—the transmitter itself could not operate properly. Inspection revealed abnormal exciter display. After confirming normal audio input signal and proper final power amplifier and antenna feed system operation, we determined the RVR exciter was malfunctioning. Opening the exciter revealed lightning burn-through damage on both the audio input port (XLR connector) and data port, with a 33pF patch capacitor at the circuit input burned out. After replacing the XLR connector and patch capacitor, the exciter returned to normal and the transmitter resumed operation. The damaged data port was disconnected to prevent interference with analog port operation. After seven hours of intensive repair efforts, our station's transmitted radio and television signals were essentially fully restored.

Analysis and Preventive Measures

To prevent similar lightning accidents in the future, we thoroughly inspected all lightning protection facilities from the 10kV supply down to low-voltage distribution and individual equipment. The condition of these facilities is critical for ensuring future normal operation.

First, we examined the 10kV high-voltage lightning discharge devices and found that the three-phase high-voltage discharge insulators had far exceeded their national standard service life without annual high-voltage withstand and threshold discharge testing. These 10kV high-voltage lightning protection devices—high-voltage insulators—required immediate replacement.

Second, during this incident, only one set of surge protectors in the low-voltage distribution cabinet and transmitter three-phase 380V power supply system activated correctly when high voltage surges entered through the power network, safely diverting the harmful lightning to ground. The other fourteen surge protectors failed to activate, allowing high-voltage lightning to enter equipment and cause damage. The preventive measure for this link is to replace all surge protectors with nationally standardized specifications.

The final critical component is the shared lightning protection grounding system for all equipment, which plays a vital role in responding to lightning disasters. Inspection revealed that our station's grounding copper plate, buried 6 meters underground, had severely corroded. The connection between the grounding copper plate and connecting copper strips had eroded to the point of being essentially disconnected. Ground resistance measured 7Ω, far exceeding the national standard of less than 1Ω. While we cannot assert that 7Ω resistance was the sole cause of this lightning disaster, high-resistance grounding significantly impacts equipment operation and is a crucial factor in safely dissipating disaster-level voltages and currents to earth. Since the grounding copper plate was severely corroded, the only solution was complete replacement. We procured a 100cm$×200*cm*×$1cm copper plate, buried it in a 6-meter-deep pit, placed 50kg of salt and 30kg of crushed charcoal beneath the plate, then welded new copper strips to the plate and connected them to all equipment in the machine room. There exists a significant resistivity difference between metallic copper plates and soil, creating a resistivity transition zone that hinders effective contact between grounding materials and earth. Salt and charcoal, under the action of soil minerals and moisture, easily form various electrolytes that facilitate effective connection between copper materials and earth, reducing grounding resistance by approximately one-third. Thus, salt and charcoal are essential auxiliary materials for lightning protection grounding. However, using salt and charcoal also has the disadvantage of accelerating copper corrosion through chemical reactions, requiring reinstallation of grounding copper plates every one to two years at relatively high cost.

We also performed grounding tests on the 33-year-old antenna tower as a precautionary measure. The grounding resistance reached 17Ω. The treatment method was similar to equipment grounding. After excavating and removing the original steel strip ground grid, we found severe corrosion with some strips oxidized and fractured, essentially losing their lightning conduction and protection capability. We then laid a 1m$×$1m grid of 4cm-wide steel strips around the tower base, incorporating salt and charcoal over an area of 320 square meters. Proper tower grounding not only effectively prevents lightning from entering equipment room via feed cables from the transmission antenna, but also provides better safety protection for equipment and operating personnel—this cannot be overlooked. After completing the grounding copper plate and tower ground grid installation, resistance measurements were 0.93Ω and 2.7Ω respectively—the former fully meeting the national standard of less than 1Ω, the latter essentially compliant.

Fortunately, the 13 sets of radio and television antennas and feed cables mounted high on the tower were undamaged in this severe lightning disaster. Antennas and feed cables are highly vulnerable to lightning strikes when exposed outdoors. The only protection for these components is the supporting tower itself—only with proper tower grounding can antenna and feed cable safety be ensured.

Lessons Learned and Recommendations

Reflecting on this emergency repair process after the severe lightning strike, several points emerged as valuable lessons for future work and for colleagues in the industry.

First, as equipment maintenance personnel, one must thoroughly understand equipment operation processes and have comprehensive knowledge of equipment status to maintain full situational awareness.

Second, these incidents often exhibit common failure patterns. For example, since the lightning strike affected the C-phase in the three-phase high-voltage supply line, we can infer that any 220V equipment connected to the C-phase supply circuit is potentially susceptible to lightning damage.

Third, the damaged equipment in the system consisted primarily of low-voltage, low-current devices, which share a common characteristic—poor surge voltage withstand capability, making them vulnerable to collateral damage. Therefore, to ensure emergency safe broadcasting at such stations under similar special circumstances, adequate spare parts for these easily damaged components should be maintained.

Fourth, during this incident, secondary (low-voltage distribution surge protectors) and tertiary (transmitter surge arresters) lightning protection played crucial roles in ensuring normal operation of major equipment. However, it should be noted that some surge protectors may lose their protective capability after a single lightning strike (either by false triggering within safe voltage ranges or complete loss of lightning resistance). To prevent similar accidents in subsequent strikes, secondary and tertiary surge protectors must be replaced after such incidents to eliminate hidden dangers. In the absence of lightning incidents, surge protector insulation resistance should be tested regularly, and they should only continue in service if measurements show no significant change from previous results.

Fifth, do not neglect inspection of high-frequency grounding for transmitters and auxiliary equipment, as well as lightning protection ground networks for transmission towers. During lightning incidents, all high-voltage surges are dissipated to ground through lightning protection facilities, and equipment high-frequency grounding serves as an important—sometimes the only—pathway for lightning dissipation. Poor high-frequency grounding (ground resistance greater than 1Ω) may prevent adequate and timely surge dissipation, potentially increasing equipment damage probability and scope, and could even cause personnel safety accidents.

References

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