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TECHNICAL SPECIFICATION

Doc No: DSF-SPC-ELE-016	Rev. 1	Page 1 of 44

HIGH PRESSURE (HP) TRANSMISSION SYSTEMS

EARTHING AND LIGHTNING PROTECTION SYSTEM

JUNE 2021

1	Second Issue	30-06-2021	PP	KM	TPI
0	First Issue	05-04-2011	PQ DPT.		V.G.
REV	**DESCRIPTION**	**DATE**	**PRPD**	**CHKD**	**APVD**

REVISION HISTORICAL SHEET

Rev.	Date	Description
0	05/04/2011	First Issue (as Spec 710/1, 783/2, 783/3)
1	30/06/2021	Second Issue validated from TPI

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3 REFERENCES

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3.2 Reference Codes and Standards

2014/34/EU	Equipment Explosive Atmospheres Directive
2014/35/EU	Low Voltage Directive
2014/30/EU	Electromagnetic Compatibility Directive
MINISTERIAL DECISION 50/12081/642/2006 F A – GG B / 1222/5.9.2006	Security Home Electrical Installations (E.I.E.). Introduction of a Differential Current Installation of Construction and Fundamental Grounding
ELOT EN 1594 E3	Gas Supply Systems. Pipelines for Maximum Operating Pressure over 16 bar. Functional Requirements
ELOT EN 14161+A1	Petroleum and Natural Gas Industries. Pipeline Transportation Systems
BS EN 62561-1:2017	Lightning protection system components (LPSC). Requirements for connection components
BS EN 62561-2:2012	Lightning Protection System Components (LPSC). Requirements for conductors and earth electrodes

BS EN 62561-3:2017	Lightning protection system components (LPSC). Requirements for isolating spark gaps (ISG)
BS EN 62561-4:2017	Lightning protection system components (LPSC). Requirements for conductor fasteners
BS EN 62561-5:2017	Lightning protection system components (LPSC). Requirements for earth electrode inspection housings and earth electrode seals
BS EN IEC 62561-6:2018	Lightning protection system components (LPSC). Requirements for lightning strike counters (LSC)
BS EN IEC 62561-7:2018	Lightning protection system components (LPSC). Requirements for earthing enhancing compounds
ELOT EN IEC 60079-0 E5	Electrical Apparatus for Explosive Gas Atmospheres - Part 0: General Requirements
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ELOT EN 60099-4 E3	Surge Arresters - Metal Oxide Surge Arresters without Gaps for A.C. Systems
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ELOT EN 62305-1 E2	Protection against Lightning, Part 1: General Principles
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ELOT EN ISO/IEC 17025 E3	General Requirements for the Competence of Testing and Calibration Laboratories
ELOT HD 384	Requirements for Electrical Installations

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EN 61000	Electromagnetic compatibility (EMC)
EN 61643-11	Low Voltage Surge Protective Devices – Part 11: SPDs Connected to Low Voltage Power Distribution Systems – Performance Requirements and Testing Methods
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IEC 60664	Insulation Coordination for Equipment within Low-Voltage Systems
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IEC 61643-22	Low Voltage Surge Protective Devices – Part 22: SPDs Connected to Telecommunication and Signaling Networks – Selection and Application Principles
IEC 62548	Design Requirements for Photovoltaic (PV) Arrays
IEC 62561-1	Lightning Protection Components (LPC), Part 1: Requirements for Connection Components
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IEC 62561-4	Lightning Protection Components (LPC), Part 4: Requirements for Conductor Fasteners
IEC 62561-5	Lightning Protection Components (LPC), Part 5: Requirements for Earth Electrode Inspection Housings and Earth Electrode Seals
IEC 62561-6	Lightning Protection Components (LPC), Part 6: Requirements for Lightning Strike Counters

IEC 62561-7	Lightning Protection Components (LPC), Part 7: Requirements for Earthing Enhancing Compounds
ELOT EN 60071-1	Insulation Coordination – Definitions, Principles & Rules
ELOT EN 60071-2	Insulation Coordination – Application Guide
EN 60664-1	Insulation Coordination for equipment within Low Voltage Systems
IEC 61643-11	Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power distribution systems - Requirements and tests

4 ACRONYMS

AC	Alternating Current
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ATEX	ATmosphères EXplosibles (Explosive Atmospheres)
ATS	Automatic Transfer System
BMS	Building Management System
BVS	Block Valve Station
BCC	Back-up Control Centre at Nea Messimvria
CCTV	Closed Circuit Television System
CPR	Construction Products Regulation
CP	Cathodic Protection
CPU	Central Processor Unit
CS	Compressor Station
DB	Distribution Board
DC	Direct current
DCS	Distributed Control System
DEG	Detailed Engineering
DIN	Deutsches Institut für Normung (German Institute of Standardization)
DVA	Digital Voice Announcer

DVD	Digital Video Disc
EDG	Emergency Diesel Generator
ELOT	Hellenic Organization for Standardization
ELV	Extra Low Voltage (nominal voltage not exceeding 50 V AC or 120 V DC (ripple-free) between conductors or to earth, as defined by the Standard EN 61558)
EN	European Norms
EPC	Engineering, Procurement and Construction
EU	European Union
ESD	Emergency Shut Down
F&G	Fire and Gas
FACP	Fire Alarm Central Control Panel
FARP	Fire Alarm Repeater Control Panel
FAT	Factory Acceptance Test
FEG	Field Engineering
FC	Floe Computer
FOC	Fibre Optic Cable
GCC	Gas Control Centre at Patima
HEDNO	Hellenic Electricity Distribution Network Operator
HDPE	High Density Polyethylene
HMI	Human Machine Interface
HVAC	Heating Ventilation Air Conditioning
I/O	Input / Output
IEC	International Electrotechnical Commission
ISO	International Organization for Standarization
ITU	International Telecommunication Union
LAN	Local Area Network
LCS	Local Control System
LED	Light Emitting Diode
LFEP	Local Fire Detection & Fire Extinguishing Panel
LV	Low Voltage

LSP	Load Share Panel
MSC/MCS/SMC	Main Station Controller
MV	Medium Voltage
MPS	Master Project Schedule
MPR	Monthly Progress Report
NFPA	National Fire Protection Association
NNGTS	National Natural Gas Transmission System
NTSC	National Television System Committee
O&M	Operation and Maintenance
PID	Piping and Instrumentation Diagram
PA/GA	Public Address / General Alarm
PCS	Process Control System
PED	Pressure Equipment Directive
PEP	Project Execution Plan
PFD	Process Flow Diagram
PLC	Programmable Logic Controller
PMS	Power Management System
POC	Project Organization Chart
PAL	Phase Alternate Line
PPC	Public Power Corporation
PTZ	Pan, Tilt, Zoom
PVC	Poly Vinyl Chloride
QA	Quality Assurance
RCC	Remote Communications and Controls
RFI	Radio Frequency Interference
RTD	Resistance Temperature Detectors
RTU	Remote terminal Unit
S/S	Scraper Station
SAT	Site Acceptance Test
SCADA	Supervisory Control and Data Acquisition (including Telemetry)
SCS	Station Control System

