

**JOHANNESBURG WATER (SOC) Ltd.**

**BULK WASTEWATER**

**PARTICULAR SPECIFICATION**

**E11 : ELECTRICAL EARTHING AND  
LIGHTING PROTECTION**



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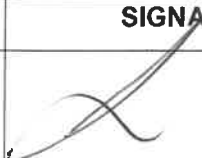
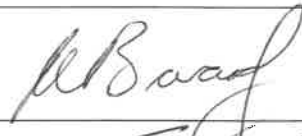
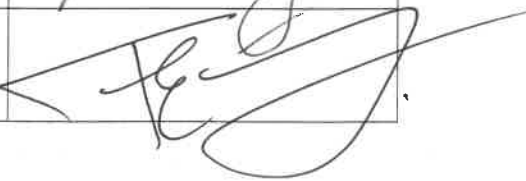
## DOCUMENT CONTROL SHEET

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### RECORD OF REVISIONS

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**PARTICULAR SPECIFICATION: VOLUME E11: GENERAL ELECTRICAL GENERAL EARTHING AND LIGHTNING PROTECTION**

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## **E11.1 SCOPE**

This specification covers the detail requirements of the general protection against lightning to be installed under the contract, including:

- a) General notes on the lightning protection measures;
- b) The risk management and definition of the risk to a structure due to lightning strikes;
- c) A Lightning Protection System (LPS) describing principles to be followed for the protection against physical damage to a structure including the installations within the structure as well as injury to living beings due to touch and step voltages;
- d) Surge Protection Measures (SPM) to reduce the risk of permanent failures of electrical and electronic installations within a structure due to a Lightning Electromagnetic Pulse (LEMP).
- e) Information for the design, installation, inspection, maintenance and testing of the above.

## **E11.2 STATUTORY DOCUMENTS AND STANDARDS**

### **E11.2.1 Standards**

The latest edition, including all amendments up to date of tender of the following particular national and international specifications, publications and codes of practice which shall be read in conjunction with this specification and shall be deemed to form part thereof:

- a) SANS 10142-1 The wiring of premises Part 1: Low-voltage installations.
- b) SANS 10142-2 The wiring of premises Part 2: Medium-voltage installations above 1 kV ac not exceeding 22 kV ac. and up to and including 3 MVA installed capacity.
- c) SANS 62305-1 Protection against lightning Part 1: General principles
- d) SANS 62305-2 Protection against lightning Part 2: Risk management
- e) SANS 62305-3 Protection against lightning Part 3: Physical damage to structures and life hazard
- f) SANS 62305-4 Protection against lightning Part 4: Electrical and electronic systems within structures.
- g) SANS 62561 Lightning protection system components (LPSC).
- h) SANS 1063 Earth rods, couplers and connections.
- i) SANS 10199 The design and installation of earth electrodes.
- j) SANS 10313 Protection against lightning — Physical damage to structures and life hazard.
- k) SANS 10292 Earthing of low-voltage (LV) distribution systems.

### **E11.2.2 Particular Specifications to be read in conjunction with this Specification**

The following particular specifications shall be read in conjunction with the Project Specification:

- a) Automation and Control Design Standards, Volume 5: Clean Power and Surge Protection.

### **E11.3 CERTIFICATE OF COMPLIANCE**

#### **E11.3.1 New or modified installations**

The Contractor shall appoint a competent and experienced lightning protection design engineer for the design, supply, installation, inspection and testing of the Lightning Protection System (LPS) as well as the Surge Protection Measures (SPM).

After installation and testing of the LPS and SPM, the lightning protection design engineer will issue a Lightning Protection System Installation Safety Report as prescribed in SANS 10313: Annex A as well as SANS10142-1, for each area of protection. The Engineer will witness the installation as well as all tests conducted.

Two copies of this report shall be submitted to the Engineer before handing over of any repair, modification or new installation involving LPS or SPM systems.

#### **E11.3.2 Maintenance of installations**

The Client shall appoint a competent and experienced lightning protection engineer to maintain and inspect the Lightning Protection System (LPS) as well as the Surge Protection Measures (SPM) on an annual basis. Tests and inspections should be done prior to the start of the lightning season.

The lightning protection engineer will issue a Lightning Protection System Maintenance Certificate as prescribed in SANS 10313: Annex B, for each area of protection.

### **E11.4 PROTECTION MEASURES**

The following protective measures should be installed as far as possible. The most suitable protective measure shall be selected during the design phase, considering technical and economic aspects based on a risk assessment.

