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NEW ZEALAND ELECTRICAL CODE OF PRACTICE

for

POWER SYSTEMS EARTHING

Issued by the Office of
The Chief Electrical Inspector,
Energy and Resources Division, Ministry of Commerce

THE ELECTRICITY ACT 1992

APPROVAL OF ELECTRICAL CODE OF PRACTICE

FOR

POWER SYSTEMS EARTHING

Pursuant to Section 36 of the Electricity Act 1992 ("the Act")

On the 1st day of February 1993, the Secretary of Commerce issued the Electrical Code of Practice for Power Systems Earthing ("the Code")

On the 4th day of February 1993, pursuant to Section 38 of the Act the Secretary published in the Gazette a notice of intention to apply to me for approval of the code, and there has been consultations with such persons (or their representatives) as will be affected by the Code and they have had the opportunity to consider possible effects and comment on those effects.

I have considered the comments concerning those effects and where necessary amendments were made to the Code.

Therefore Pursuant to Section 38 of the Act, I, John Luxton, Minister of Energy, have this day approved the Code as attached to this approval, which Code shall come into force on the 1st day of April 1993.

Dated this 18th day of March 1993.

John Luxton
Minister of Energy.

COMMITTEE REPRESENTATION

This Code of Practice for Power Systems Earthing was prepared by the Ministry of Commerce, Chief Electrical Inspector's Office.

Represented on the working party which was responsible for the preparation of this Code of Practice were the following:

The Electrical Supply Engineers' Association
Electricity Corporation
Trans Power
Ministry of Commerce
Telecom

ACKNOWLEDGEMENT

The source material for this Code was derived from the following documentation, ESA (Australia) Section 12 of the Guidelines for Design and Maintenance of Overhead Distribution and Transmission Lines C(b)1 1991, IEEE Guide for Safety in AC Substation Grounding (ANSI/IEEE 80) 1986, Earthing Handbook issued by the Electricity Authority of NSW 1975.

REVIEW

This Code of Practice will be revised as occasions arise. Suggestions for improvement of this Code are welcome. They should be sent to the Chief Electrical Inspector's Office, Ministry of Commerce, P O Box 1473, WELLINGTON.

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INTRODUCTION

This code of practice is intended to provide guidance on acceptable methods for determining the safety of earthing systems associated with works.

SECTION 1

SCOPE, PURPOSE, INTERPRETATIONS, GLOSSARY AND NUMBERING

1.1 SCOPE

1.1.1 This Code sets earthing requirements associated with:

- (a) High voltage (HV) stations with earth grids;
- (b) Distribution systems;
- (c) High voltage installations on consumers' premises; and
- (d) Special locations and frequented locations as defined in this Code.

1.1.2 This Code does not apply to:

- (a) Lines and associated fittings operating at or above a voltage of 66kV;
- (b) Low voltage (LV) earthing on consumers' installations;
- (c) Systems not operated at a nominal frequency of 50 Hz; and
- (d) Location not defined as special locations and frequented locations in this Code.

1.2 INTERPRETATIONS

In this Code, unless the context otherwise requires:

- 1.2.1 Distribution Centre - means any substation or generating station from which electricity is supplied direct at low or high voltage to an electricity distribution system of works or to an electrical installation. The distribution centre may consist of one or more transformers on a pole, on the ground, underground, in a building, in a generating station, or in a zone substation; and includes the enclosure or building surrounding the transformer(s) and switchgear, if any.
- 1.2.2 Distribution System - means that portion of an electricity supply system from where electricity at low or high voltage is conveyed from a distribution centre, to the premises of consumers connected to that distribution centre, but does not include distribution or service mains.
- 1.2.3 Earthed - means electrically connected to the general mass of the earth.
- 1.2.4 Earth electrode - means a conducting element or electrically bonded group of conducting elements in electrical contact with the earth and designed for dispersing electric currents into the earth.
- 1.2.5 Earth fault current path - means the complete loop through which earth fault current flows. It includes system plant as well as dedicated earth connections and the main body of the earth.

- 1.2.6 Earth grid - means a system of interconnected bare conductors buried in the earth providing a common earth for fittings. The grid may be specifically designed to control surface potential gradients.
- 1.2.7 Earth impedance in respect of an earth electrode system - means the ohmic impedance at system frequency between the electrode system and the general mass of earth.
- 1.2.8 Earthing conductor - means a conductor connecting any part of an earth electrode to fittings required to be earthed.
- 1.2.9 Earthing system - means all conductors, electrodes, clamps or other connections used to provide a path to earth.(see figure 1 at page 5).
- 1.2.10 Frequented location - means any urban area associated with a city or town other than a Special Location.
- 1.2.11 Multiple Earthed Neutral (MEN) System - means a system of earthing in which the earthing conductor within an electrical installation is connected to the neutral as well as to an earthing electrode. In this system, the distribution system neutral is earthed at the point of supply at a distribution centre, and at one or more points along the distribution or service mains, and provides a continuous electrical path between the consumer and the distribution centre earthing point.
- 1.2.12 Special location - means within a school's grounds or within a children's playground, or within a public swimming pool area, or at a popularly used beach or water recreation area, or in a public thoroughfare within 100 metres of any of the above-named locations.
- 1.2.13 Station - means substation or generating station.
- 1.2.14 Step voltage - means the difference in surface potential experienced by a person bridging a distance of 1 metre with the person's feet apart, without contacting any other earthed object.
- 1.2.15 System voltage - means the difference of potential normally existing between conductors, or between conductors and earth. (phase to phase in a multi phase system and phase to earth in a single phase system).
- 1.2.16 Telecommunications system - means all plant that is part of a telecommunication network. This includes cables, aerial lines, pillars, exchange equipment, and customer's fixed telecommunications wiring and attached equipment (eg. PABX's, phones, etc.).