SFP	Small Form-factor Pluggable
SPD	Surge Protection Device
SPL	Sound Pressure Level
UDP	User Datagram Protocol
UPS	Uninterruptible Power Supply
UV	Ultraviolet
VGA	Video Graphics Array
VMS	Video Management Software

5 EARTHING AND LIGHTNING PROTECTION SYSTEM DESIGN

5.1 Earthing System Design

An earthing and bonding system to earth shall be provided to ensure safety to personnel, earthing for operational reasons, protection against static electricity and limiting a circuit's voltage when design voltage is exceeded. An earthing and bonding system to earth is also necessary for electric / electronic instrumentation and communication system, as well as for protection against lightning. Earthing and bonding system shall be according to relevant codes and standards, including ELOT HD 384 and ELOT HD 60364.
Lightning Protection System design is described in following paragraphs.

A common equipotential earthing system shall be provided for all earthing purposes, unless otherwise specified. Exposed conductive parts (metal parts of electrical equipment which can be touched, and which may become live in the event of a fault) shall be earthed by a connection to the common earthing system. Extraneous conductive parts (metal parts that are not parts of, but in proximity to the electrical installation and are liable to introduce earth potential) shall be connected to the common earthing system or bonded to adjacent exposed conductive parts.
An earthing arrangement is made up of an earth termination system, an earthing conductor and an earthing terminal or earthing bar.
Moreover, in accordance with ministerial decision 50/12081/642/2006 FA-GGB/1222/5.9.2006 a foundation earth system is mandatory for new structures, as well as

equipotential bonding of internal conductive parts. Therefore, a foundation earthing shall be constructed, and other earth electrodes shall be added (if required), so as that resistance of earthing system should be low.

The resistance of equipotential bonding protective conductors must be so as to secure that:

- if a fault of negligible impedance occurs anywhere in the installation between a phase conductor and a protective conductor or exposed conductive part, automatic disconnection of the supply shall occur within the specific time, as defined in ELOT HD 384.
- touch voltage between simultaneously accessible conductive parts shall not exceed 50V.

Electrical continuity of earth termination system and of protective and bonding conductors shall be preserved.

Minimum cross-sectional areas of protective conductors shall be as per ELOT HD 384 (chapter 543).

Moreover, the use of residual current devices with a rated operating residual current not exceeding 30mA, is recognized as additional protection in case of direct contact in the event of failure of other measured of protection or carelessness by users.

According to the above-mentioned ministerial decision, the installation of current protective devices is mandatory for additional protection from shock to all electrical installations listed in the scope of Article 103 of ELOT HD 384.

The minimum cross-sectional areas for neutral grounding conductors should not be less than the area determined with the following formula:

$$S = \frac{Ik3\sqrt{t}}{k}$$

Where: k = 143 for PVC cables and 176 for XLPE cables (according to HD 384, Table 54-B), Ik3 (the r.m.s. value of the maximum earth fault) and t=0.1sec (the operating time of the disconnecting).

5.2 Lightning Protection System Design

In order to minimize the risk of damage in a structure and its contents, as well as the risk of injury or loss of humans or pets, a Lightning Protection System (LPS) must be used. Both external and internal LPSs shall exist.

5.2.1 Risk Management

The need to install a LPS in a structure derives from the application of standard ELOT EN 62305-2 E2. It introduces the risk assessment method, the assessment of risk components for structures and for services.

According to ELOT EN 62305-1 E2, there are four protection classes (I, II, III and IV) of which class I is the most rigorous. Each Protection class corresponds to specific lightning current parameters. Maximum values of lightning parameters according to Lightning Protection level are shown in Table 1.

Table 1 – Maximum values of Lightning parameters according to LPL

First short stroke			**LPL**			
Current parameters	Symbol	Unit	I	II	III	IV
Peak current	*I*	kA	200	150	100	
Short stroke charge	*Q*	C	100	75	50	
Specific energy	*W/R*	MJ/Ω	10	5,6	2,5	
Time parameters	T_1/T_2	μs/μs	10/350			

where:

T1 = front time of short stroke current (virtual parameter defined as 1,25 times the time interval between the instants when the 10% and 90% of the peak value are reached).

T2 = time to half value of short stroke current (virtual parameter defined as the time interval between the virtual origin of short stroke current and the instant at which the current has decreased to half the peak value).

According to ELOT 62305-2 E2, the sources of the damages that are described below, may cause different types of damages to a structure. The following sources of damages are to be taken into consideration depending on the position of the point of strike relative to the structure considered (see Table 2):

- S1: flashes striking a structure
- S2: flashes striking near a structure
- S3: flashes striking a service
- S4: flashes striking near a service

A lightning strike may cause damages depending on the characteristics of the object to be protected, among which the most important are:

- type of construction
- contents and application
- type of service
- protection measures provided

The damage caused from lightning to a structure may be limited to a part of the structure or may extend to the whole structure and may even involve the surrounding structures or the environment (e.g. chemical or radioactive emissions).

Lightning affecting a service can cause damage to the physical mean itself – line or pipe – used to provide the service, as well as to related electrical and electronic systems. The damage may also extend to internal systems connected to the service.

For practical applications of the risk assessment, it is useful to distinguish between three basic types of damages, which can appear as the consequence of lightning flash. They are as follows (see Table 2):

- D1: injuries to living beings
- D2: physical damages
- D3: failures of electrical and electronic systems

Each type of damage, alone or in combination with others, may produce different consequential loss in the object to be protected. The type of loss that may appear depends on the characteristics of the object itself.

The following types of loss should be taken into account (see Table 2):

- L1: loss of human life
- L2: loss of service to the public
- L3: loss of cultural heritage
- L4: loss of economic values (structure and its content, service and loss of activity)

And the relevant corresponding risks:

- R1: risk of loss of human life
- R2: risk of loss of service to the public
- R3: risk of loss cultural heritage
- R4: risk of loss of economic values

For each type of loss (L1 to L4) the relevant risk R (R1 to R4) is the sum of different risk components (RX). Each risk component RX depends on:

- the number of dangerous events N
- the probability of damage Px and
- the consequent loss Lx

and may be calculated by:

$$Rx = N\ Px\ Lx$$

The following procedure for decision of the need of protection is described in ELOT EN 62305-2 E2:

- identify the structure to be protected
- identify the types of loss relevant to the structure or the service to be protected
- for each type of loss, identify the tolerable value of risk RT, as well as identify and calculate all relevant risk components Rx
- then calculate $R = \Sigma R_x$
- if $R \leq R_T$, the structure or service is protected for this type of loss
- if $R > R_T$, install adequate protection measures suitable to reduce R and repeat the calculations until $R \leq R_T$.