#### **E11.4.1 Protection measures to reduce injury of living beings by electric shock**

- a) Adequate insulation of exposed lightning conductive parts;
- b) Equipotential bonding of equipment and conductive parts and connection to a meshed earthing system;
- c) Physical restrictions and warning notices where the above is not achievable.

#### **E11.4.2 Lightning Protection System (LPS) to reduce physical damage**

- a) Air-termination system on high points;
- b) Down-conductor system;
- c) Earth-termination system;
- d) Equipotential bonding;

#### **E11.4.3 Surge Protection Measures (SPM) to reduce failure of electrical and electronic systems**

- a) Earthing and bonding measures;
- b) Magnetic shielding;
- c) Line routing;
- d) Isolating interfaces;
- e) Coordinated Surge Protection Device (SPD) system.

### **E11.5 RISK MANAGEMENT**

Risk to a structure exposed to lightning flashes is managed by a process based on risk evaluation or assessment. Appropriate protection measures are selected to reduce the risk to or below the tolerable limit.

The following basic procedure must be followed during the risk assessment:

- a) Identification of the structure to be protected;
- b) Partitioning of the structure into zones;
- c) Identification of all the types of loss in the structure;
- d) The identification and calculation of the corresponding risk components for each type of loss;
- e) Evaluation of need of protection;
- f) Selection of protective measures (LPS, SPM or other protection measure);
- g) Evaluate the cost-effectiveness of the protection measures;
- h) Re-evaluation of the corresponding risk components and the need for further protection.

The risk assessment and the evaluation of loss and risks as well as protection selection must be done by a competent and experienced lightning protection design engineer. It is the responsibility of the contractor to appoint a lightning protection design engineer for this purpose.

## **E11.6 EXTERNAL LIGHTNING PROTECTION SYSTEM (LPS)**

An external LPS is installed on a structure to intercept a direct lightning flash to the structure, conduct the lightning current safely towards earth and to disperse the lightning current into the earth. It consist out of an air-termination system, a down-conductor system and an earth-termination system.

### **E11.6.1 Design of the LPS**

The design of the LPS must be done in accordance with SANS 62305-3 with specific reference to Annex E.

The LPS should be designed and installed by competent and experienced LPS design engineer and LPS installer (person who is competent to install, construct and test an LPS for compliance with this SANS 10313). It is the responsibility of the contractor to appoint a competent and experienced LPS design engineer and installer. The Contractor is responsible to manage consultation between the various parties involved in the project (client, local authorities, LPS design engineer, LPS installer, architect, civil contractor/builder and electrical engineer). In new structures, the LPS should be installed during the construction phase; proper timing for soil resistivity test and the design of the LPS is of utmost importance.

The LPS design engineer and installer will be responsible for the quality assurance on the project.

### **E11.6.2 Isolated LPS**

On structures at risk of explosion and fire an isolated external LPS must be installed.

### **E11.6.3 Air-termination systems**

Air-termination systems can be composed of any combination of the following elements:

- a) Rods (including free-standing masts);
- b) Catenary wires;
- c) Meshed conductors.

Air terminals installed shall be located at corners, exposed points and edges on a structure. To determine the exact location one or more of the following methods should be followed:

- a) Protection angle method;
- b) Rolling sphere method;
- c) Mesh method.

All types of air terminals shall comply in full with SANS 62305-3. The positioning of air termination system shall comply with SANS 62305-3 (Annexure A).

All air-termination components must be fixed and secured in such a way to withstand accidental external mechanical forces as well as electromechanical forces during a lightning strike.

#### E11.6.4 Down-conductor systems

If the air-termination system is supported by one or more non-conductive columns, at least one down-conductor is required for each column. Steel columns do not require additional down-conductors.

All down-conductor components must be fixed and secured in such a way to withstand accidental external mechanical forces as well as electromechanical forces during a lightning strike.

Down conductors may be placed on the surface of non-combustible walls. On structures at risk of explosion and fire, all down conductors must be isolated from the structure walls.

#### E11.6.5 Earth-termination system

For lightning protection, a single integrated structure earth-termination system is preferable and is suitable for all purposes (i.e. lightning protection, power systems and telecommunication systems).

An earthing resistance not exceeding  $3\Omega$  (measured at low frequency) is required for earth termination systems. Should it be impossible to achieve this earthing resistance value, the Engineer must approve the value obtained and deemed reasonable.