- 1.2.17 Touch voltage - means the voltage which will appear between any point of contact with uninsulated metalwork located within 2.5 metres from the surface of the ground and any point on the surface of the ground within a horizontal distance of 1.25 metres from the vertical projection of the point of contact with the uninsulated metalwork.

1.3 GLOSSARY OF ABBREVIATIONS USED IN THIS CODE

| | |
|----------------|---|
| HV | High Voltage |
| Hz | Hertz |
| I _b | Permissible body current limit |
| kg | Kilograms |
| kV | Kilo-volts (1000 volts) |
| LV | Low Voltage |
| MEN | Multiple Earthed Neutral |
| NZECP | New Zealand Electrical Code of Practice |
| PVC | Polyvinyl chloride |
| t | Time |

1.4 NUMBERING SYSTEM OF THIS CODE

- 1.4.1 Sections are numbered 1 to 4.
- 1.4.2 Subsections are numbered by one full stop between two numbers. (eg 1.4)
- 1.4.3 Clauses are numbered by two full stops between three numbers. (eg 2.2.1)
- 1.4.4 Paragraphs contain numbering punctuated by one or more full stops together with a parenthesised letter. (eg (a))
- 1.4.5 Subparagraphs are represented by lower case roman numerals enclosed in parenthesis following paragraphs. (eg (ii))

Figure 1

**TYPICAL EARTHING SYSTEM
ILLUSTRATION OF DEFINED TERMS**

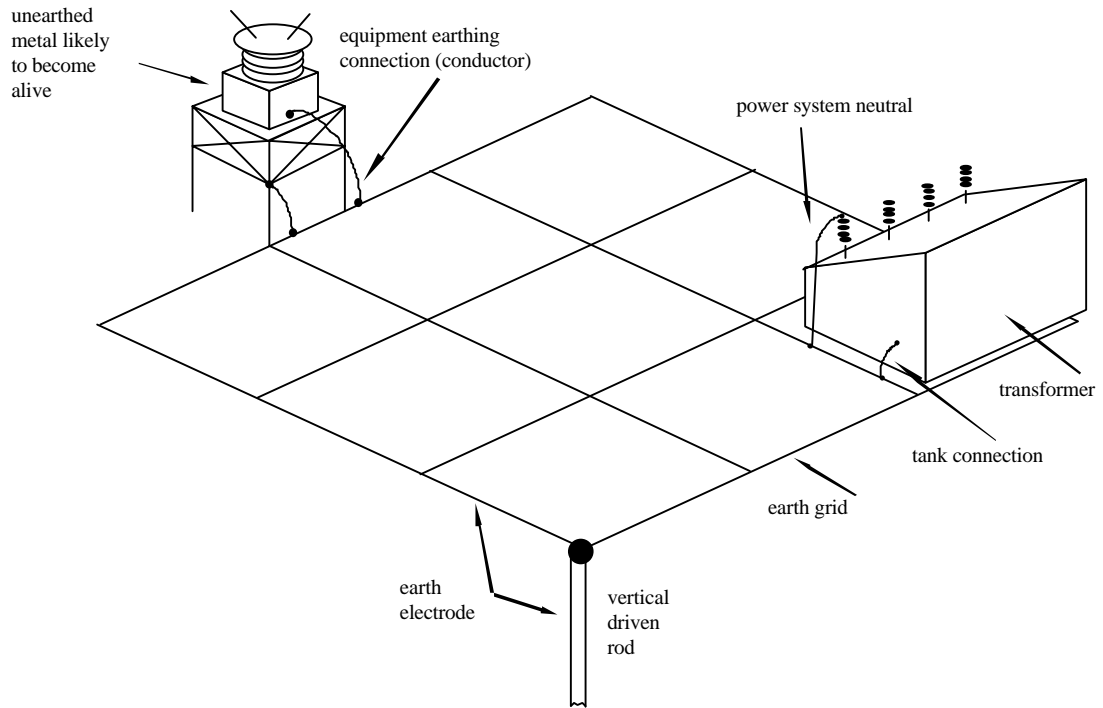
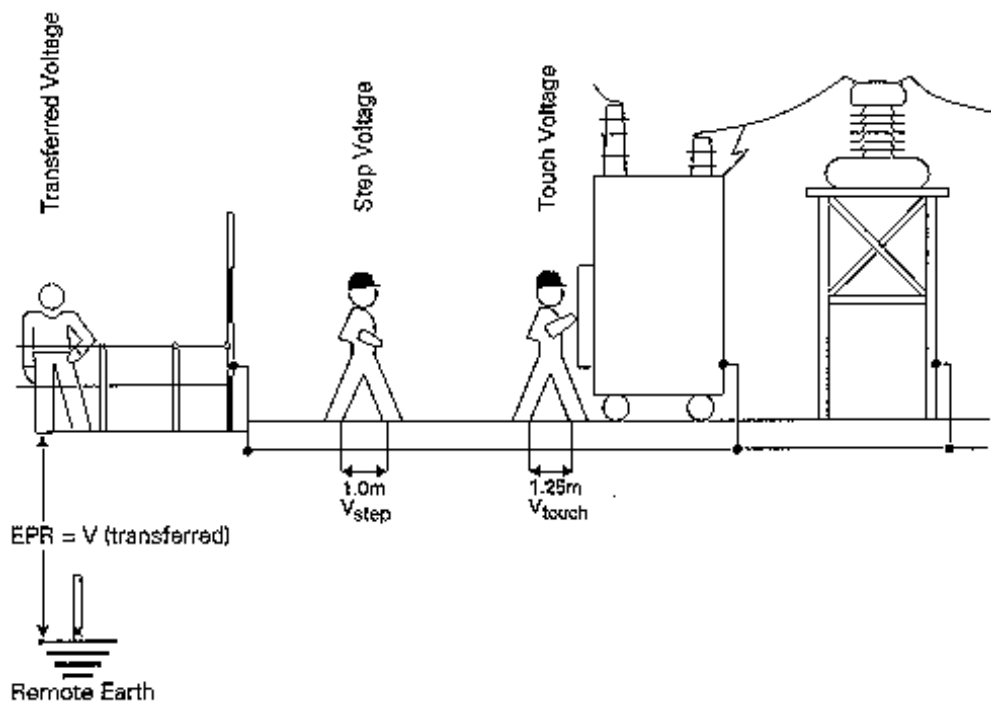