Besides the need for lightning protection for the object to be protected, it may be useful to evaluate the economic benefits of providing protection measures, in order to reduce the economic loss L4.

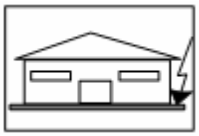
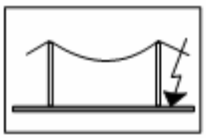
The following procedure for decision of the economic convenience of protection measures is, also, described in ELOT EN 62305-2 E2:

- identify the value of structure and of its activities, as well as of internal installations
- calculate all relevant risk components Rx relevant to R_4
- calculate the annual cost C_L of total loss without protection measures and the cost C_{RL} of residual loss in presence of protection measures
- calculate the annual cost C_{PM} of selected protection measures
- if $C_{PM} + C_{RL} > C_L$, it is not convenient to adopt protection measures
- if $C_{PM} + C_{RL} \leq CL$, it is convenient to adopt protection measures

Procedures for selection of protections measures in a structure or in a service are shown in ELOT EN 62305-2 E2.

Damages and loss depending on different points of strike are shown in Table 2.

Table 2: Damages and loss depending on different points of strike

Point of Strike	S	Structure			Service		
		D	R	L	D'	R'	L'
	S1	D1	R1, R4(2)	L1, L4(2)			
		D2	R1, R2, R3, R4	L1, L2, L3, L4	D2	R' 2, R'4	L' 2, L'4
		D3	R1(1), R2, R4	L1(1), L2, L4	D3	R' 2, R'4	L' 2, L'4
	S2	D3	R1(1), R2, R4	L1(1), L2, L4			
	S3	D1	R1, R4(2)	L1, L4(2)			
		D2	R1, R2, R3, R4	L1, L2, L3, L4	D2	R' 2, R'4	L' 2, L'4
		D3	R1(1), R2, R4	L1(1), L2, L4	D3	R' 2, R'4	L' 2, L'4
	S4	D3	R1(1), R2, R4	L1(1), L2, L4	D3	R' 2, R'4	L' 2, L'4

(1) In the case of hospitals and of structures with risk of explosion

(2) In the case of agricultural properties (loss of animals)

5.2.2 External Lightning Protection System

The external LPS aims to protect the structural parts of a structure against direct lightning strike, including lateral strike. At the same time, it must safely conduct the lightning current to earth without producing dangerous sparks and electric arcs between the LPS and parts of the structure. Only if the structure is constructed with flammable material or contains flammable materials, it is recommended an external LPS isolated form the structure to be installed.

An external LPS is consisting of the following:

- Air Termination System

- Down Conductors
- Earth termination system

For a complete external LPS, the design and installation of the internal LPS consisting of equipotential bonding by direct bonding to the LPS of metal installations and conductive parts of the structure or via Surge Protective Devices (SPD) for electric power and telecommunication lines, shall be taken into consideration.

5.2.2.1 Air Termination System

The air termination system intervenes between the lightning and the structure by protecting its structural parts against damage. The air termination system is installed on the roof surface of a structure and must cover all exposed parts and in particular the corners, edges and overhangs of the building.
In accordance with ELOT EN 62305-3 E3, in order to design an air termination system, the following methods are applied (see Table 3):

- Rolling sphere method
- Protection angle method
- Mesh method

Table 3: Methods for the design of air-termination system according to ELOT EN 62305-3

Rolling sphere method	Protection angle method	Mesh method

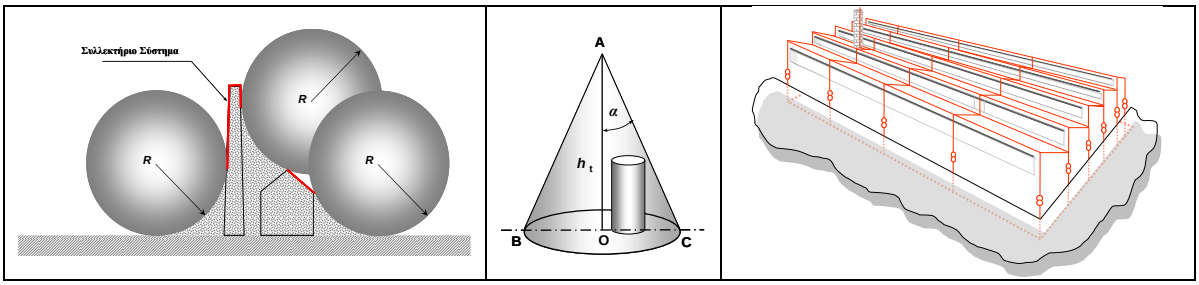
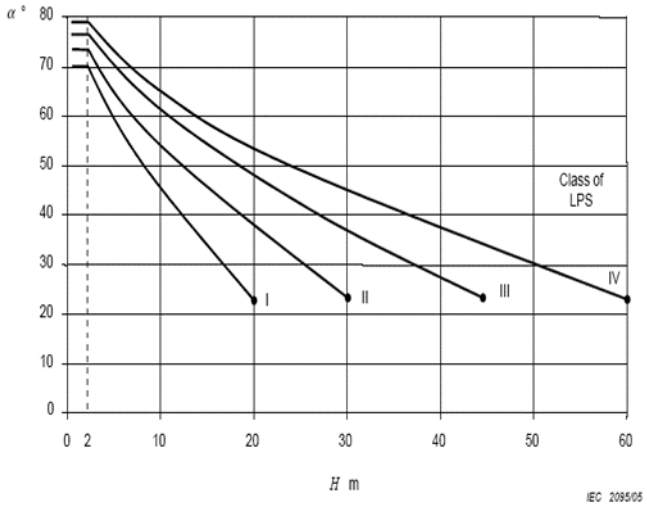


Table 4: Typical dimensions of an air termination

Protection Class	Rolling Sphere radius R(m)	Height of the structure h(m)				Mesh dimensions(m)
		20	30	45	60	
		Protection angle (min)				
I	20	See the following diagram				5
I I	30					10
I I I	45					15
I V	60					20



All the metal installations with distance lower than the separation distance (as stated in ELOT EN 62305-3 E3, clause 6.3) shall be bonded to the air termination system at least at two points.

The rolling sphere diameter, the angle of the protection radius, as well as the dimensions of meshes depend on the protection class established and could be selected from Table 4.
An air – termination system could be composed of the following parts:

- Air – termination rods
- Catenary's wires
- Meshed conductors

The before mentioned parts can be used independently or in combination between them.

