SECTION-B 2.12

EARTHING & BONDING OF ELECTRICAL SYSTEM

2.12.1 PREMABLE

A. This Section includes complete installations to earth every source of energy and to provide protective earthing and equipotential bonding, based on the TN-S system arrangement, including:

1 Transformer neutral earthing and RMU
2 Main earthing terminals or bars in electrical and mechanical rooms.
3 Exposed conductive parts of electrical equipment (light fittings, switches and socket outlets, etc...).
4 Extraneous conductive parts.
5 Building main ring electrode.
6 Separate clean earth for the ELV systems for each ELV and control room (less than 1 ohm)

B. Earthing requirements specified in this Section may be supplemented by special requirements of systems described in other Sections.

2.12.2 SUMMARY

A. This section specifies engineering, supply, installation, testing, commissioning and setting of the complete earthing network for individual earthing systems, circuit protective conductors and bonding conductors. A complete earthing network comprising copper cables /GI/AL tapes, electrodes and earth bonding of all relevant necessary non-current carrying metal parts of equipments/ apparatus shall be connected as required & as per the drawings.

B. Section includes earthing systems and equipment, plus the following special applications:
1 Underground distribution earthing.
2 Ground bonding of lightning protection system.

C. The system shall have a common earthing system as described in the specification and as shown on the drawings. Individual earthing systems as per drawing shall be provided as follows. Earth main MV / LV / Generator Electrical Earthing shall have 2 connection to the earthing system to provide for redundant paths:
1 MV Electrical Functional Earthing
2 LV Electrical Functional & Trafo Neutral Earthing
3 Generator Functional and Neutral Earthing
4 ELV Earthing
5 Data Communication Earthing/CLEAN EARTH SYSTEM FOR IT, FAS, PAVA, BMS,ETC
6 Equipotential bonding of all containment/cable trays, etc, metallic conduits, metallic parts of equipments & all type of panel boards, metallic installation of HVAC, fire fighting, plumbing, drainage, etc,
7 Equipotential bonding to all incoming services within each area
8 Supplementary bonding within internal areas and plant areas including piped services.

D. Code & Standards: - The earthing & bonding system shall be designed and executed in accordance with the latest applicable sections of the IEC/BS/IS codes. Since IS Standards are originated from IEC standards, technical requirements listed in the latest IEC standards supersedes IS standards requirements which do not cover them.

NEC 2011	National Electrical Code
IS: 3043	Earthing
IEC 60364	Electrical installations of buildings
IEEE 80	IEEE Guide for Safety in AC Substation Grounding
IS: 2309	Code of practice for the protection of buildings and allied structures against lightning
BS EN 62305 (1 to 4)	Lightning Protection System

The detail of the Earthing System shall also conform to the requirements of all relevant local codes as applicable together with the additional requirements referred to in the Specification and Drawings, whichever is the more stringent and acceptable to the Engineer.

2.12.3 SUBMITTAL

A. Product Data: Prior to ordering materials, submit data for approval including, but not limited to, manufacturer's catalogues for each type of product indicated including the following:
1 Ground rods.

2 Connecting clamps.
3 Earthing conductors, protective conductors, and bonding conductors.
4 Connectors and other accessories.
5 Exothermic welding kits and tools.

B. Field Test Reports: Submit certified, numbered, written test reports to include the following:
1 Test procedures used and test conditions.
2 Test results that comply with requirements.
3 Results of failed tests and corrective action taken to achieve test results that comply with requirements.

C. Shop and Construction Drawings: Submit Drawings for approval including, but not limited to, the following:
1 Overall earthing schematic indicating cross sectional area of all earthing, protective and bonding conductors.
2 Overall earthing layout indicating earthing provisions at substations, switchgear, distribution panel boards etc., identifying fittings used, insulation, plates and marking, passage and routing of earthing conductors, conduit, sleeves, grooves, niches etc., giving sizes and dimensions of component parts, and exact location of earth pits, rods and details of installation and connections, and exact routing of buried earthing conductors with indication of cross-section, depth of laying and covering.
3 Records: Submit the following:
4 Scaled Drawings, As-built, showing actual layout and specification of all components of earthing system, in accordance with requirements of the Specification.
5 Nature of soil and any special earth arrangements etc.
6 Date and particulars of soil conditioning method and agents if used.

