Telescope Grounding - Lightning and LEMP Protection

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1 Introduction and Scope

This specification provides the requirements in terms of grounding, protection against lightning and LEMP applicable to the CTAO telescopes and analogous array elements (Lidar, Weather station….). permanently installed at the CTAO sites.

The requirements herein are based on the international standards listed in the applicable documents listed herein and are collected here for ease of use by the telescope designers. The intention of this document is not as a substitute for the applicable standards. The referenced standards are therefore integral part of this specification. The standards are superseding in case of conflict with the present document.

1.1 Applicable Documents

The following documents are integral part of this specification within their limits:

AD #	Title
AD01	IEC 62305 -1: 2011 Protection against lightning Part 1 - General Principles
AD02	IEC 62305-2: 2012 Protection against lightning Part 2 Risk management
AD03	IEC 62305-3: 2011 Protection against lightning Part 3 - Physical damage to structures and life hazard
AD04	IEC 62305- 4: 2010 Protection against lightning Part 4 - Electrical and electronic systems within structures
AD05	IEC 60364-5-54 Low-voltage electrical installations: Selections and erection of electrical equipment – Earthing arrangements and protective conductors
AD06	IEC 62561 Series all parts, Lightning protection system components (LPSC)
AD07	IEC/TR 62713:2013 Safety procedures for reduction of risk outside a structure
AD08	IEC 61000 – 5 -2 Electromagnetic compatibility (EMC) Part 5: installation and mitigation guidelines – Section 2: Earthing and cabling

1.2 Referenced Documents

The following documents are referenced inside this specification, but are not applicable to it:

RDD #	Title
RD01	IEC 60364-4-44 Low-voltage electrical installations: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances
RD02	NFPA 780 Standard for the installation of Lightning Protection System (2020 edition)

1.3 Abbreviations and Acronyms

Abbrevation	Definition
CTAO	Cherenkov Telescope Array Observatory
LEMP	Lightning Electromagnetic Pulse
LPS	Lightning Protection System
LPZ	Lightning Protection Zone
LPSC	Lightning Protection System Components
SPD	Surge Protective Device

2 Grounding, Protection Against Lightning & LEMP

2.1 General Requirements

2.1.1 Applicability

For the purpose of this specification telescope shall be considered as constituted by

- telescope structure proper
- telescope structure foundation
- Cherenkov camera
- parking structure with foundation if existing
- Camera tower and its foundation if existing
- and consequently appurtenances of the above elements like electrical systems in structures, chillers, cable ducts and trays, UPS, interface cabinets…..(list not exhaustive).

2.1.2 Grounding - General

The telescope shall be equipped with safety grounds and equipment ground features. To this purpose a telescope grounding (earth) electrode shall be built into each telescope foundation.

Similarly, all metallic structures, like the camera tower and the parking structure foundation, if present, shall be equipotential bonded and equipped with earthing points for connection to the underground earthing grid (earth electrodes).

The earth electrodes shall be a mesh of earthing wires bonded to each other by means of multiple connections in between them and between the underground earth electrodes of different structures, when practicable.

Moving parts of the telescope shall have by-pass grounding connections, allowing to maintain grounding and electrical continuity in all conditions of the telescope (operating and non).

The grounding system of the telescope shall be specifically designed to prevent or minimize ground loops.

2.1.3 Lightning Protection System

The telescope shall be equipped with a lightning protection system conforming to AD01, AD02, AD03 (IEC 62305) and in particular conforming to:

Part 1: General Principles

Part 2: Protection against lightning Part 2 Risk management

Part 3: Physical damage and life hazard B

The Lightning Protection System shall be designed to achieve a Lightning Protection Level I according to AD01.

To determine the zone of protection – zone not subjected to direct lightning stroke , LPZ 0_B - the rolling sphere model shall be used.

2.2 Constructive Requirements

2.2.1 Earth Electrode System Design and construction

For the Earth termination system, the requirements of AD01 to AD04 applies.

The earth termination system (ground terminal) shall comprise a ring earth electrode (bonded to or constituted by a foundation earth electrode in form of a loop) directly buried in the soil supplemented by radial or other provisions where required. The earth electrode shall be designed and constructed in accordance with AD01 and AD02 as relevant.

In the case of multiple structures (example: Telescope foundation and camera tower foundation) the earthing meshes shall be meshed earth electrodes bonded to each other by means of multiple connections between the earth electrodes of the different structures, when practicable.

The earth electrodes shall be designed and interconnected so to simultaneously achieve:

- earth-termination of the lightning protection system in accordance with as demanded by AD01, AD02 and AD03.

and (but not specifically covered by this specification)

- system earthing of low-voltage electrical installations with nominal voltage up to 1 kV a.c.
- Earthing of electronic installations and equipment

For these last points above refer to the associate standards (AD08, RD01)

2.2.1.1 Earth Electrodes in foundations

Telescope and other structures shall be provided with earth electrodes embedded in the foundations (natural earth electrodes)

The earth electrode embedded in the foundation must be bonded (amongst others, like LPS down-conductor test points and other metallic bonding points) to the ring earthing electrode buried in soil as per Section 2.2.1.2 below.