5.2.2.1.1 Natural Air Termination Components

In accordance with ELOT EN 62305-3 E3, the following parts of a structure should be considered as "natural" air termination components and part of an LPS:

- metal sheets covering the structure to be protected providing that
  - the electrical continuity between the various parts is made durable (e.g. by means of brazing, welding, crimping, seaming, screwing or bolting)
  - the thickness of the metal sheet is not less than the value t' given in Table 5 if it is not important to prevent puncture of the sheeting or to consider ignition of any readily combustible materials underneath
  - the thickness of the metal sheet is not less than the value t given in Table 5 if it is necessary to take precautions against puncture or to consider hot spot problems
  - they are not clad with insulating material

- metal components of roof construction (trusses, interconnected reinforcing steel, etc.), underneath non-metallic roofing, providing that this latter part can be excluded from the structure to be protected
- metal parts such as gutters, ornamentation, railings, pipes, coverings of parapets, etc., whose cross-section is not less than that specified for standard air termination components
- metal pipes and tanks on the roof, providing that they are constructed of material whose thickness and cross section are in accordance with ELOT EN 62305-3 E3, Table 6.
- metal pipes and tanks carrying readily combustible or explosive mixtures, providing that they are constructed of material whose thickness is not less than the appropriate value of t given in Table 5 and that the temperature rise of the inner surface at the point of strike does not constitute a danger.

If conditions for thickness are not fulfilled, the pipes and tanks shall be integrated into the structure to be protected.

Piping carrying flammable or explosive mixtures shall not be considered as air termination natural components if the gasket in the flange couplings is not metallic or if the flange-sides are not otherwise properly bonded.

Table 5: Minimum thickness of metal sheets or metal pipes in air-termination systems

Type of LPS	Material	Thickness [a] *t* (mm)	Thickness [b] *t'* (mm)
I to IV	Fe	4	0,5
	Cu	5	0,5
	Al	7	0,7
[a] *t* prevents puncture, hot spot or ignition [b] *t'* only for metal sheets if it is not important to prevent puncture, hot spot or ignition problems			

5.2.2.2 Down Conductors

Down Conductors connect preferably straight and by the shortest possible path the air – termination system with the earth termination system, according to ELOT EN 62305 series.

Down Conductors are installed either externally, around the structure or embedded in the reinforcement concrete column of the structure. The number of down conductors depends on the dimensions of the structure (at least two down conductors) and the typical distances between them are related to the class of LPS that has come after risk assessment/ management (see Table 6). Preferably down conductors should be installed at the exposed corners of the structure.
At the connection of the earth termination, a test joint should be fitted on each down-conductor, except in the case of “natural” down-conductors combined with foundation earth electrodes.

Table 6: Typical distances between down conductors

Class of LPS	Typical distances (m)
I	10
I I	10
I I I	15
I V	20

5.2.2.2.1 Natural Down Conductor Components

The following parts of the structure should be considered as "natural" down-conductors:

- the metal installations provided that:
  - the electrical continuity between the various parts is made durable
  - their dimensions are at least equal to that specified in ELOT EN 62305-3 E3, Table 6 for standard down-conductors.

Piping carrying flammable or explosive mixtures shall not be considered as down-conductor natural components, if the gasket in the flange couplings is not metallic or if the flange-sides are not otherwise properly bonded.

- the metal or electrically continuous reinforced concrete framework of the structure
- the interconnected reinforcing steel of the structure
- the facade elements, profile rails and metallic sub-constructions of facades, provided that:
  - their dimensions comply with the requirements for down-conductors as shown in ELOT EN 62305-3 E3, Table 6 and that for metal sheets or metal pipes the thickness shall be not less than 0,5mm
  - their electrical continuity in a vertical direction is secured

5.2.2.3 Earth Termination System

The aim of LPS is the discharge of Lightning current. According to ELOT EN 62305-3 E3 the accepted earthing resistance is 10Ω. However, if this value is not possible to be achieved, a minimum length of electrode should be used. The LPS may consist of type "A" or "B" arrangement or combination of both types.

5.2.2.3.1 Type “A” arrangement

It is composed of vertical or radial-horizontal earth electrodes or earth plates installed outside the structure to be protected. Each down conductor shall be connected to one separate earth electrode consisted either of a radial-horizontal electrode with a minimum length [ℓ1] stated in Figure 1 according to the protection class to be applied, or vertical electrode of a length [0,5ℓ1]. The minimum number of earth electrodes of an LPS must be 2.
In low resistivity soils the minimum lengths may be disregarded if the value of the earthing resistance is equal or less than 10Ω.

5.2.2.3.2 Type “B” arrangement

It is composed of a ring earth electrode external to the structure to be protected or embedded in the foundation of the structure. The mean radius [re] of the area enclosed by the ring or the foundation earth electrode must not be less than the value of [ℓ1] stated in Figure 1 according to the protection class to be applied.

$$re \geq \ell 1$$

When the required length of [ℓ1] is larger than the convenient length [re], additional radial, horizontal [ℓr] or vertical [ℓv] electrodes must be added whose individual lengths are given by:

$$\ell r = \ell 1 - re \text{ or } \ell v = \ell r/2$$

Additional length [ℓr] or [ℓv] should be installed where down conductors are connected to the ring earth electrode.

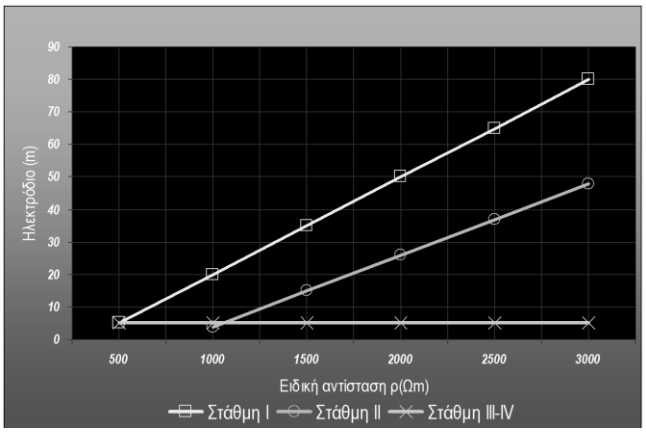


Figure 1: Minimum length of horizontal earth electrode (ℓ_1)

5.2.2.3.3 Natural Earth Electrodes

Interconnected reinforcing steel in concrete foundations, or other suitable underground metal structures should be preferably used as an earth electrode, provided that:

- components of LPS should be manufactured from the materials listed in ELOT EN 62305-3 E3, Table 5 or from other materials with equivalent mechanical, electrical and chemical (corrosion) performance characteristics
- Configurations and minimum dimensions of earth electrodes should be as shown in ELOT EN 62305-3 E3, Table 7.