D. Samples: Submit samples of conductors, as requested.

E. Final earthing design calculations for approval, clearly indicating expected maximum earth fault levels and suitable conductor sizes, before implementation.

2.12.4 QUALITY ASSURANCE

A. Installer Qualifications: Engage an experienced installer. Submit qualifications for approval.

B. Comply with BS EN 62305 (1 to 4) to when interconnecting with lightning protection system.

C. Products shall be sourced either directly from manufacturer or from manufacturer's authorized dealer/agent.

D. Local/CPWD Regulations.

2.12.5 TECHNICAL REQUIREMENT

2.12.5.1 SOIL SURVEY AND CALCULATIONS

A. The Contractor shall carry out an earth resistivity survey on each site and report in writing to the Engineer in accordance with the approved program. The report shall detail the methods and instruments used and the results of the surveys. Based on the results the Contractor shall include in the report his proposals for the resistivity to be used in the design of the earthing system.

B. The value of resistivity to be used in the design of the earthing system shall be subject to the Engineer's approval.

C. The surveys shall show the variation of resistivity across the site and with the depth below the site. The Contractor shall consider if there is a need to model the resistivity in two layers and if there is any advantage in the use of long rods. The surveys shall also determine the depth and nature of any underlying rock, which may limit the depth for driving earth rods or if boring will be necessary for installing earth rods.

D. The weather conditions prior to and at the time of the surveys shall be recorded in the report and an assessment made of the seasonal variations in resistivity based on meteorological data for the area. The program for the project should, as far as possible, time the resistivity surveys to take place during a dry season.

E. The report should also state if there are any indications that the ground is corrosive to earth conductor or if there is any risk of galvanic corrosion on other metal structures in the neighbourhood.

F. The report shall be approved by the Engineer before proceeding with the design of the earthing system.

2.12.5.2 FAULT CURRENT AND DURATION

A. The earthing system design calculation by the Contractor shall be based on earth fault withstand current as per system requirement equipment & approved earth fault calculation.

B. The estimated maximum duration of the fault current shall not be less than 1.0 seconds for the 11 kV systems.

2.12.5.3 DESIGN

A. The calculations shall be submitted for approval prior to commencing the design of the earthing system. The resistance between earthing system and the general mass of earth shall not be greater than 1 ohm.
B. The earth loop resistance to any point in the electrical system shall not be in excess of 0.5 ohms in order to ensure satisfactory operation of protective devices.
C. The resistance to earth shall be measured at the following:-

1. At each electrical system ground or system neutral ground.
2. At one point each earthing system used to ground electrical equipment enclosures.
3. At one point each earthing system used to ground wiring system enclosures such as metal conduits and cable sheaths or armoured.

D. All earthing conductors shall be of GI/copper for Neutral of Transformer and DG Set/GI for all equipments other than Neutral of Transformer/DG Set and able to protect against mechanical damage as per BOQ. The cross-sectional area of earth conductor shall not be smaller than half that of the largest current carrying conductor. However, the contractor shall use the sizes specified in the bill of quantities of the Tender. The earth mats shall comprise the complete earth electrodes, earth strips/grids, earth inspection chambers, earth leads, main earth terminals, earth test link boxes at ground level, etc. Each individual earthing system shall have earth leads connecting its main earth terminal directly to an earth electrode underground as specified.
E. All earthing products/accessories shall be in accordance to IS standards.
F. The mating surface of all tapes at joints etc shall be cleaned before clamping and riveted with proper connector or exothermic welded. All connections to electrical apparatus shall be made by bolted connection in a visible and accessible position

2.12.5.4 PILE CAP EARTH ELECTRODE

A. Pile cap connections shall be made as specified in BOQ/Drawing.
B. Pile cap earth electrodes shall be fitted with a heavy-duty inspection enclosure complete with heavy-duty cover. The connection between each enclosure and the pile cap earth electrode shall be clearly marked ‘Safety Electrical Earth Connection – Do Not Remove’.
C. Connections shall be capable of providing high pressure contact between the pile cap and the earth leads to achieve low contact resistance.
D. At each inspection enclosure a separate earth electrode shall be provide and installed to provide for continuity of earthing connection during testing.
E. Recommended water seal insert sleeve approved by the **Lodha Representative** shall be provided with all earth electrode penetrations through basement water proofing membranes and the installation is done under strict supervision.