Figure 2

BASIC SHOCK SITUATIONS



SECTION 2

GENERAL REQUIREMENTS

2.1 THIS SECTION APPLIES TO PARAGRAPHS A, B, C AND D OF CLAUSE 1.1.1

2.2 PERFORMANCE OF EARTHING SYSTEMS

The performance of the earthing system shall satisfy the safety and functional requirements of the electrical installation and the fittings of that installation. The earthing system may be used jointly or separately for protective or functional purposes according to the requirements of the installation.

2.3 DESIGN, SELECTION AND INSTALLATION

The design, selection and installation of the earthing systems shall be such as will ensure:

- (a) Protection against indirect contact;
- (b) Proper functioning of electrical protective devices;
- (c) That the protective and functional requirements are complied with under the expected conditions;
- (d) Earth fault currents and earth-leakage currents can be carried without danger including thermal, thermomechanical and electromechanical stresses;
- (e) Adequate strength or additional mechanical protection appropriate to the assessed external influences;
- (f) The value of earthing resistance is in accordance with the protective and functional requirements of the installation and is continuously effective.

2.4 EARTH ELECTRODES

2.4.1 Only the following types of earth electrodes shall be used:

- (a) Vertical driven rods or pipes not less than 1.8 m into the ground;
- (b) Horizontal grid, mesh or plates;
- (c) Electrodes embedded in foundations;
- (d) Metallic reinforcement of concrete.

2.4.2 The type and embedded depth of the earth electrodes shall be such that soil drying and freezing will not increase the earth resistance of the earth electrodes above the required value. Where practicable, the earth electrodes shall be embedded below permanent moisture level, except for electrodes which are used for gradient control.

2.4.3 The design of the electrode shall take into consideration the type,

temperature and moisture content of the soil as well as the magnitude and duration of expected current flow so as to minimise soil dryness in the vicinity of the electrodes.

- 2.4.4 The material and total cross-sectional area of the earth electrodes shall be such as to provide a conductance of not less than that of the earthing conductor.
- 2.4.5 The design, selection of materials, and construction of the earth electrodes shall take into consideration the possible deterioration and increase of resistance due to corrosion over the expected period of use of the installation.
- 2.4.6 In areas where corrosion is likely to be severe, the electrodes shall be of hard drawn copper, copper clad or stainless steel, or other metal of such a nature or so treated as to be not less resistant to corrosion than hard drawn copper, or copper clad or stainless steel.
- 2.4.7 In areas where corrosion is not severe, galvanised or plain steel electrodes may be used.
- 2.4.8 Aluminium shall not be used as a buried electrode.

2.5 TESTING AND INSPECTION

- 2.5.1 The earth impedance of an earthing system shall be determined by testing at the time of installation.
- 2.5.2 Inspections of earthing systems shall verify the connections from the earth grid to driven rods and the connections from earth grid to system neutrals.
- 2.5.3 Initial testing of an earthing system shall verify that the actual earth impedance is below its maximum safe calculated value.
- 2.5.4 When work has taken place that may have interfered with the earthing system, the system in that area shall be inspected and checked. All parts of the earthing system exposed by excavation shall be inspected for damage or deterioration.
- 2.5.5 Where there is any probability of significant corrosion of the buried earth grid or of connections to it, more frequent inspections of the earth grid and connections shall be carried out and replacements made where necessary.

- 2.5.6 To enable the integrity of the earthing installation and its suitability for present fault levels to be assessed the following records shall be maintained:
- (a) Initial design calculations;
 - (b) Results of periodic inspections;
 - (c) Updating of fault level;
 - (d) Drawings showing the location of all earth grid connections and or joints.

2.6 PERMISSIBLE SHOCK CURRENT AND STEP AND TOUCH VOLTAGES

- 2.6.1 Any earthing system shall be constructed to minimise the risk of electric shock to persons.
- 2.6.2 This may be achieved by either:
- (a) The limitation of shock currents to the safe values as set in section 3;
or
 - (b) The limitation of step and touch voltages to safe values as set in section 4.

SECTION 3**CURRENT LIMITATION****3.1 LIMITATION OF SHOCK CURRENTS**

- 3.1.1 Where works are installed in an enclosed area with restricted access and where control over ground conditions is being employed to control shock currents, shock currents shall be deemed to be safe if they are limited to less than I_b as determined by:

$$I_b = \frac{0.116}{\sqrt{t}} \text{ amp (for 50 Hz current, } t = \text{ seconds)}$$

provided that:

- (a) t is within the range of 0.3 to 3 seconds; and
 - (b) a body resistance of 1000 ohms is applied.
- 3.1.1.1 When this method of determining shock current is applied a record shall be kept of all information relating to the determination and control of shock current.

SECTION 4

PERMISSIBLE STEP AND TOUCH VOLTAGES

4.1 PERMISSIBLE TOUCH VOLTAGES

Where works are installed in a special location or a frequented location as defined in this Code, the touch voltages shall be within the limits set in clauses 4.1.1 and 4.1.2.