5.2.3 Internal Lightning Protection System

The aim of the internal LPS is to protect human life and electrical/ electronic installations against surge overvoltage, which are caused either by direct or indirect lightning strike. As described in ELOT EN 62305-4 E4, the volume of the structure that is to be protected against lightning shall be divided into zones (Lightning Protection Zones LPZ) with respect to the electromagnetic effect of the lightning current and to the dielectric strength of the under-protection equipment.

The basic LPZ are the following:

LPZ 0A: Exposed to direct lightning strikes. Full lightning current and full lightning magnetic field.

LPZ 0B: Protected against direct lightning strikes. Partial lightning or induced current and full lightning magnetic field.

LPZ 1: Protected against direct lightning strikes. Partial lightning or induced current and damped lightning magnetic field.

LPZ 2.n: As LPZ1 but further damped lightning magnetic field.

All equipment that is installed in the same zone should be at the same potential. This can be succeeded by applying equipotential bonding to all conductive parts including the reinforcement of the structure, where this is possible to be achieved, with respect to earth either by a direct bonding or through a surge protective device.

5.2.3.1 Categories of Surge Protective Devices

In accordance with ELOT EN 61643-11, the surge protective devices which are connected to a low voltage system are separated into three categories:

1st Type 1 (T1) – Class I, primary protection against lightning current, Iimp (10/350μs)

2nd Type 2 (T2) – Class II, secondary protection against surge current, Imax (8/20μs)

3rd Type (T3) – Class III, fine protection against surge currents, Isc (8/20μs) and surge overvoltage, Uoc (1.2/50μs)

T1 surge protective devices are mainly installed at the entry point of the electrical installation into a structure (i.e. main switchboard) at the borders between LPZ 0A - LPZ 1 or LPZ 0B - LPZ 1, providing protection against lightning currents (10/350μs), having a voltage protection level (Up) lower than 4KV and protecting equipment of overvoltage category III and IV.

T2 surge protective devices are installed at main node points of the electrical installation (i.e. secondary switchboards) at the borders between LPZ 1 - LPZ 2, providing protection against surge currents (8/20μs), having a voltage protection (Up) level lower than 2,5KV and protecting equipment of overvoltage category II.

T3 surge protective devices are installed independently of the zone boundaries. Their installation point is as near as possible to the under-protection equipment which contains electronic circuits (i.e. PC, PLC, etc.) providing fine protection against both surge currents (8/20μs) and surge voltages having a voltage protection level (Up) lower than 1,5KV, protecting equipment of overvoltage category I. T3 surge protective devices should always be installed after at least T2 surge protector.

According to ELOT EN 62305-4 E4, the installation of power SPDs in a distribution board shall be with connection wire equal or shorter than 0.5m.

The maximum wire length between the SPD and the equipment that it protects should be 10m, or else additional SPDs should be installed.

Moreover, SPDs shall be according to EN 61000.

5.3 Documentation

During detail design, the following drawings and documents shall be developed and submitted to the Client for review, but not limited to:

- Application of the Risk Management Method
- Earthing and Lightning Protection Drawings
- Material Take off for conductors, earthing rods, SPDs and other material and accessories used for earthing and lightning protection.

5.3.1 Application of the Risk Management Method

The application of the Risk Assessment / Management method described in this specification shall prove the need (if applicable) of the installation of an LPS. The selection of protection measures in a structure or in a service shall be provided by the use of relevant procedures described in ELOT EN 62305-2 E2.

5.3.2 Earthing and Lightning Protection Drawings

Regarding outdoor earthing, the following information shall be provided, as a minimum:

- Conductors sizes and types
- Direct buried conductors
- Conductors laid in duct banks
- Earthing rods
- Above ground conductors
- Connections to equipment

Concerning indoor earthing, the following information shall be shown, but not limited to:

- Conductors sizes and types
- Connections to equipment
- Foundation earthing

For external lightning protection system, the information described below shall be at least provided:

- Air termination system
- Bonding of structure to lightning protection system
- Down conductors
- Connections of down conductors to air termination system and earth termination system
- Test joints

Supports of conductors

Regarding internal lightning protection system, SPDs and their types shall be determined, as a minimum.

5.3.3 Material Take off

Material Take off and detail drawings for material and accessories concerning earthing and lightning protection are required for the supply of the above-mentioned material.

6 SUPPLY OF EARTHING AND LIGHTNING PROTECTION MATERIAL

6.1 General

Supply of earthing and lightning protection material shall include, but not limited to, procurement planning, purchasing, expediting, inspection and testing, spare parts procurement, packaging, shipment, transportation and delivery at site.

Earthing and lightning protection material shall be selected to comply with the latest editions of relevant EU Directives, Greek Legislation, European Standards and International Codes or Standards, as well as relevant project job specifications or requirements specified in other project documents or drawings.

Therefore, all latest approval revisions of relevant project documents and drawings shall be forwarded to Supplier(s).

Apart from earthing and lightning protection material, Supplier(s) shall submit to the Client their documentation package consisting of necessary drawings and data to cover project requirements.

Procurement of earthing and lightning protection material shall be performed in accordance with job specification for Supply of Electrical Equipment and Materials.

6.2 Shop Inspection and Testing

All components used for the earthing and external lightning protection system, including the earth termination system and the equipotential bonding should fulfill the requirements of ELOT EN 50164 and IEC 62561 series. The manufacturer must provide the documentation (test reports) which proves compliance to ELOT EN 50164 and IEC 62561 series.

Connection components used for the installation of an earthing and external LPS such us connectors, clamps, pipe clamps, test joints, expansion pieces etc. shall be tested according to ELOT EN 50164-1 and IEC 62561-1. Mechanical, electrical properties and of all conductors' corrosion withstand shall be verified by tests according to ELOT EN 50164-2 and IEC 62561-2.

All surge protection devices used for internal lightning protection system and connected to a low voltage system should fulfil the voltage protection level and the operating duty cycle of EN 61643 – 11. The manufacturer must provide the documentation (test reports) which proves compliance to EN 61643 – 11.

All components used for earthing and lightning protection should have a test report published by an accredited laboratory according to ELOT EN ISO 17025 (a copy of the accreditation diploma of the laboratory should be submitted, certificates of general certification bodies, such as ELOT EN ISO 9001 are not equivalent). Otherwise, it is upon to the user to request additional testing into an independent laboratory. The contents of the test reports should fulfill the requirements of this specification.
The manufacturer of the earthing and lightning protection components should be certified for design and production of lightning protection components, earthing and surge protection components, according to ELOT EN ISO 9001.

