REPORT 943-1 *

PROTECTION OF SOUND-BROADCASTING STATIONS AGAINST ATMOSPHERIC ELECTRICITY

(Question 48/10)

(1982-1986)

1. Introduction

The WARC-79 identified the requirement for the service Study Groups of the CCIR to give consideration to the needs of their services to effect protection of installations against atmospheric electricity, particularly lightning discharges. This Report, relating to sound broadcasting, complements information for the fixed and radio-relay services contained in Reports 861 and 932 respectively.

CCITT Study Group V is currently considering the protection of telecommunication lines and equipment against lightning discharges and the overall subject of lightning protection is under review by IEC Committee TC 81.

2. The lightning process

Lightning discharges occur when the electrostatic potential created by convective charge generation in thunderclouds exceeds the breakdown potential. Discharges may occur from cloud-to-cloud, cloud-to-air or cloud-to-ground. With the cloud-to-ground type, both the discharge itself and the electrostatic stress before and during a storm which can be as great as 5-10 kV/m [Surutka and Veličković, 1973], may cause damage.

As a charged cloud approaches a mast, it induces charges of opposite sign on the sections of the stays. When the cloud is discharged by a lightning stroke to the ground, the field collapses in a time interval of the order of a microsecond. Charges on the stays produce high voltage across the insulators. Voltages as great as 400 kV arise, leading to flashovers and breakdowns. It has been suggested [CCIR, 1982-86a] that arcs caused by static atmospheric electricity represent a greater risk of damage than direct or near lightning strokes.

* The Director, CCIR, is requested to bring this Report to the attention of the IEC.

3. Frequency of incidents

There are marked seasonal, diurnal and geographical variations in the incidence of thunderstorms. Storms tend to occur in the afternoon hours and are least frequent in the post-dawn period. They are most prevalent in the local summer at mid- and high-latitudes, but have little seasonal variation in the tropics. Their incidence is greatest over tropical land masses, but the proportions of cloud-to-cloud and cloud-to-air discharges are also higher in the tropics than at other latitudes.

Current evidence on reported incidents causing damage is scanty, but there is a marked dependence on geographical position and the precise locations of installations. In France, they are appreciably more frequent in the southern part of the country and in high mountainous areas, and in Japan, in the northern part of the country which is subject to heavy snowfalls.

4. Power dependence

Although atmospheric electricity can give rise to problems to domestic receivers, these are minor compared with those occurring at transmitting installations which generally use high masts. High-power installations (with transmitter powers in excess of 10 kW) tend to be more prone than lower-power installations, because the transmitter power is sufficient to maintain an arc discharge across components, once it is initiated, either by a lightning stroke or by wind-borne static. This situation becomes more serious as the power of the transmitters is raised.

5. Locations of flashover points and damage caused

Antennas for LF and MF use include base-fed or loop-fed steel masts which are either self-supporting or guyed with steel ropes divided by insulators into sections shorter than the resonant length. Lightning strikes can cause flashovers between the mast and the ground or on the guy insulators. Moreover, the surges thus created may result in equipment being damaged. Solid-state transmitter circuitry, antenna feed lines and antenna matching-unit capacitors, are particularly vulernable.

Base insulators are generally ceramic pillars and provided these are shunted by a discharge gap (see § 6.1) damage is rare. For low transmitter powers, stay insulators are invariably of the simple slotted glazed-ceramic egg-type set between interlocking wire loops. Although flashovers occur during lightning storms, no obviously observable mechanical damage or electrical deterioration to antenna performance is noticed in the long term. However, with the sustained discharge arising with high-power transmitters, cracked stay insulators and arc-erosion of stay wires adjacent to insulators may occur.

6. Protection methods

6.1 *Traditional spark gaps*

Base-fed radiators may have discharge gaps permanently fitted to the structure. Generally, the earthed side is connected to the radial ground system through copper conductors. Discharge gaps have a variety of forms, ranging from spheres and cylinders with gaps of less than half the diameter, to rods and loop structures. Gap settings are generous, typically 8-16 mm, to prevent rain droplets from coalescing.

In Japan, judiciously placed spark gaps made of cylindrical hard-carbon electrodes are used. Gap shapes and sizes are optimized as a function of the dominant lightning waveform encountered [CCIR, 1978-82a; NHK, 1982].

6.2 *Non-linear resistances at the guying insulators*

Silicon carbide non-linear resistances of about 1 MΩ at the working RF voltage can be employed at the guy-insulator terminals. These release the static charges on the insulated parts of the gaps, but are often destroyed if lightning strikes the mast directly.