4.1.1 Special locations.

- (a) Works installed in special locations and operating at voltages not exceeding 66 kV shall comply with the requirements of curve A1 of figure 3, page 12 of this Code.
- (b) Works installed in special locations and operating at voltages exceeding 66 kV shall comply with the requirements of curve A2 of figure 3, page 12 of this Code. These requirements shall not apply to any lines and associated fittings operating at or above a voltage of 66 kV.

4.1.2 Frequented locations.

- (a) Works installed in frequented locations and operating at voltages not exceeding 66 kV shall comply with the requirements of curve B1 of figure 3, page 12 of this Code.
- (b) Works installed in frequented locations and operating at voltages exceeding 66 kv shall comply with the requirements of curve B2 of figure 3, page 12 of this Code. These requirements shall not apply to any lines and associated fittings operating at or above a voltage of 66 kV.

4.2 PERMISSIBLE STEP VOLTAGES

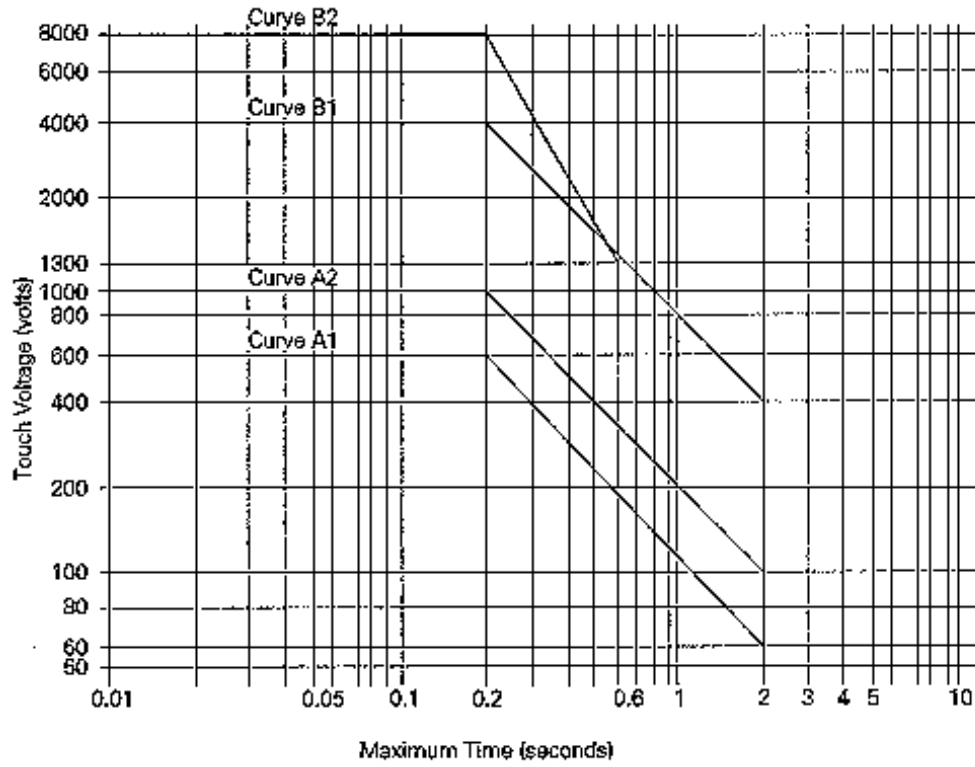
Step voltages shall not exceed TWICE the values of touch voltage as determined in subsection 4.1.

4.3 TRANSFERRED POTENTIALS

Allowances shall be made for transferred potentials when designing an installation. Where voltage rises on the earthing system are transferred by metalwork such as neutral conductors of a MEN system, water pipes, and the like to locations remote from the installation, allowance may be made for voltage drop in these conductors. Otherwise, the transferred potential shall be regarded as being equal to the earthing system voltage rise.

Figure 3

PERMISSIBLE TOUCH VOLTAGES



SECTION 5

HIGH VOLTAGE STATIONS WITH EARTH GRIDS

5.1 THIS SECTION APPLIES TO HIGH VOLTAGE STATIONS WITH EARTH GRIDS

5.2 POWER SYSTEM NEUTRAL EARTH

5.2.1 The power system neutral earth is provided by the interconnection of the station earthing system with the power system neutral.

5.2.2 Power system neutral earthing shall comprise one of the following connections:

- (a) A solid connection, usually to a transformer starpoint;
- (b) An impedance connection employing, a resistance, a reactance, or an earthing transformer.

5.2.3 The earthing of the power system neutral shall:

- (a) Provide an earth reference for the power system;
- (b) Prevent abnormal system over-voltages during intermittent earth faults; and
- (c) Permit the selective operation of current operated earth fault protection.

5.3 DESIGN OF EARTHING SYSTEMS

5.3.1 All fittings and any uninsulated metalwork, other than cable screens or armouring, which are liable to become alive shall be connected to the earthing system with a minimum of one conductor, capable of carrying full design fault current for the duration of any fault which may liven the fitting or uninsulated metalwork. Cable screens and armouring shall be regarded as metalwork traversing the earth grid shall be bonded or left unbonded in accordance with clause 5.3.2.

5.3.2 Metalwork bonded to the earth grid and projecting beyond the earth grid may introduce a hazard from transferred potential and shall be considered during the design.

5.3.3 Earthing system conductors shall be sufficiently large to:

- (a) Minimise the probability of mechanical damage;
- (b) Minimise the consequence of minor corrosion; and
- (c) Provide adequate current carrying capacity.