2.2.1.2 Ring earth electrode

The natural earth electrodes of section 2.2.1.1. shall be connected to and interconnected to a non-natural ring earth electrode directly buried in soil. At least one ring earth electrode shall be realized around the telescope.

The ring earth electrode shall conform to AD01 and to AD04 as type “B” earth electrode.

The ring electrode shall surround the telescope and other structures mentioned in the scope above, to be protected and be buried at least 0.5m depth and not closer than 1m from the structure.

In case that the soil resistivity show that deeper soil strata can be reached with sensibly lower resistivity, earth electrodes of the vertical type (earth rods) shall be employed and connected to the

earth ring electrode in order to achieve the low level of resistivity specified herein. Earth rods if used shall be installed in earthing pits allowing inspection.

Earth electrodes being designed and realized as “Type B arrangements” shall exhibit a low earth resistance, whenever technically possible lower than 10 Ω, when measured at low frequency. Deviations from this value shall be agreed with CTAO.

2.2.1 Lightning Protection System Design

Members of the external lightning protection system (air-terminations, down-conductors, earth-termination system) shall be chosen by adopting, as far as practicable, “natural” components (that is, components that perform a lightning protection function but that are not installed specifically for that purpose, example metallic structures). To this purpose the AD06 and AD07 shall be used.

While doing this the designer shall consider the possibility of lightning strikes while the telescope is parked[1].

Metallic reinforcement of concrete and steel frames of metallic structures shall be adopted as natural components of the LPS, wherever possible. To be used as natural components, they shall be made electrically continuous. To this purpose the provisions Section 2.2.2.1 shall be considered.

Within structures comprised of mobile parts, like telescopes, the continuity between the air- and the earth-terminations shall be achieved by means of methods and components type-tested to provide such continuity for the specified lightning protection level I. (Examples of such components are those adopted for wind turbines, like those covered by IEC 61400-24:2019 Wind energy generation systems – Part 24: Lightning protection)

Down-conductors shall not be installed in any gutters or down-spouts even if they are covered by insulating material.

Any wiring comprising metallic conductors running between separate structures of the CTAO telescope (example structure and camera tower) shall be laid inside metallic cable ducts (such as metal conduit, metal tubes, grids or grid-like reinforcement of concrete), which shall be conductive from end to end, shall be integrated into the earth mesh electrode and shall be bonded to the bonding bars of the separate structures. Metal sheaths, screens and shields of cables shall be bonded to these bars at both extremities. An example of this is provided in the picture below.

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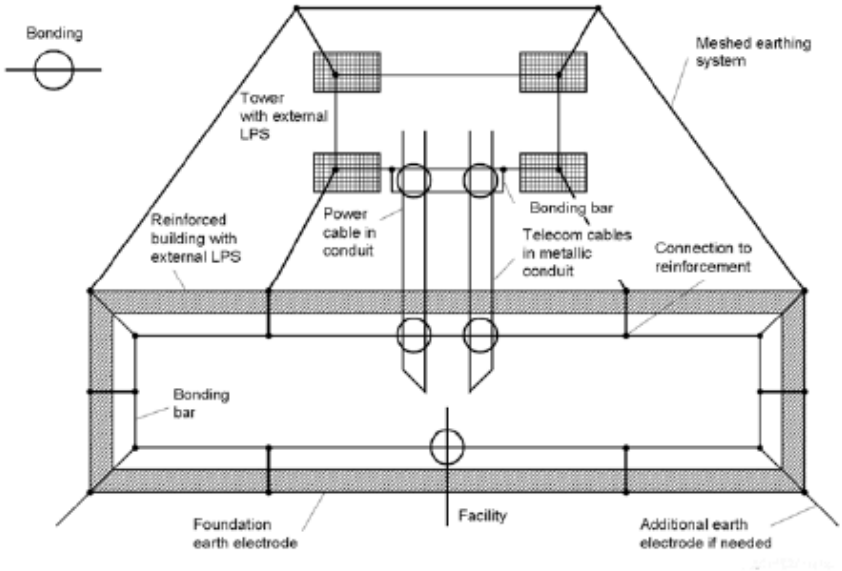
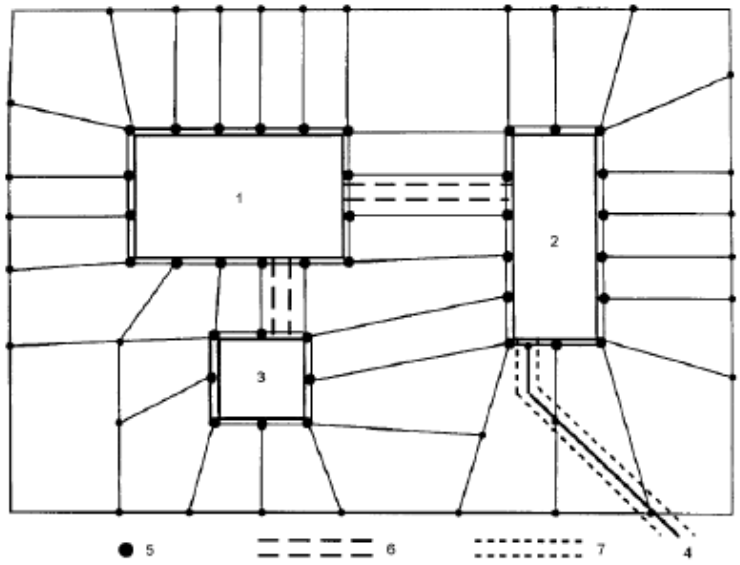
[1] It is expected that all telescopes will be parked in conditions of bad weather.