2.12.5.5 PIPE EARTH ELECTRODE

A. G.I pipe shall be of medium class as specified in BOQ/Drawing.
B. G.I. Pipe electrode shall be cut tapered at bottom and provided with holes of 12mm dia drilled not less than 7.5cm from each other up to 2m of length from bottom.
C. The electrode shall be buried in the ground vertically with its top being 20cm minimum below ground level.

D. Clamping of the earth leads to the earth rod shall be made by earth clamp. The clamps shall be capable of providing high pressure contact between the earth rod and the earth leads to achieve low contact resistance.
E. When two or more electrodes are driven to form a group, the heads of the electrodes in the group shall be bonded to each other by means of a GI/Copper strip, laid at a depth of at least 600 mm in soil.
F. Recommended water seal insert sleeve approved by Engineer-in-charge shall be provided with all earth electrode penetrations through basement water proofing membranes and the installation is done under strict supervision.

2.12.5.6 MAINTENANACE FREE EARTHING

A. Shall have Cooper bonded rod as per UL-467.
B. Shall have minimum 250 micron copper for higher corrosion resistance.
C. Earth enhancing compound shall meet the requirement of IEEE- 80.
D. Earth Enhancing compound shall have moisture retention properties & should provide stable ohmic value.
E. The electrode shall be buried in the ground vertically with its top being 20cm minimum below ground level.
F. Clamping of the earth leads to the earth rod shall be made by earth clamp. The clamps shall be capable of providing high pressure contact between the earth rod and the earth leads to achieve low contact resistance.
G. When two or more electrodes are driven to form a group, the heads of the electrodes in the group shall be bonded to each other by means of a GI/Copper strip, laid at a depth of at least 600 mm in soil.
H. Each earth pit shall be provided with a masonry pit with suitable chamber cover as per the loading requirement of the project. i.e. earth chamber provided in the road must have architecture/structure approval for the loading.

2.12.5.7 EARTH INSPECTION CHAMBER

A. Earth electrode shall be fitted with a heavy-duty pre-cast concrete inspection chamber/pit complete with heavy-duty cover as specified on drawings.
B. For earth electrodes located outside or on the apron of the building, earth inspection chambers shall extend to a depth of not less than 300 mm below finished ground level and kept free of soil. For earth electrodes located inside building, earth electrodes shall be buried not less than 100 mm below the floor slab structure. Each earth electrode shall be clearly marked '**Safety Electrical Earth Connection – Do Not Remove'.**
C. The chamber and cover shall be heavy duty detail to consider the traffic load at the location of installation. The cover shall be recessed cover to receive the Architectural floor finish at the location of installation.

2.12.5.8 EARTH STRIP

A. Earth strips/grids shall be of bare GI/Copper strips as specified in BOQ / Drawings.
B. Earth strips shall be riveted or joint with proper connector to earth electrodes underground below the floor slab structure, and shall be buried not less than 300 mm below the floor slab structure.
C. In order to minimise the mutual inductance between strips, earth strips shall be positioned at a distance not less than 6m apart unless otherwise specified.

2.12.5.9 CIRCUIT PROTECTIVE CONDUCTOR

A. Circuit protective conductor (CPC) is a system of conductors joining together all exposed conductive parts and connecting them to the main earth terminal.
B. The purpose of circuit protective conductor is to provide a path for earth fault circuit so that the protective device will operate to remove dangerous potential differences during a fault condition.
C. The circuit protective conductors shall take the form of separate cable with a PVC sheath in green/yellow color or copper tape with sleeves as specified in the drawing.
D. All exposed non-current carrying metal parts of light fittings, switchgears, motors, enclosures, etc. shall be effectively earthed by circuit protective conductors for earth continuity protection.