5.3.4 If necessary earthing systems shall be upgraded where fault levels increase above the original design level.

5.3.5 Allowances shall be made for current distribution in the earthing system.

5.4 TRANSFERRED EARTH POTENTIAL RISE

- 5.4.1 Earthing systems shall be designed to prevent:
- (a) Transfer of earth grid potentials to a remote earth;
 - (b) Transfer of a remote earth potential into a station; and
 - (c) Breakdown of cable oversheaths because of voltage differences:
 - (i) between metallic screens or sheaths earthed at the station and the ground surrounding a cable;
 - (ii) between metallic screens or sheaths earthed at a remote point and the ground surrounding a cable;
 - (iii) appearing in the ground surrounding a station in which the cable is buried.
- 5.4.2 Telecommunications circuits into high voltage stations may be protected by the appropriate use of isolation transformers and/or optocouplers.
- 5.4.3 Cross-bonding of long cable sheaths may be carried out in order to limit induced sheath voltages.
- 5.4.4 Fences and pipes sectionalised by inserting insulating sections may be used to prevent transfer of potentials.
- 5.4.5 Services, such as telecommunications systems, near the earthing systems shall be designed to avoid danger to people using or maintaining the services.

SECTION 6

DISTRIBUTION SYSTEMS

6.1 THIS SECTION APPLIES TO DISTRIBUTION SYSTEMS

6.2 DISTRIBUTION EARTHING SYSTEM

- 6.2.1 Earth fault current paths for distribution systems may include:
- (a) The transformer winding;
 - (b) The distribution system phase conductor;
 - (c) The return earth path between the location of the fault and the distribution centre earth electrode; and
 - (d) The earth connections at the distribution centre which form the MEN system including the distribution system neutral.

6.3 CONNECTION OF NEUTRAL TO EARTH

- 6.3.1 In a low voltage alternating current system, the neutral conductor shall be earthed at or near the distribution centre (see subsection 6.8). It shall also be earthed at such other places as will ensure that under fault conditions the earthing system provides a low impedance path for earth fault currents. Where applicable, fault conditions shall include those faults involving the associated high voltage system.
- 6.3.2 Separate LV and HV earths may be installed to minimise the earth potential rise on the LV neutral during HV earth faults.
- 6.3.3 In calculating the earth impedance of a combined HV/LV distribution system, account may be taken of all connections of the neutral conductor to earth, including:
- (a) The earth connection at the distribution centre as specified in subsection 6.5;
 - (b) Such earths as may be installed on the distribution system;
 - (c) The earth connections at consumers' installations; and
 - (d) The effect of any permanent interconnections (ie, where no links are fitted) between the neutral conductor of a given distribution system and the neutral(s) of other distribution system(s).
- 6.3.4 In a high voltage system, the neutral conductor shall be earthed at or near the source of supply by:
- (a) Direct earthing of the neutral point;
 - (b) Earthing an artificial neutral point obtained from an earthing transformer;
 - (c) Earthing in accordance with paragraph (a) or (b) of this clause via an earthing resistor or reactor.

6.3.5 In addition the neutral may be earthed at other points in the system.

6.4 IMPEDANCE OF EARTH FAULT CURRENT PATH

6.4.1 In an alternating current system, the impedance of the earth fault current path (including the distribution centre or zone substation transformer, the phase conductor of the distribution system and the earth return path) shall be such as to ensure the correct operation of the protective devices which disconnect the supply. A minimum factor of safety of two (2) shall be used when calculating the impedance required and specifying protective device operating values.

6.4.2 The earthing system impedance shall be such that the earthing system, and any fitting connected to it, does not introduce a danger to persons and property.

6.5 EARTHING CONNECTIONS AND EARTHING AT DISTRIBUTION CENTRES

6.5.1 This subsection applies to distribution centres.

6.5.2 All fittings associated directly with any high voltage system shall be earthed by a minimum of two independent earthing systems and connected in such a manner that either can be disconnected independently for the purpose of testing.

6.5.3 The following fittings shall be connected to the earthing system of a distribution centre (see figures 5 to 8 at pages 19 - 22):

- (a) Transformers and circuit breakers;
- (b) Metallic cable sheaths or screens;
- (c) Low voltage neutrals, except where separate HV and LV earthing systems are installed, in which case only the LV neutrals shall be connected to the LV earthing system;
- (d) Lightning arresters; and
- (e) Any uninsulated metalwork within 2.5 metres of the ground that may become alive.

6.6 EARTHING OF FITTINGS OTHER THAN AT DISTRIBUTION CENTRES

6.6.1 This subsection applies to fittings of distribution systems other than at distribution centres.

- 6.6.2 Any metalwork liable to become alive within 2.5 metres of the ground and with which persons may come into contact shall be connected to earth (but may not require a separate earthing connection), provided that the impedance to earth is such that the step and touch potentials specified in sections 4 of this Code are not exceeded. Any such metalwork may also be connected to a multiple earthed neutral system.
- 6.6.3 Lightning arresters shall be earthed by a direct earth connection which presents a low earth impedance path to high frequency currents. They may be bonded to the earthing point of high voltage systems.
- 6.6.4 The metal operating handles of all high voltage switching fittings shall be directly earthed unless the handles are insulated to the full working voltage so as to avoid hazardous touch potentials.

6.7 EARTHING CONNECTIONS

- 6.7.1 Earthing conductors used for making connections of fittings to earth shall have a capacity not less than the size calculated on the Nomogram in figure 4, page 19 of this Code. The clearance times specified in the Nomogram relate to the protection associated with the portion of high voltage line and the distribution centre fuses.
- 6.7.2 Earthing conductors, where exposed, shall be:
- (a) 0.6/1kV rated; and either
 - (b) Green or green/yellow PVC insulated; or
 - (c) Enclosed in insulating conduit.
- Insulated conductors shall be used wherever electrical workers may come into contact with the conductor.
- 6.7.3 Buried conductors shall be copper and shall be bare unless there are special reasons for using insulated copper. Bare aluminium shall not be buried.