##### Type A earthing arrangement

Each down connector is connected to a horizontal or vertical earth electrode installed outside the protected structure. A minimum of two earth electrodes will be installed, buried at an upper end depth of minimum 0.5 m with a separation distance to minimize electrical coupling effects in the earth. The minimum length of the earth electrodes will be calculated during the design phase, based on the soil resistivity.

##### Type B earthing arrangement

A ring conductor is installed external to the protected structure, buried at an upper end depth of at least 0.5 m and at a distance of about 1 m away from the external walls. The radius of protection will be calculated during the design phase, based on the soil resistivity. Additional electrodes should be added to obtain the desirable protection radius. The number of electrodes shall not be less than the number of down conductors (with a minimum of two electrodes).

##### Test points

A test point must be installed at the connection between each down-conductor and earth termination electrodes. The joint will only be opened for testing and will remain closed at all times.

##### Conductor connections

Conductor connections shall be made secure by exothermic welding. Clamping or bolting of conductor connection points shall only be accepted with permission from the Engineer. All points of connection must be covered with a cold applied anti-corrosion and sealing tape based on a synthetic fabric, impregnated and coated with a neutral petrolatum compound.

#### E11.6.6 LPS Installation

Type B earthing will be installed as the preferred arrangement. Type A earthing will only be accepted with prior approval from the Engineer (in writing). The installation of the earth electrodes will be inspected and approved by the Engineer during the construction phase.

The LPS shall be bonded to the fixed electrical installation protective earthing in accordance with the requirements of SANS 10142-1. Where an installation may typically consist of a main building or plant and one or more satellite subsystems, the various earth networks shall be interconnected to form one earth system. Only in the rare instance of a subsystem being totally isolated, with no cables, pipes, fences or other conductive structures connecting it to the rest of the installation, may a system be provided with a separate earth network.

#### E11.6.7

#### Components

All material and components used in a LPS must conform to the requirements specified in SANS 62561.

#### Minimum cross-sectional area of conductors

a) Air-termination conductors, air-termination rods and down-conductors:

Configurations and minimum cross-sectional areas of air-termination conductors, air-termination rods and down-conductors are given in SANS 62305-3: Table 6 "Material, configuration and minimum cross-sectional area of air-termination conductors, air-termination rods, earth lead-in rods and down-conductors".

The following material and dimensions will be specifically applicable. No copper conductors will be accepted.

Material	Configuration	Cross-sectional area (sq. mm)
Aluminium	Solid tape	70
	Solid round	50
Stainless steel	Solid tape	50
	Solid round	50

**Table 1:** *Specific configurations and minimum cross-sectional areas of air-termination conductors, air-termination rods and down-conductors.*

b) Earth conductors and electrodes:

Configurations and minimum dimensions of earth electrodes are given in SANS 62305-3: Table 7 "Material, configuration and minimum dimensions of earth electrodes".

The following material and dimensions will be specifically applicable. No copper conductors will be accepted.

Material	Configuration	Dimensions	
		Earth rod diameter (mm)	Earth conductor (sq. mm)
Copper coated steel	Solid round	14	
Stainless steel	Solid round	15	78
	Solid tape		100

**Table 2:** *Specific configurations and minimum dimensions of earth conductors and electrodes*

#### E11.7

#### **LPS FOR STRUCTURES WITH A RISK OF EXPLOSION**

The design, construction, extension and modification of lightning protection systems for structures with a risk of explosion must comply with SANS 62305-3: Annex 3.

- The LPS must be isolated from the structure. This includes the air termination conductors as well as all down conductors. Under no circumstances may any parts of the structure be used as part of the LPS
- The distance between down conductors will not exceed 5m. The down conductor count and spacing will be determined during the design phase with a minimum of two down conductors installed.
- The earth-termination system will be a type B arrangement
- All installations/structures/equipment will be equipotential bonded to the lightning protection system. Junctions shall be provided for the joining of connection and earthing leads to containers, metal construction parts, drums and tanks
- Aboveground metal piping shall be earthed at least every 30 m. Bonding conductors will



be connected to the piping at tap holes in the flanges for taking up screws. Where this is not possible, welded-on lugs or bolts will be used

- f) Such devices shall be suitable for the environment in which they are installed.