E. For equipment where an earth terminal is provided, the earth continuity wire shall be firmly clamped. Where no earth terminal is provided, the exposed metal part shall be cleaned of paint and surface rust before welding the earth continuity lead.
F. The minimum size of the principal protective conductors shall be in accordance with to the current edition of IS: 3043 and IEC 287, **IEE 17TH Wiring Edition 2008**.
G. The external earth terminal on the outside of the end panel of any switchboard shall be connected to the main earth bar provided in two independent points.
H. Circuit protective conductors shall be provided in electrical and mechanical rooms and along the routes for the bonding of all exposed conductive parts and extraneous conductive parts. A suitably sized earth terminal shall be provided at each zone of the building for this purpose.
I. All exposed conductive parts shall be effectively connected in an approved manner to the principal protective conductors. The circuit protective conductors shall be single core copper cables or high conductivity annealed copper tapes specified. Unless otherwise specified, the minimum cross-sectional area of the circuit protective conductors shall be selected in accordance with IS: 3043/ BS7671 latest edition, IEE emerald book 1100:

2.12.6 EXECUTION

A. GENERAL EARTHING

1. Earthing Bus: Install in electrical and telephone equipment rooms, in rooms housing service equipment, and elsewhere as indicated.
    a. Install bus on insulated spacers 50mm minimum from wall, 300mm above finished floor unless otherwise indicated.
    b. Where indicated on both sides of doorways, route bus up to top of door frame, across top of doorway, and down to specified height above floor; connect to horizontal bus.
2. Conductor Terminations and Connections:
    a. Pipe and Equipment Earthing Conductor Terminations: Bolted connectors.
    b. Underground Connections: Welded connectors except at test wells and as otherwise indicated.
    c. Connections to Structural Steel: Welded connectors.
3. It shall be noted that wherever conductors pass through walls or floors etc., they shall do so via an insulated sleeve provided and installed under this Contract.
4. It shall also be noted that all trunking or trays containing ELV, communication or data/CCMS signals shall be electrically continuous and bonded at one single point (at the start of the run). Earthing arrangements shall not form networks or loops along the trunking or tray such that induced circulating currents can flow.
5. All cable glands shall be complete with a proprietary earthing tag from which a bond shall be extended to the panel earth bar. The earthing system shall be installed in accordance with all sections of the specification and as indicated on the drawings.
6. Typical details are indicated on the typical earthing drawing. Installation to comply with requirements of specification and local supply authority. Provide dedicated CPC for every main, sub-main and final circuit conductor. All conductors to shall be banded indicating which items they serve.
7. An equipotential bond shall emanate from each main LV earth bar to bond incoming services, structure and main building services engineering systems (i.e. whole project services) etc. and bonded at each floor level or area onto the distribution centre for that floor or area where these distribute through the building.
8. The equipotential bonds to building services engineering systems shall emanate from the substation or main LV intake panel, i.e. ladder rack, trunking, tray, water main, fire/sprinkler main, gas and oil pipe work, steam etc.

9. Where services emanate from plant areas i.e. ductwork, HWS, DHS, chilled water, etc., the equipotential bond shall be made to the earth bar of the switchgear or motor control panel serving that area. The cable shall terminate in a tag, in turn clamped to the metallic ductwork or pipe work.
10. If not indicated on the drawing, conductor sizes shall be a minimum of 25x3mm GI tape for equipotential bond and 6mm sq G/Y PVC sleeved Cu cable for supplementary bonds. Equipotential and Supplementary bonds shall also be provided in any generator area.
11. The main equipotential bonding conductors shall be PVC sheathed with copper/Aluminium conductors, sheathing coloured green and yellow. The bonding connection to the mechanical services being with sweated or crimped lugs onto a purpose made connection point on ductwork or the like or purpose made GI clamp to pipe work. Main equipotential bonding conductors shall conform to NEC 2011.
12. This Contract shall include for the installation of all supplementary bonding in wet areas, etc necessary to comply with NEC 2011.
13. All metal sinks, work surfaces (in kitchens etc.), tanks, exposed pipe work, etc., shall be supplementary bonded under this Contract to the earth terminal of an adjacent socket outlet or accessory on a power circuit using green/yellow PVC insulated cable in accordance with the NEC 2011. The earth wire shall be installed in flush conduit terminating at low level with 50.8mm fixing centre conduit box fitted with a bushed dome lid. The supply and installation of all necessary bonding terminals to the sinks, tanks, etc., shall be included in this Contract.
14. Other Items shall be bonded or earthed as applicable, unless otherwise stated. The Contractor shall include for the testing for earth continuity of all extraneous conductive parts where work has been undertaken under this Contract.
15. The Contractor shall include for all continuity links between services run on tray and conduits to the final outlet points. The Contractor shall include for bonding all equipment. The Contractor shall include for bonding the LV intake earth bar to the lightning protection installation. Any Functional Earths provided shall be coloured cream and sized in accordance with their intended application.