6.8 LOW VOLTAGE EARTHING CONDUCTORS ASSOCIATED WITH LV SYSTEM

Conductors used to connect the neutral terminal or bar of a LV system to the earth bar, or the neutral conductor of an outgoing overhead line, shall not be smaller than that calculated in the Nomogram of figure 4, page 19 of this Code based on the expected fault current and duration.

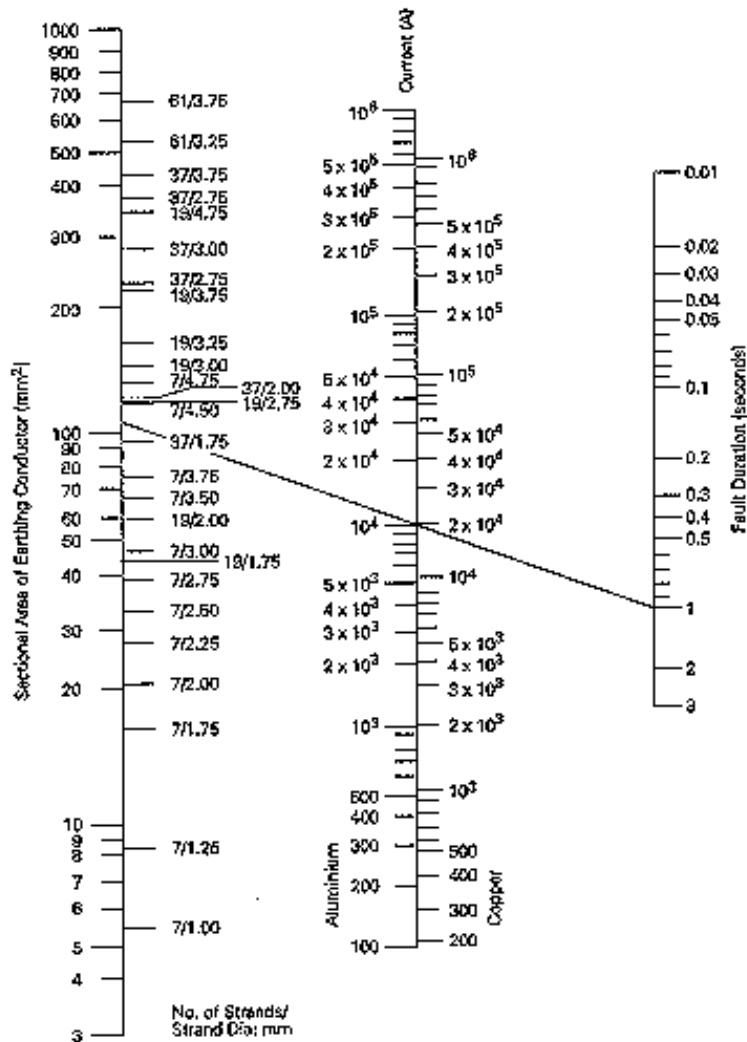
6.9 CONNECTIONS TO EARTHING ELECTRODES

- 6.9.1 Where conductors which are connected to earth electrodes, and are accessible to the public (as at pole type distribution centres or where the neutrals within the distribution system are connected to earth) those conductors shall be protected against mechanical damage.
- 6.9.2 The conductors shall be brought out of the ground parallel and close to the foot of the pole and shall be protected to a height of 2.5 metres. Fibreglass channel section or a suitable wood may be used to provide mechanical protection.
- 6.9.3 Joints between earthing conductors and earth electrodes shall be of adequate mechanical strength and current carrying capacity and so arranged as to ensure that there will be no failure of the connection under any conditions of use or exposure that may be reasonably anticipated. Clamps and similar mechanical connections shall be so designed and constructed that the connection will not slacken off under use.
- 6.9.4 Where conductors connecting driven electrodes in parallel are not kept above the ground, they shall be buried no less than 0.5 metres below the surface. Connections of conductors to such electrodes shall be made by welding, or exothermic welding, processes.
- 6.9.5 If test links are inserted in earthing conductors connected to electrodes, they shall be bolted links and arranged so that the opening of one link does not interfere with earth connections other than the one under test.

Figure 4

FAULT DURATION LEVELS FOR STANDARD ALUMINIUM AND COPPER NON TENSIONED EARTHING CONDUCTORS

(refer to clause 6.7.1 and subsection 6.8)



EXAMPLE: THE CALCULATED FAULT CURRENT IS 20 000 AMPERES AND THE FAULT CLEARING TIME IS 1 SECOND. WHAT IS THE MINIMUM STANDARD SIZE COPPER CONDUCTOR REQUIRED? **METHOD:** DRAW A STRAIGHT LINE THROUGH 1 SECOND ON RIGHT HAND ORDINATE AND 2X10⁴ ON RIGHT HAND SIDE OF CENTRE ORDINATE TO CUT LEFT HAND ORDINATE. THE NEAREST CONDUCTOR SIZE ABOVE POINT OF INTERSECTION IS 7/4.50. **NOTE:** THE ABOVE FAULT DURATIONS ARE FOR A ONE SHOT OPERATION WITH A COOLING PERIOD OF ONE MINUTE. WHERE AUTO RECLOSERS ARE USED THE TOTAL "ON" TIME BEFORE LOCKOUT SHOULD BE USED.