6.3 Format and contents of the test report, according to standards ELOT EN 50164 and IEC series

Test report according to standards ELOT EN 50164 and IEC 62561 series shall include, but not limited to, the following:

- Report identification
  - A title or subject of the report
  - Name, address and telephone number of the test laboratory
  - Unique identification number (or serial number) of the test report
  - Name and address of the Supplier
  - Report shall be paged, and the total number of pages indicated
  - Dates of performance of the tests and date of issue of the report
  - Signature and title or an equivalent identification of the person(s) authorized to sign for the testing laboratory and for the content of the report
  - Signature and title of person(s) conducting the tests

- Specimen description
  - Sample description
  - Detailed description and unambiguous identification of the test sample and/or test assembly
  - Characterization and condition of the test sample and/or test assembly
  - Sampling procedure, where relevant
  - Date of receipt of test items
  - Photographs, drawings or any other visual documentation, if available
- Standards and references
  - Identification of the test standard used and the date of issue of the standard
  - Other relevant documentation and the documentation date
- Test procedure
  - Description of the test procedure
  - Justification for any deviations, additions or exclusions from referenced standard

- Any other information relevant to a specific test, such as environmental conditions
- Configuration of testing assembly
- Location of the arrangement in the testing area and measuring techniques

- Testing equipment description

  Description of equipment used for every test conducted i.e. generator, condition/ageing device
- Measuring instruments description

  Characteristics and calibration date of all instruments used for measuring the values specified in the standard i.e. radius gauge shunts, tensile testing machine, extensometer, ohmmeter, torque meter, thickness caliper gauge etc.
- Results and parameters recorded

  The measured, observed or derived results shall be clearly identified at least for:
  - Tests according to ELOT EN 50164 - 1 and IEC 62561-1:
    - ✓ Current
    - ✓ Charge
    - ✓ Specific energy
    - ✓ Duration
    - ✓ Ohmic resistance
    - ✓ Tightening torque
    - ✓ Loosening torque
  - Tests according to ELOT EN 50164 - 1 and IEC 62561-1:
    - ✓ Dimensions (thickness, width, cross sectional area)
    - ✓ Coating tests (coating thickness, adhesion test)
    - ✓ Mechanical tests (tensile, elongation, bend test)
    - ✓ Ohmic resistance
    - ✓ Electrical resistivity

The above shall be presented by tables, drawings, photographs, or other documentation, as appropriate.

6.4 Format and contents of the test report, according to standard EN 61643-11

Test report according to standards EN 61643 – 11 series shall include, but not limited to, the following:

- Report identification
  - A title or subject of the report
  - Name, address and telephone number of the test laboratory
  - Unique identification number (or serial number) of the test report
  - Name and address of the Supplier
  - Report shall be paged, and the total number of pages indicated
  - Dates of performance of the tests and date of issue of the report
  - Signature and title or an equivalent identification of the person(s) authorized to sign for the testing laboratory and for the content of the report
  - Signature and title of person(s) conducting the tests
- Specimen description
  - Sample description
  - Detailed description and unambiguous identification of the test sample and/or test assembly
  - Characterization and condition of the test sample and/or test assembly
  - Sampling procedure, where relevant
  - Date of receipt of test items
  - Photographs, drawings or any other visual documentation, if available
- Standards and references
  - Identification of the test standard used and the date of issue of the standard
  - Other relevant documentation and the documentation date
- Test procedure
  - Description of the test procedure
  - Justification for any deviations, additions or exclusions from referenced standard
  - Procedure of voltage protection (Up) measurement
  - Procedure of SPDs operation cycle tests

- Procedure of temporary overvoltage withstand (TOV) tests

- Recorded results and parameters

  The measured, observed or derived results shall be clearly identified at least for:

  - Voltage protection (Up)
  - SPD operation cycle
  - Class I tests (for T1 SPDs)
  - Class II tests (for T2 SPDs)
  - Class III tests (for T3 SPDs)
  - Temporary overvoltage withstands ability (TOV)

The above shall be presented by tables, drawings, photographs, or other documentation, as appropriate.

7 EARTHING AND LIGHTNING PROTECTION SYSTEM INSTALLATION

7.1 Responsibility

Contractor shall provide labor, supervision, appropriate tools, equipment, consumables, services and all materials and accessories necessary for the earthing and lightning protection system installation. It is Contractor's responsibility to execute earthing and lightning protection system installation according to approved detail design drawings and documents, as have been described in this specification, as well as all relevant specifications and applicable codes and standards.

Contractor's engineers are responsible for:

- receipt and visual check for damages or omissions of earthing and lightning protection system material.
- visual inspection of the execution of earthing and lightning protection system installation with reference to the applicable Project's Specifications.

- performing all works according to the safety requirements set by the Supplier and the Local Authorities.
- keeping the corresponding quality records for erection works and examination procedures.
- ensuring the quality of any remedial works that are essential to take place.

Besides, Contractor must execute appropriate civil works, which are relevant to electrical installations. These works may be excavation for passage of earthing conductors and refilling works, covering of foundation earthing by concrete, etc.

7.2 General Notes for Earthing and Lightning Protection System Installation

As it has already been mentioned, all components that shall be used for Earthing and external LPS, the earth termination system and the equipotential bonding should comply with ELOT EN 50164 series, whereas SPDs (connected to Low Voltage Power Systems) that shall be used for Internal LPS should comply with EN 61643-11. SPDs connected to telecommunication and signaling networks shall be according to EN 61643-21.

A common earthing system shall be constructed for all earthing purposes unless otherwise specified, as it has already been stated in this document.

All metal parts of structure that fulfill the requirements of this document shall be considered natural air termination components, natural down conductors or natural earth electrodes, respectively and therefore parts of earthing and lightning protection system.

A foundation earthing shall be constructed, and additional earthing rods shall be provided, (if required) so as that total earthing resistance should be less than 1Ω. Moreover, requirements stated in this document must be taken into consideration.

Foundation earthing shall consist of hot-dip galvanized steel (St / tZn) tape of 30x3.5mm embedded in the foundation of buildings. The foundation earth system shall form a loop in the perimeter of the foundation and must be installed with its 30mm side vertical to the ground. The foundation earth system must be covered at least by 50mm concrete to be protected against corrosion.

The earth conductor shall be fastened-connected to the concrete reinforcement rebars at about every 2m through adequate clamps-fasteners.

Connections of the ends of foundation earthing tape or cross connections shall be provided via adequate clamps.

Provision shall be made for foundation earthing connections to additional earthing rods, if required.

All electrical equipment, system neutral, non-current-carrying metal parts, protective devices, cable sheaths, pit covers, lighting poles, fences, buildings structure, in general all metal structures that may receive short circuit currents etc. shall be connected to the earthing system.

Distribution panels shall be grounded by connecting each ones' grounding bar to the grounding bar of the panel from which they are fed with power. Protection and grounding of the consumers shall be realized through protective conductors that form part of their power supply wiring.

Bimetallic connectors shall be used between the surfaces of steel and copper surfaces in order to avoid electrochemical corrosion.