1, 2, 3 Neighboring structures
4 Earth mesh conductor in a cable trench filled with soil
5 Corrosion resistant joint between earth-termination conductors
6 Cable duct
7 Cable trench filled with soil

Picture 2.2.1: Example of a meshed earth termination system for neighbouring structure and their interconnections

2.2.1.1 Electrical Continuity

Metal sheets and metal structural members shall be realized as electrical continuous in order to perform the following functions:

I. constitute electrically continuous paths towards the earth-electrode (natural air-terminations and natural down-conductors of the LPS);
II. shields of the inner volumes with respect to the outer electromagnetic environment (shielding between different lightning protection zones.

Electrical continuity as per point a) above shall be realized along both of the two dimensions of the surfaces used for continuity.

In creating electrical continuity, bets practice shall be adopted like the ones listed here below (list not exhaustive). Refer also to RD02:

Bonding techniques:

a. direct bonding by welding or brazing (permanent bonding, no soldering, no rivets) or high pressure contact between mating surfaces semi-permanent bonding) preferred over indirect bonding, in all cases with resistance not exceeding 1 milliohm
b. Appropriate dimensions of welding seam, with full penetration welds in case of joints between members of thickness < 6mm; distance not exceeding 300mm between discontinued welds;
c. In case of bolted connections, sizing, spacing and torquing of bolts in order to achieve pressure of the order of 8000-10000 kPa in the contact surface, with use of load distributing washers (teethed washers not permitted), with previous treating of the mating surface (blank metal in case of steel);
d. In case of indirect bonding the provisions of AD08 shall be adopted;

Prevention of corrosion:

a. Pairing of dissimilar material should be avoided. When not possible the anodic member shall have a larger size.
b. When exposed to weather, copper and copper alloys shall not be bonded to aluminum, aluminum alloys and to carbon steel.
c. Stainless steel, carbon steel may be bonded to aluminum and aluminum alloys provided a protective finishing is applied.

2.3 Protection of Equipment

Equipment installed onto the telescope as well as cables, wiring and any lines interconnecting them (thereby including any metallic pipes) shall be provided with protection against overvoltage and against lightning electromagnetic pulse (LEMP) conforming to AD04. To this purpose the designer shall assess which are the lightning protection zones - LPZs - around and within the telescope structure.

Structural bonding shall be adopted to obtain from “natural” components - as far as reasonably possible - the protection and the shielding measures required by the lightning protection zones LPZ 0_B and higher.

For each piece of equipment to be installed and for each conductive part to be laid (including cables of any types and for any applications, metallic pipes, etc.), the Designer shall choose which is the

appropriate lightning protection zone. Upon need, the Designer shall conveniently design or re-design dimensions, form and borders of the lightning protection zone of the requested level.

As far as possible, conductive parts (i.e., cables of any types and for any applications, metallic pipes, etc.) within a given lightning protection zone (e.g., LPZ 0_B) shall enter into an inner lightning protection zone (e.g., LPZ 1) at a single point of entry. At this point the conductive parts shall be bonded to the boundary (shield) between the outer and the inner LPZ. Conductive parts not carrying operating currents/voltages - and, therefore, including protective conductors (equipment grounding conductors), metal conduit, armours, sheaths, shields, etc. - shall be bonded directly to the boundary (shield).

Live conductors of any circuits (power, data, signal, communication, control, etc., thereby including the neutral conductor N of power circuits) shall be bonded to the boundary by means of surge protective devices – SPDs (surge arresters).

2.3.1 SPDs

SPDs shall be chosen, arranged and coordinated at the LPZ interfaces (transitions from one LPZ to another) in conformity with what specified by AD04.

Live conductors to be connected to equipment particularly susceptible to overvoltages shall be bonded to the LPZ boundary by means of a chain of SPDs (e.g., a gas discharge tube, a varistor and a Zener diode with inductors as decoupling elements) in order to provide the necessary protection against transient overvolatges.