Figure 5

(refer to clause 6.5.3)

Recommended earthing arrangement
for pole mounted transformer

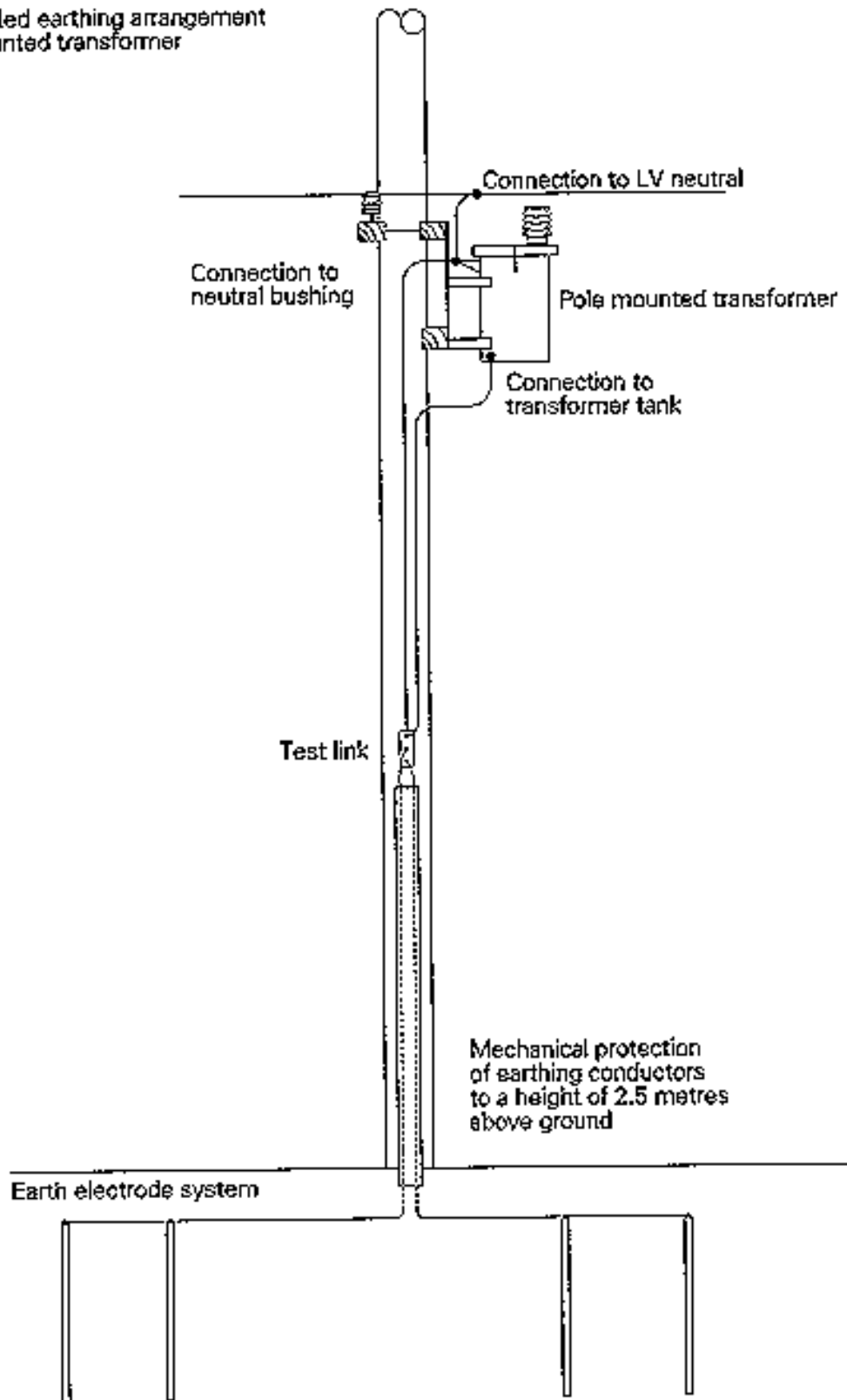


Figure 6

(refer to clause 6.5.3)