7.3 Electrical Substation Earthing System

An earthing system shall be constructed for each electrical substation (where applicable) to ensure protection against step and touch voltage, protection against atmospheric discharges (see lightning system), for the earthing of all metal non-current carrying parts and the earthing of the neutral points of transformers and emergency generators.

To ensure protection against step and touch voltage a grounding grid consisting of 5 mm diameter steel rods shall be embedded in the floor of each electrical substation.

The grounding grid shall consist of small modules of 300 mm x 300 mm, as a maximum and shall be installed at a depth of 5 cm - 10 cm inside the floor. The grid shall be laid inside the floors of each Substation rooms.

Galvanized Steel tapes shall be welded on the grounding grid and shall be brought out of the concrete floor at certain points, in order to interconnect the grounding grid with the copper earth bus ring, installed inside each substation.

The copper earth bus ring shall consist of 30 x 3 mm copper tape installed at a height of 50 cm above finishing grade, inside each Substation room.

The copper earth bus ring shall be connected to foundation earthing at several points.

The minimum cross-sectional areas for neutral grounding conductors should be calculated as shown in this specification.

All metal non-current carrying parts, located in each Substation room such as electrical panels frames and metal supports, doors, transformers, rails, trays, conduits etc. shall be grounded through bare stranded copper connections with the copper earthing tape.

Emergency generators and diesel oil tanks shall also be grounded to common earthing system. Bimetallic fittings shall be inserted between the surfaces of steel and copper tapes in order to eliminate electrolytic phenomenon.

7.4 Outdoor Earthing System

Outdoor earthing system shall consist of main earth loop to carry the highest fault current arising. Its cross-sectional area shall be equal or more than 70mm^2 stranded tinned bare copper wire. It shall also be connected to indoor earthing system.

Branch earth conductor shall be not less than 25 mm^2 stranded tinned copper wire. All buried conductors shall be laid at a minimum depth of 600mm below finished grade.
All above ground conductors shall be yellow / green color insulated. Connections to equipment shall be made with clamps equipped with screws, star lock washer and nuts of adequate material.

Earth rods shall be copper-clad, low carbon steel. Concrete pits for the earth rods shall be constructed. All underground connections including connections to ground rods shall be cad weld type. Above ground pipeline system shall be earthed, where it is electrically isolated from the underground one. Isolating spark gaps shall be installed, where required.

7.5 Indoor Earthing System

Inside electromechanical rooms of buildings, main earth conductor shall consist of copper earth bus ring of 30 x 3 mm copper tape installed at a height of 50 cm above finishing grade and branch earth conductors of not less than 35mm^2 copper with PVC insulation (Y/G) to be connected to metal parts, cable trays etc.

To this copper earth bus ring, all branch insulated earth conductors shall be connected.
At the door, the grounding copper tape shall be run along the door frame. Perimeter copper tape shall also be connected to foundation earthing. At certain points inside buildings, foundation earthing tapes shall be left out of the concrete for this reason.
Where clean instrument copper earth bars are required for instrumentation panels, they shall be of adequate dimensions and be installed at a height of 300mm above the floor. To these bars all clean earth bus bars of instrumentation panels shall be connected via 35mm^2 copper earthing conductors with PVC insulation (Y/G). The clean instrument copper earth bars shall be connected to the common equipotential earthing system.

7.6 External Lightning Protection System

The need of an LPS and LPS class shall be derived from the application of risk assessment method.

An air termination system shall be installed and shall consist of conductors which shall form meshes of dimensions depending on the LPS class.

It shall be installed on the roof surface of a structure and shall cover exposed parts, corners and edges. Roof conductor shall be of 10mm diameter hot-dip galvanized steel wire and shall be fastened every 1m and in every change of conductors' direction with suitable supports. Cross and "T" connections of conductors shall be provided with suitable hot-dip galvanized steel clamps.

Hot dip galvanized steel contraction – expansion absorbing components shall be installed at 20m intervals (if any) of straight conductors or at crossings of conductors to compensate for contraction – expansion of conductors caused by temperature changes. Structures that exceed the roof (e.g. chimneys) shall be protected by means of air termination rods.

All metal structures (heating – cooling units, pipes etc.) with distance lower than the separation distance (as stated in clause 6.3 in ELOT EN 62305-3 E3) shall be bonded to the air termination system at least at two points via hot-dip galvanized steel conductors and clamps.

Down conductors (other than "natural" ones) shall be of 10mm diameter hot-dip galvanized steel wire and installed either externally, around the structure or embedded in the reinforcement concrete column of the structure. The number of down conductors shall depend on LPS class, but at least two down conductors shall be installed.
Down conductors shall be fastened by means of suitable supports every 2m in case of conductors embedded in the reinforcement concrete or every 1m when installed externally.

Down conductors shall be connected to air termination system and earth termination system (foundation earthing for buildings). They shall follow the most direct possible path between the air terminal network and the earth termination network.

At the connection to the foundation earthing, a test joint shall be fitted on each down conductor.

7.7 SPDs Technical Characteristics and Installation

The following types of SPDs shall be installed, where required:

- MV Surge Arresters

  At the medium voltage field, a surge arrester per phase for each transformer shall be installed. The arresters shall be fastened on the body of the transformer or on metal base fastened on the wall. The arresters shall be earthed through copper stranded conductor 50 mm^2 cross sectional area, which must follow the shortest path to the earth termination system (foundation earth electrode), without forming loops.

- Main LV distribution board

  In the main low voltage distribution board surge protective devices shall be installed, as described below:

  - Between every phase and the neutral (L – N), combined protection type T1+T2 surge protective device with the following characteristics: Iimp (10/350) ≥35kA, up<2kV and TOV withstand >1400V shall be installed.
  - Between neutral and protective earth conductor (N – PE) one surge protective device protection type T1 with the following characteristics: Iimp (10/350)≥100kA, Up<4kV and TOV withstand >1400V shall be installed.

  The surge protective devices shall be earthed to the earthing bar of the board through the shortest path without forming loops.

- LV PPC meter

  The same types of surge protective devices that shall be installed in the main low voltage distribution board, shall also be installed as close as possible to the PPC meter

- Secondary distribution boards

  - Three phase secondary distribution boards. In the three phase secondary distribution boards a four-pole surge protective device protection type T2 with the following characteristics: Imax (8/20) ≥160kA (4 poles), Up<2kV and TOV withstand >1400V

shall be installed. The surge protective devices shall be earthed to the earthing bar of the board through the shortest path without forming loops.