The above will be applicable to aeration basins, bioreactors, HOW, digester (high risk areas)

## **E11.8 INTERNAL LIGHTNING PROTECTION SYSTEM (LPS)**

An internal LPS is intended to prevent flashover between electrically conducting elements within the structure and the external LPS components using either equipotential bonding or an adequate separation distance.

### **E11.8.1 Equipotential bonding**

All equipment likely to be subjected to surge currents shall be securely bonded together and to the earth network.

#### **Bonding bar**

A single bonding bar shall be installed for equipotential bonding. The bar shall be manufactured from electrical grade hard drawn aluminium 80sq mm complete with mounting insulators. The bar will be pre-drilled with ten M8 holes, fitted with stainless steel high tensile hex bolts with nuts and washers. The bar will be fitted with two removable test links, one on each end of the bar.

The bonding bar shall be connected to the earth-termination system at two connection points with two separate cables.

A ring bonding bar where more than one interconnected bonding bars are installed can be used for larger installations.

#### **External conductive parts**

External conductive parts shall be bonded to the bonding bar from a point as near as possible to the point of entry into the structure. This will include all electrical conductive pipes, cable ladder, fences and gates.

#### **External electrical lines**

Live conductors shall be bonded to the bonding bar via SPD's. (See Paragraph E11.1 Surge Protection Measures). All gland plates in electrical panels will be bonded to the earth network. Power cable armouring shall be bonded to the earth network at both ends of the cable via the cable glands on the gland plates.

#### **Telecommunication and Instrumentation lines**

Please refer to Automation and Control Design Standards, Volume 5: Clean Power and Surge Protection.

#### **Internal systems**

Screened cables installed in the internal system must be bonded to the bonding bar via the screen. Cables in metal conduits installed in the internal system must be bonded to the bonding bar via the conduits. Unscreened cables must be connected to the bonding bar via SPD's (See Paragraph E11.1 Surge Protection Measures).

#### **Bonding conductors**

Bonding conductors shall be short and shall run in straight or smoothly contoured routes. Material, dimensions and conditions of use shall comply with SANS 62305-3. The minimum cross-section for bonding components shall comply with SANS 62305-4 Table 1 "Minimum cross-sections for bonding components".

The following material and dimensions will be specifically applicable.

Bonding component	Material	Cross-section (sq. mm)
Bonding bars	Aluminium	80
Bonding to LPS	Aluminium	70
Connecting conductors from internal metal installations to bonding bars (carrying a partial lightning current)	Aluminium	70

**Table 3:** Specific material and cross-section area for bonding components

## **E11.9 INSPECTION AND MAINTENANCE OF LPS**

### **E11.9.1 Inspection**

Inspections should be conducted during the construction period as well as after completion of the installation. A Lightning Protection System Installation Safety Report as described in SANS 10313 Annex A (or similar) must be issued by the LPS installer after completion of the installation. All tests conducted during the commissioning of the LPS must be witness by the Engineer. Inspections must be conducted after any alteration or repair of the LPS.

Regular periodic inspections must be conducted on the LPS system of explosives facilities. A maintenance and inspection plan shall be developed for the installed protection systems. The system shall be tested every 12 months. A register shall be kept for this purpose. Only qualified personnel having the necessary training and expertise shall be permitted to maintain, inspect, test and sign off these facilities.

### **E11.9.2 Maintenance**

Routine inspections should be conducted on a 12-monthly basis. Any observed faults must be repaired immediately.

## **E11.10 INJURY TO LIVING BEINGS DUE TO TOUCH AND STEP VOLTAGES**

The area surrounding the down-conductor (within a 3-meter radius) may be hazardous despite measures described in this specification. Additional measure must be installed to reduce this risk to acceptable values:

### **E11.10.1 Touch voltage**

- The area is demarcated to prevent access and relevant notices are displayed (ISO 3864-1), or
- The number of down-conductors are increased to above 10, which will reduce the current and induced voltages, or
- Increasing the contact resistance of the soil to above 100kΩ, or
- The down conductors are insulated against the lightning impulse (100 kV, 1, 2/50 μs impulse withstand voltage).

### **E11.10.2 Step voltage**

- The area is demarcated to prevent access and relevant notices are displayed (ISO 3864-1), or
- The number of down-conductors are increased to above 10, which will reduce the current and induced voltages, or
- Increasing the contact resistance of the soil to above 100kΩ, or
- The down conductors are insulated against the lighting impulse (100 kV, 1,2/50 μs impulse withstand voltage), or

- e) The installation of a meshed earth-termination system.