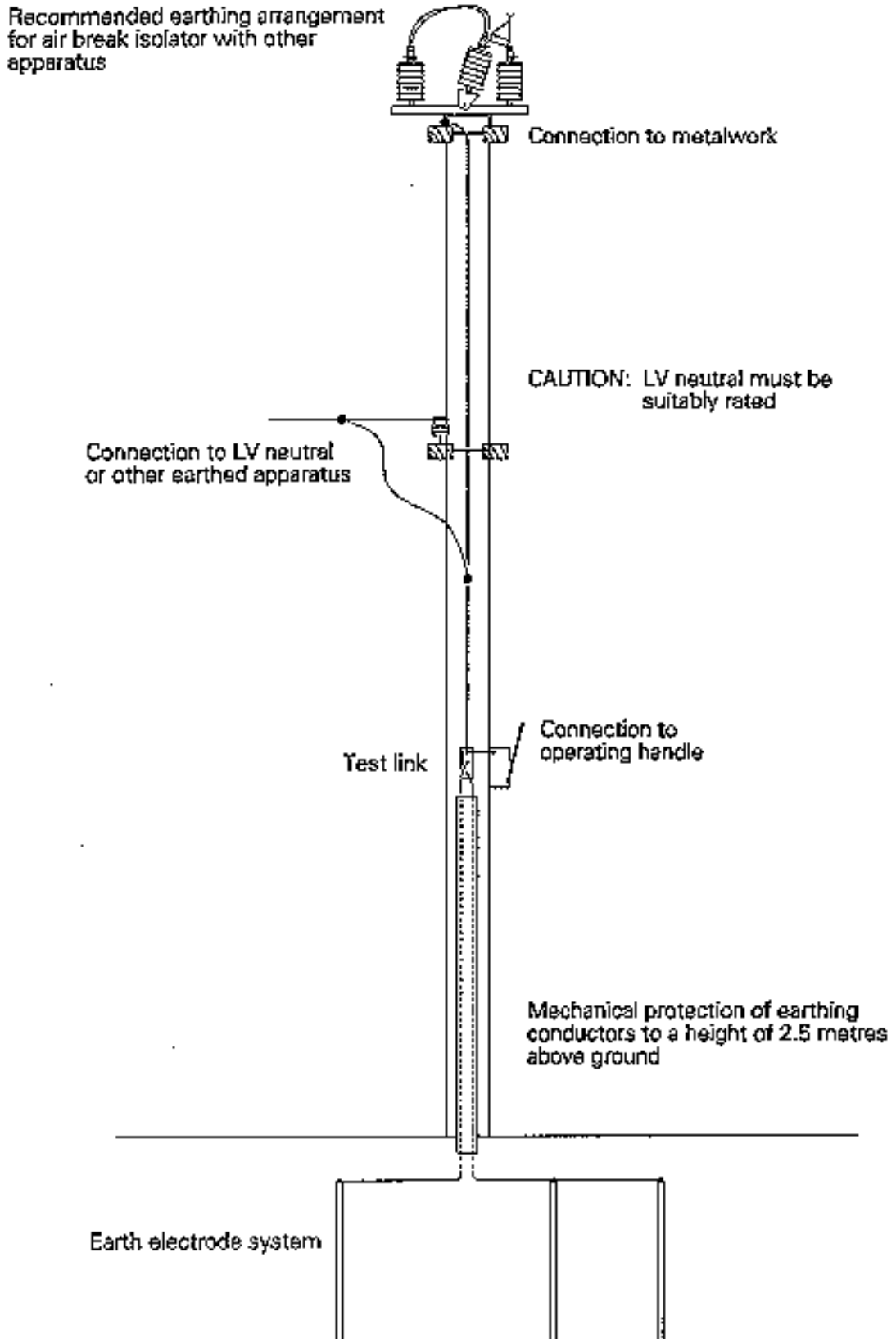


Figure 7

(refer to clause 6.5.3)

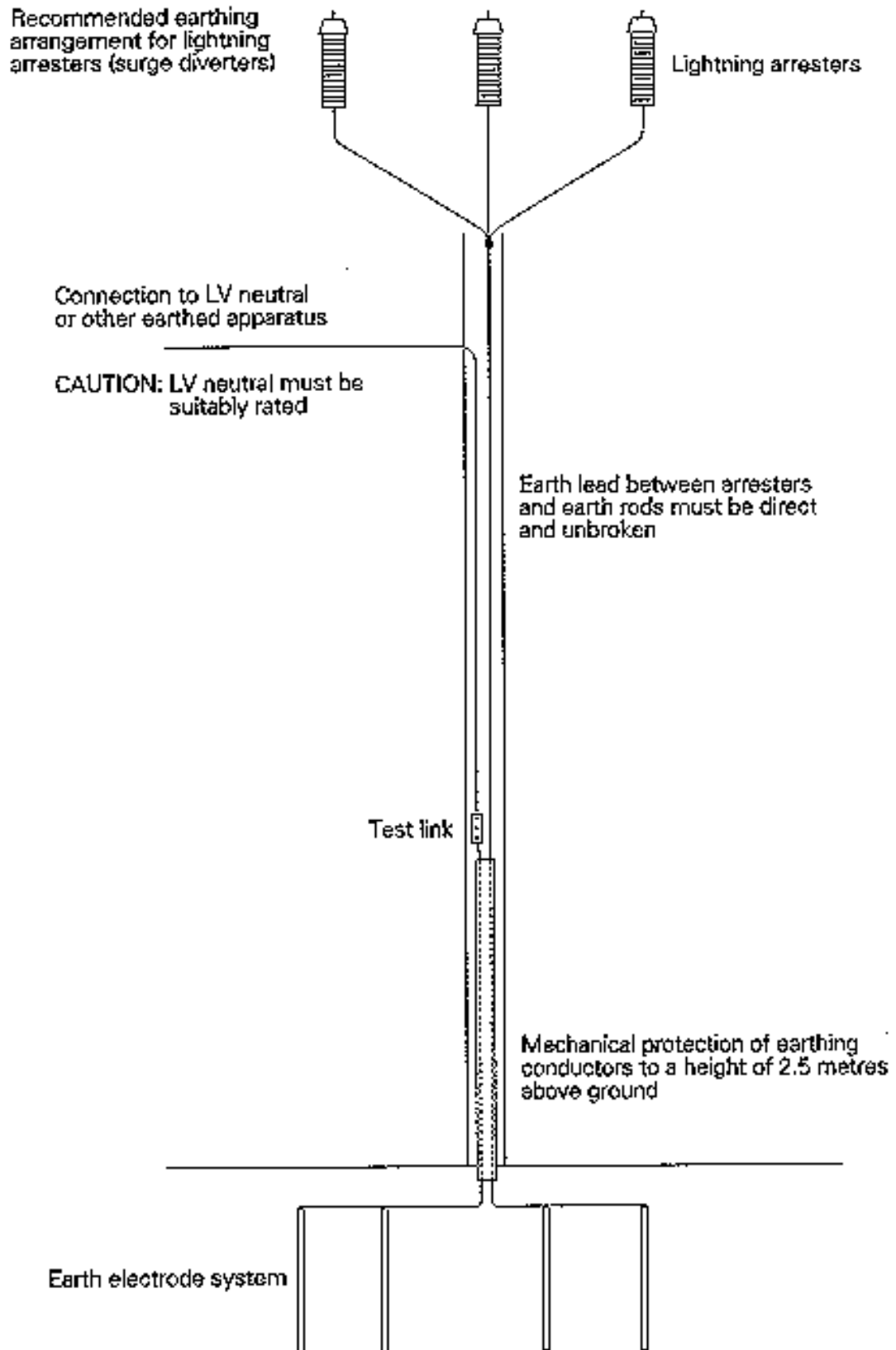


Figure 8

(refer to clause 6.5.3)

**RECOMMENDED EARTHING ARRANGEMENT FOR HIGH VOLTAGE
INSTALLATION AT CONSUMERS PREMISES**