B. EQUIPMENT EARTHING

1. Install insulated equipment earthing conductors with all feeders and branch circuits.
2. Install insulated equipment earthing conductors with the following items, in addition to those required by relevant codes.
    a. Feeders and branch circuits.
    b. Lighting circuits.
    c. Receptacle circuits.
    d. Single-phase motor and appliance branch circuits.
    e. Three-phase motor and appliance branch circuits.
    f. Flexible raceway runs.
    g. Armoured and metal-clad cable runs.
3. Busway Supply Circuits: Install insulated equipment earthing conductor from earthing bus in the switchgear, switchboard, or distribution panel to equipment earthing bar terminal on busway.
4. Computer and Rack-Mounted Electronic Equipment Circuits: Install insulated equipment earthing conductor in branch-circuit runs from equipment-area power panels and power distribution units.
5. Air-Duct Equipment Circuits: Install insulated equipment earthing conductor to duct-mounted electrical devices operating at 230 V and more, including air cleaners, heaters, dampers, humidifiers, and other duct electrical equipment. Bond conductor to each unit and to air duct and connected metallic piping.
6. Isolated Earthing Socket Circuits: Install an insulated equipment earthing conductor connected to the Socket earthing terminal. Isolate conductor from raceway and from panel board earthing terminals. Terminate at equipment earthing conductor terminal of the applicable derived system or service unless otherwise indicated.

7. Isolated Equipment Enclosure Circuits: For designated equipment supplied by a branch circuit or feeder, isolate equipment enclosure from supply circuit raceway with a non metallic raceway fitting listed for the purpose. Install fitting where raceway enters enclosure, and install a separate insulated equipment earthing conductor. Isolate conductor from raceway and from panel board earthing terminals. Terminate at equipment earthing conductor terminal of the applicable derived system or service unless otherwise indicated.
8. Signal and Communication Equipment: In addition to earthing and bonding required by IS 732 and IS 3043, provide a separate earthing system complying with requirements of communication system.
    a. For telephone, alarm, voice and data, and other communication equipment, provide No. 4 AWG minimum insulated earthing conductor in raceway from earthing electrode system to each service location, terminal cabinet, wiring closet, and central equipment location.
    b. Terminal Cabinets: Terminate earthing conductor on cabinet earthing terminal.
    c. Metal and Wood Poles Supporting Outdoor Lighting Fixtures: Install earthing electrode and a separate insulated equipment earthing conductor in addition to earthing conductor installed with branch-circuit conductors.

2.12.7 FIELD QUALITY CONTROL

A. Combined resistance of earth electrodes is to be measured during dry season and checked against specified resistance.

B. Excessive Ground Resistance: If resistance to ground exceeds specified values, notify the Engineer promptly and include recommendations to reduce ground resistance.

C. Electrical continuity of all earthing and protective conductors including main and supplementary equipotential bonding conductors is to be checked.

D. Earth fault loop impedance of all circuits is to be measured and checked against calculated impedance figures.

E. Operation of residual current protective devices is to be checked.

F. Field tests shall include all tests as per recommended practice.

G. All test records shall be numbered and certified.

END OF SECTION- B 2.12