## **E11.11 SURGE PROTECTION MEASURES (SPM)**

Surge Protection Measures (SPM) are implemented to reduce the risk of permanent failures of electrical and electronic installations within a structure due to a Lightning Electromagnetic Pulse (LEMP).

Equipment failure due to LEMP is caused by surges conducted by connected wiring or by radiated electromagnetic fields. The effect of line surges is reduced by the installation of Surge Protection Devices (SPD's). The effect of radiated electromagnetic fields is reduced by shielding of equipment and shielded lines. Equipment generally complies with EMC product standards, which is sufficient to protect such equipment against LEMP.

### **E11.11.1 Design and installation of SPM**

The SPM should be designed, installed and signed off by a competent and experienced SPM design engineer and SPM installer (person who is competent to design, install, construct and test an SPM with a broad knowledge of Electromagnetic compatibility (EMC)). It is the responsibility of the contractor to appoint a competent and experienced SPM design engineer and installer.

The design of the Surge Protection Measures (SPM) must be done in accordance with SANS 62305-4 as well as the Risk Assessment study done as described in SANS 62305-2.

### **E11.11.2 Earthing and bonding**

A meshed network with a 5m mesh width is installed around the structure. This mesh is connected to the Type B ring earth electrode as well as the structure's interconnected mesh reinforced concrete floor to form a meshed earth termination system. The earth-termination systems of all internal systems should be bonded together to prevent potential differences between the systems.

Bonding bars in a stand-alone or ring configuration should be used to bond all conductive parts and incoming services (metal pipes, power lines, signal lines) together. Incoming lines should be bonded with SPD's. The material and minimum cross-sections for bonding component must comply with SANS 62305.

### **E11.11.3 Magnetic shielding and line routing**

Spatial shielding is used to define protection zones. It can be grid like and can use electrical conductive reinforcement in the building. Internal lines can comprise of shielded cables or metallic enclosures of cables. Cables must be routed close conductive parts in the shielding system (reinforced concrete) to minimise induction.

The requirement of SANS 62305 concerning the material and minimum cross-sections or thickness of air-termination and down conductors must be followed.

### **E11.11.4 Coordinated SPD system**

Please read this section in conjunction with the document Automation and Control Design Standards, Volume 5: Clean Power and Surge Protection for system compatibility.

The principle of a coordinated SPM is based on the division of the protected area/s into Lighting Protection Zones (LPZ), where the first LPZ<sub>n</sub> is the overall protection zone which borders the inner zone LPZ (LPZ<sub>n+1</sub>). The effect of the LEMP is reduced with each zone employed. LPZ 0 is the unprotected outer zone where equipment will be exposed to full LEMP and lightning surge currents. LPZ 1...n is the inner zones where equipment is exposed to limited surge current and attenuated electromagnetic field. (Refer to SANS 62305-4 typical drawings.)

SPD's must be selected to reduce the surge overvoltage between the live conductors and earth to a value lower than the equipment's rated impulse withstand voltage  $U_w$  at its terminals (common mode withstand voltage). The type of SPD, the location of the SPD (as close as possible to the point of entrance of the line vs as close as possible to the equipment to be protected) as well as the connecting conductors must be considered.

Types of SPD's:

There are three types of SPD's:

a) Type 1 SPD

The Type 1 SPD is recommended in the specific case of service-sector and industrial buildings, protected by a lightning protection system or a meshed cage. It protects electrical installations against direct lightning strokes. It can discharge the back-current from lightning spreading from the earth conductor to the network conductors. Type 1 SPD is characterized by a 10/350  $\mu$ s current wave.

b) Type 2 SPD

The Type 2 SPD is the main protection system for all low voltage electrical installations. Installed in each electrical switchboard, it prevents the spread of overvoltages in the electrical installations and protects the loads. Type 2 SPD is characterized by an 8/20  $\mu$ s current wave.

c) Type 3 SPD

These SPDs have a low discharge capacity. They must therefore mandatorily be installed as a supplement to Type 2 SPD and in the vicinity of sensitive loads. Type 3 SPD is characterized by a combination of voltage waves (1.2/50  $\mu$ s) and current waves (8/20  $\mu$ s).

E11.11.5

SPM management

A Management Plan must be implemented by a competent and experienced SPM design engineer:

- a) Risk analysis;
- b) SPM planning;
- c) SPM design;
- d) Installation of the SPM;
- e) Approval of the SPM;
- f) Recurrent inspections (documented);
- g) Maintenance (following defects noted during recurrent inspections).