- One phase secondary distribution board. In the one phase secondary distribution boards surge protective devices shall be installed, as described below:
  - Between phase and neutral (L – N) protection type T2 surge protective device with the following characteristics: Iimp (8/20) ≥40kA, up<2kV and TOV withstand >1400V shall be installed.
  - Between neutral and protective earth conductor (N – PE) protection type T2 surge protective device with the following characteristics: Iimp (8/20) ≥40kA, up<1,4kV and TOV withstand >1400V shall be installed.

The surge protective devices shall be earthed to the earthing bar of the board through the shortest path without forming loops.

- Secondary distribution boards which supply sensitive electronic equipment
  - Three phase secondary distribution boards which supply sensitive electronic equipment

In the three phase secondary distribution boards which supply sensitive electronic equipment surge protective devices shall be installed, as described below:

- Between every phase and the neutral (L – N) protection type T3 surge protective device with the following characteristics: Iimp (8/20) ≥10kA, up<1,5kV and TOV withstand >1400V shall be installed.
- Between neutral and protective earth conductor (N – PE) protection type T3 surge protective device with the following characteristics: Iimp (8/20) ≥20kA, up<1,3kV and TOV withstand >1400V shall be installed.

The surge protective devices shall be earthed to the earthing bar of the board through the shortest path without forming loops.

- One phase secondary distribution board which supply sensitive electronic equipment

In the one phase secondary distribution boards which supply sensitive electronic equipment surge protective devices shall be installed, as described below:

- Between phase and neutral (L – N) protection type T3 surge protective device with the following characteristics: Iimp (8/20) ≥10kA, up<1,5kV and TOV withstand >1400V shall be installed.
- Between neutral and protective earth conductor (N – PE) protection type T3 surge protective device with the following characteristics: Iimp (8/20) ≥40kA, up<1,3kV and TOV withstand >1400V shall be installed.

The surge protective devices shall be earthed to the earthing bar of the board through the shortest path without forming loops.

- UPS

In the distribution boards of the UPS surge protective devices shall be installed, as described below:

- Between every phase and the neutral (L – N) protection type T3 surge protective device with the following characteristics: Iimp (8/20) ≥10kA, up<1,5kV and TOV withstand >1400V shall be installed.
- Between neutral and protective earth conductor (N – PE) protection type T3 surge protective device with the following characteristics Iimp (8/20) ≥20kA, up<1,3kV and TOV withstand >1400V shall be installed.

The surge protective devices shall be earthed to the earthing bar of the board through the shortest path without forming loops.

- Protection of sensitive electronic equipment which are supplied by schuko outlet

  For the protection against overvoltages of sensitive electronic equipment which are supplied by schuko outlet (e.g. telecommunication center, PC) schuko single pole surge protective devices, protection type T3, with the following characteristics: Iimp (8/20) ≥3kA, up<1,3kV and TOV withstand >300V shall be installed.

- Electrical equipment in the Field

  Outgoing feeders of distribution boards (located inside buildings) for electrical equipment in the field shall have surge protective devices, as described below:

  - Between every phase and the neutral (L – N), combined protection type T1+T2 surge protective device with the following characteristics: Iimp (10/350) ≥35kA, up<2kV and TOV withstand >1400V shall be installed.

- Between neutral and protective earth conductor (N – PE) one surge protective device protection type T1 with the following characteristics: Iimp (10/350) ≥100kA, up<4kV and TOV withstand >1400V shall be installed.

The surge protective devices shall be earthed to the earthing bar of the board through the shortest path without forming loops.

- Telecommunication center
  - Power supply

    A schuko single pole surge protective device, protection type T3, with the following characteristics: Iimp (8/20) ≥3kA, up<1,3kV and TOV withstand >300V shall be installed.
  - Telecom lines

    Unless otherwise specified in relative documents or/and drawing, every incoming line shall be protected by a surge protective device which can offer primary and secondary protection.

- Instrument equipment in the field

  Regarding instrument equipment in the field (pressure transmitters), surge protective devices shall be installed, as described below:

  For each pressure transmitter, one Ex surge protection device with the following characteristics shall be installed:

  Nominal voltage UN = 24VDC,

  Maximum operating voltage, UC = 33VDC,

  Maximum operating current, IL = 0.5A,

  Maximum signal frequency, F = 6MHz,

  Series line (input-output) resistance, R = 1.8Ω,

  In, C2 test, (8/20μs), 2P/1P = 10KA/5KA and

  Up (at In) < 50V (L1 – L2), < 1.5KV (L – GND)

  Installation and earthing of surge protective devices for pressure transmitters shall be according to ‘Electrical Std Details’.

- Photovoltaic modules in the field and DC input terminals of inverter

  For each photovoltaic string and DC part of corresponding inverter, one combined protection type T1+T2 surge protection device with the following characteristics shall be installed at the input terminals of the inverter just after the entrance of the DC current arriving from the photovoltaic panel:

  Nominal voltage UN = 690VDC,

  Iimp (10/350μs) ≥ 12.5KA,

  Up<4kV,

  Number of Poles: 2 and

  Connection between terminals: L+ - PE, L- - PE

  The surge protective devices shall be earthed to the earthing bar of the board through the shortest path without forming loops.

- Photovoltaic system AC distribution board

  In the photovoltaic system AC distribution board surge protective devices shall be installed, as described below:

  - Between every phase and the neutral (L – N), combined protection type T1+T2 surge protective device with the following characteristics: Iimp (10/350) ≥12.5kA, up<1.4kV and TOV withstand >1400V shall be installed.
  - Between neutral and protective earth conductor (N – PE) one surge protective device protection type T1 with the following characteristics: Iimp (10/350) ≥12.5kA, up<2kV and TOV withstand >1400V shall be installed.

  The surge protective devices shall be earthed to the earthing bar of the board through the shortest path without forming loops.

7.8 Field Inspection and Testing

Field inspection and testing of earthing and lightning protection system shall be carried out by properly qualified and experienced personnel with calibrated test equipment provided by the Contractor.

Field inspection and testing shall also be witnessed by Client Representative.
Inspection and testing shall be according to project documentation or / and applicable codes and standards. Minimum test requirements are described below.
Earth continuity tests shall be made by use of a heavy-duty earth megger.
The resistance before connection and after connection of each electrode shall be measured.

Total earthing resistance shall be measured, so as that if it is not less than 1Ω, additional rods shall be installed, until its value is less than 1Ω.
Furthermore, all tests related to earthing system according to ELOT HD 384, including measurement of the resistance of equipotential bonding protective conductors shall be provided.

Inspection shall ensure, as a minimum, that all connections have been executed and provision for testing purposes have been made, as specified in this document and in relevant codes and standards.

Material which shall fail the tests shall be replaced by new one, which shall be tested.
A complete record of all tests that shall be carried out and their results shall be retained.

7.9 As-Built Documentation

At the completion of the works, a copy of all related project drawings, where all modifications and variations marked in red, shall be provided to Client Representative and as-built drawings shall be issued.