6.3 *Transmitter shut-off*

A lightning detector placed on one of the mast stays may be installed which, when it registers a lightning discharge, momentarily (for about 1 s) causes the transmitter drive to be interrupted. In this way any flashover on a stay insulator is not followed by a power arc; the flashover extinguishes immediately and no damage is caused. The device can be made sensitive to about 5 A which is much less than the current required to cause an arc.

Alternatively, the transmitter may be shut off by measuring the standing-wave ratio at the antenna terminals arising from the arc mismatch.

6.4 *Power reduction during storms*

Substantial reduction of transmitter power during storms for high power carriers can be a useful procedure to avoid self-sustained arcs.

6.5 *Fast EMP gas discharge tubes*

These can be fitted across the output terminals of solid-state transmitters to provide protection, but have only limited life and may themselves become damaged.

6.6 *Earthing arrangements*

It is important to pay particular attention to earthing arrangements.

In some station earthing systems the radial-wire ground systems in a directional array are bonded together and connected to the earth at the transmitter building via a copper tape of cross-section not less than 75 mm^2 in a trench alongside the buried coaxial feeders from the antenna. The tape is connected to transmitter earth so as to by-pass any joints or connections in the coaxial feeders and thus reduce lightning surges in their outer and inner conductors. This practice has resulted in no known instance of lightning damage to inaccessible buried feeders.

Stay ropes are earthed alongside their concrete anchor blocks using either copper tape, aluminium tape or multi-strand stainless-steel wire. A straight path down to earth is adopted in order to prevent lightning from smashing the concrete block. Local earthing plates or spikes are used, which are not always connected to the main radial earthwire systems.

6.7 *Protection of VHF antennas*

It is common practice with VHF antennas for the radiating elements to form a d.c. short circuit (e.g. folded dipoles) and to be bonded to the mast so that lightning surges are suppressed between the inner and outer sections of their coaxial feeder cables. Decoupling of VHF feeders from MF masts using inductor-wound methods [CCIR, 1982-86b] has hitherto prevented lightning damage.

6.8 *Use of plastic ropes*

Plastic fibre "Parafil" stay ropes for low-power stations can be used to overcome the problems encountered with conventional guys.

In Yugoslavia, "Philistran" stay wires have been used successfully with transmitter powers of up to 600 kW.

7. Specific antenna designs

7.1 *France* [CCIR, 1978-82b]

7.1.1 *The Allouis LF antenna (164 kHz)*

An LF antenna specially designed for protection against lightning has been developed in France. It consists of masts less than $\lambda/4$ high and the ring of guys at the top of each mast has no insulators; this means that lightning strikes are released directly into the ground and the guys form a protective cage for the other parts of the antenna. The radiation pattern is the same as for a conventional mast. The efficiency of this type of antenna has been proved during many years of operation.

7.2 *The Netherlands* [CCIR, 1982-86c]

7.2.1 *The Flevoland MF antenna (simultaneous 400 kW on 747 kHz and 400 kW on 1008 kHz)*

The $5\lambda/8$ antenna mast is divided in half and centre-fed. The lower part is grounded and the upper section is electrostatically grounded via a $\lambda/4$ stub in the mast (the insulated ladder). The guys are not divided into sections but are insulated at both ends. The lower insulators are bridged by a network which keeps the RF current in the guys as low as necessary in order not to deform the radiation pattern. Each guy has such a network so that the total antenna system is protected against atmospheric electricity and no other special protection devices are needed.

7.2.2 *The Lopik MF antenna (120 kW on 675 kHz)*

In this base-fed $5\lambda/8$ antenna, the insulators in the guys are also bridged by a copper wire, except for those two at the ends. Coils parallel to the lower insulators minimize the currents in the guys. With this arrangement, the transmitter no longer keeps tripping in order to protect the guy insulators.

7.3 *Yugoslavia* [CCIR, 1982-86a]

7.3.1 *The Belgrade MF antenna (2000 kW on 684 kHz)*

An efficient and simple solution for eliminating static electricity has been applied to the 235 m high Belgrade MF antenna. It is based on the use of static-drain coils, which are connected in parallel to the guy insulators, forming anti-resonant circuits with them at the operating frequency [Surutka, 1978, 1979; Surutka and Veličković, 1984].

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[1978-82]: **a.** 10/187 (Japan); **b.** 10/179 (France).

[1982-86]: **a.** 10/63 (Yugoslavia); **b.** 10/33 (United Kingdom); **c.** 10/4 (Netherlands).

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