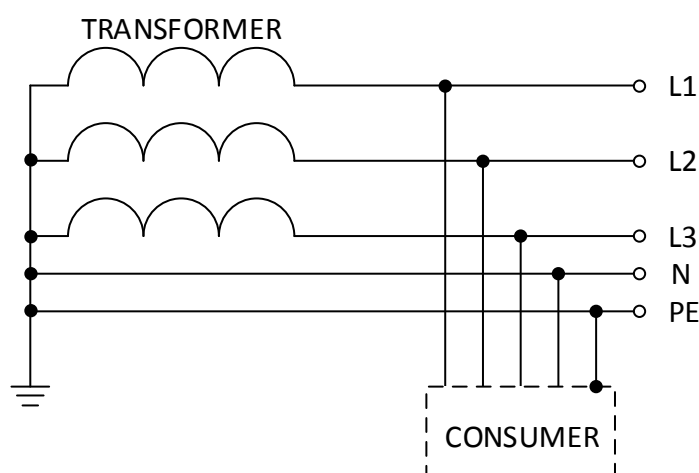
**E11.12**

**EARTHING OF THE LV DISTRIBUTION SYSTEM**

E11.12.1

TN-S system earthing – Separate neutral and protective conductors

The protective conductor (PE) is a separate conductor connected to the transformer neutral (star point). The transformer neutral is connected to the structure earth-termination system.



**Figure 1.** *TN-S System earthing*

E11.12.2 Requirements of the TN-S system earthing

- a) In a single-phase TN-S system, the equivalent area of the neutral (N) conductor should be not less than the area of the phase conductor.
- b) In a three-phase TN-S system, the equivalent area of the N conductor should be not less than half the area of one phase conductor.
- c) In a three-phase TN-S system, all power cables will be four core, with the fourth (black) core used as the N conductor.
- d) The protective earth (PE) conductor shall be able to carry the maximum fault current for the duration of the fault. This applies to any point in the distribution system.
- e) The PE conductor should be of copper not less than 10mm<sup>2</sup>.
- f) The minimum cross-sectional area of the PE conductor for phase conductors 16mm<sup>2</sup> to 35mm<sup>2</sup> is 16mm<sup>2</sup>.
- g) The minimum cross-sectional area of the PE conductor for phase conductors above 35mm<sup>2</sup> is at least 50% of the phase cross-sectional area.
- h) No mechanism (circuit breaker, disconnector, fuse or removable link) which can separate the neutral conductor from the neutral point may be installed.

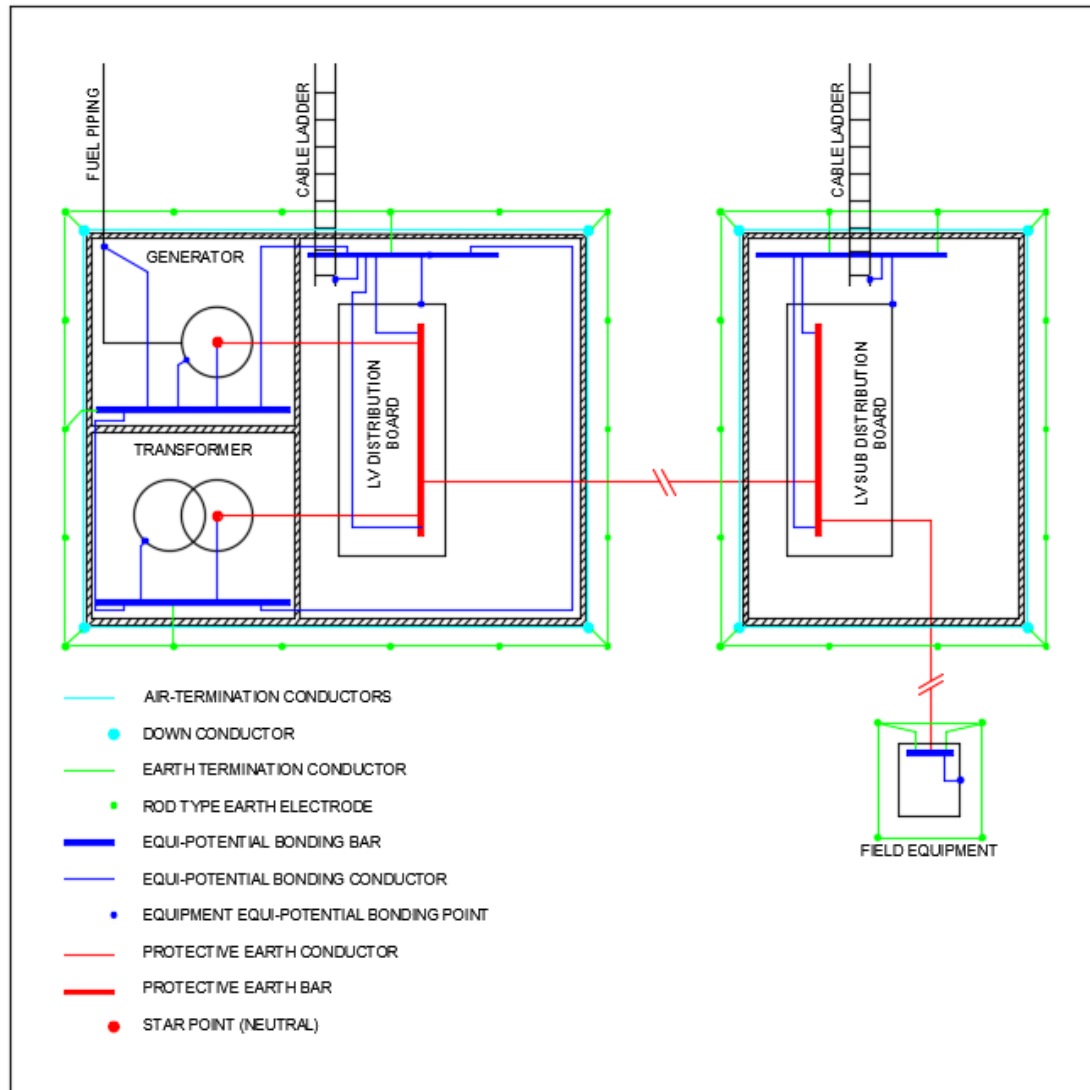
E11.12.3 Installation of the TN-S system earthing

- a) The PE conductor will be installed next to the associated LV power cable.
- b) Where the PE conductor is installed directly in the ground, bare copper earth wire will be used.
- c) Where the PE conductor is installed in a covered cable trench or on a cable rack, black PVC insulated earth wire will be used. Both ends of the PE conductor will be identified with yellow/green crimp sleeves.

E11.14

**LIGHTNING PROTECTION SYSTEM (LPS)**

Figure 2 shows a typical LPS as implemented by Johannesburg Water



**Figure 2.** *Lighting Protection System (LPS)*

**E11.16**

**MEASUREMENT AND PAYMENT**

<b><u>Item</u></b>	<b><u>Unit</u></b>
Earth resistivity tests .....	No

The tendered rate shall include for the carrying out of the earth resistivity tests by a competent and experienced LPS engineer. The unit for measurement shall be per point where such tests have to be carried out.

<b><u>Item</u></b>	<b><u>Unit</u></b>
Design of a Lightning Protection System (LPS).....	No

The tendered rate shall include for the design by a competent and experienced LPS engineer and must include the design of the Surge Protection Measures (SPM). The unit for measurement shall be an area of design.

<b><u>Item</u></b>	<b><u>Unit</u></b>
Installation of a structure LPS .....	Sum

The tendered rate shall include full compensation for the supply of all material required and the installation of the Lightning Protection system as per the design by a competent and experienced LPS engineer. It shall include for the testing of the LPS by a competent and experienced LPS engineer.

<b><u>Item</u></b>	<b><u>Unit</u></b>
Extra over for the supply and installation of additional rod type earth electrodes of specified length including welding/clamps for the connection of earth-termination conductors .....	No

The tendered rate shall include full compensation for the supplying and installation of the earth electrodes.

<b><u>Item</u></b>	<b><u>Unit</u></b>
Provision for additional earthing as required .....	Provisional sum

The provisional sum provided shall include for any additional earthing which may be specified by the Engineer after the acceptance of the contract.

The Contractor shall submit a written quotation to the Engineer when requested to by the Engineer and shall not commence with the installation of any additional earthing without the written instruction of the Engineer.

<b><u>Item</u></b>	<b><u>Unit</u></b>
Testing of a LPS.....	No

The unit of measurement shall be the number of tests undertaken by a competent and experienced LPS engineer, including the supply of the equipment required to do the test.