EXCAVATION AND CABLE LAYING

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1. EXCAVATION AND CABLE LAYING

1.1 TRENCHING

1.1.1 General

The Contractor shall be responsible for all trenching excavations unless specified to the contrary. The Contractor shall refer to SANS 1200.

The Contractor shall, before trenching commences, familiarise himself with the routes and site conditions and the procedure and order of doing the work shall be planned in conjunction with the general construction programme for other services and building requirements.

The Contractor shall acquaint himself with the position of all the existing services such as storm water pipes, water mains, sewer mains, gas pipes, telephone cables, etc. Before any excavations are commenced. For this purpose he shall approach this Engineer's representative, the local municipal authority and any other authority which may be involved, in writing.

The Contractor will be held responsible for damage to any existing services brought to his attention by the relevant authorities and shall be responsible for the cost of repairs.

The Contractor shall take all the necessary precautions and provide the necessary warning signs and/or lights to ensure that the public and/or employees on site are not endangered.

The Contractor shall ensure that the excavations will not endanger existing structures, roads, railways, other site constructions or other property. The final ground levels shall be determined before commencing trenching.

1.1.2 Mechanical Excavators

Power driven mechanical excavators may be used for trenching operations provided that they are not used in close proximity to other plant, services or other installations likely to be damaged by the use of such machinery.

The use of power driven mechanical excavators shall be subject to the approval of the Engineer. Should the excavator produce trenches that exceed the required dimensions, payment based on volumetric excavation rates will only be calculated on the required dimensions.

1.1.3 Blasting

No guarantee is given or implied that blasting will not be required.

Should blasting be necessary and approved by the engineer, the contractor shall obtain the necessary authority from the relevant government Engineers and local authorities. The contractor shall take full responsibility and observe all conditions and regulations set forth by the above authorities.

1.1.4 Routes

Trenches shall connect the points shown on the drawings in a straight line. Any deviations due to obstructions or existing services shall be approved by the Engineer beforehand.

The Engineer reserves the right to alter any cable route or portion thereof in advance of cable laying. Payment in respect of any additional or wasted work involved shall be at the documented rates.

The removal of obstructions along the cable routes shall be subject to the approval of the Engineer.

1.1.5 Shoring and Waterlogging

The Contractor shall provide shoring for use in locations where there is a danger of the sides of the trench collapsing due to waterlogging or other ground conditions. Refer to the Occupational Health and Safety Act.

The strength of shoring must be adequate for site conditions prevailing and the shoring must be braced across the trench.

The Contractor shall provide all pumps and equipment required to remove accumulated water from trenches. Water or any other liquid removed shall be disposed of without any nuisance or hazard.

1.1.6 Trenching

Trenching shall be programmed in advance and the approved programme shall not be departed from except with the consent of the Engineer.

Trenches shall be as straight as possible and shall be excavated to the dimensions indicated in this specification.

The bottom of the trench shall be of smooth contour, and shall have no sharp dips or rises which may cause tensile forces in the cable during backfilling.

The excavated material shall be placed adjacent to each trench in such a manner as to prevent nuisance, interference or damage to adjacent drains, gateways, trenches, water furrows, other works, properties or traffic. Where this is not possible the excavated materials shall be removed from site and returned for backfilling on completion of cable laying.

Surplus material shall be removed from site and disposed of at the cost of the Contractor.

Trenches across roads, access ways or footpaths shall not be left open. If cables cannot be laid immediately the contractor shall install temporary "bridges" or cover plates of sufficient strength to accommodate the traffic concerned.

In the event of damage to other services or structures during trenching operations the contractor shall immediately notify the Engineer and institute repairs.

Prior to cable laying the trench shall be inspected thoroughly and all objects likely to cause damage to the cables either during or after laying shall be removed.

Where ground conditions are likely to reduce maximum current carrying capacities of cables or where the cables are likely to be subjected to chemical or other damage or electrolytic action, the Engineer shall be notified before installing the cables. The Engineer will advise on the course of action to be taken.

Extreme care shall be taken not to disturb surveyor's pegs. These pegs shall not be covered with excavated material. If the surveyor's pegs are disturbed, they shall be replaced by a person qualified to do so.

1.1.7 Dimensions of Trenches

Cable trenches for one or two cables shall not be less than 300 mm wide and need not be more than 450 mm wide. This dimension shall be valid for the total trench depth.

The width shall be increased where more cables are installed to allow for the spacing stipulated.

Where trenches change direction or when cable slack is to be accommodated, the Electrical Contractor shall ensure that the requirements of the relevant SABS specification regarding the bending radii of cables are met when determining trench widths.

Trench depths shall be determined in accordance with cable installation depths and bedding thickness.

Payment will be made on a volumetric excavation rate calculated based on the given maximum dimensions or the actual dimensions whichever is the lesser.

For MV distribution cables only, trenches shall be 900 mm deep with bedding of 100 mm bedding below cable, (cable 800 mm deep), and 150 mm bedding above cable.

For LV distribution and street lighting cables only, trenches shall be 600 mm deep with bedding of 100 mm bedding below cable, (cable 500 mm deep), and 150 mm bedding above cable.

Where trenches change direction or when cable slack is to be accommodated, the Electrical Contractor shall ensure that the requirements of the relevant SANS Specification regarding the bending radii of cables are met when determining trench widths.

Pole holes shall be kept to the minimum, commensurate with providing adequate space to efficiently and safely plant the pole to the required depth. In general, the pole depth shall be 15% of the mounting height.

1.1.8 Measurement & Classification

For the purpose of measurement and payment, the excavation will be classified in seven categories. The Electrical Contractor may however, use whichever method he wishes to excavate any type of material but his chosen method shall not determine the classification.

All measurements for payments shall be made jointly by the Engineer and the Electrical Contractor and the Electrical Contractor shall obtain the signature of the Engineer including approval of such measurements.

No allowance shall be made for the breaking away of the trench sides, other earth movements or for trenches excavated more than the stipulated dimensions.

All low voltage cables must be installed 600 mm to the bottom of the cable, below final ground level. Electrical Contractors must base their rates for cable trenches in soil, soft rock and hard rock on the quantities given in the Schedule of Prices. The actual quantities shall be determined on site. Adjustments to the Contract Sum shall be calculated using the rates in the Schedules of Prices, after completion of the installation.

The Engineer before back filling or application of bedding material shall classify the excavation and complete the excavation & backfill schedule.

SOFT AND PICKABLE:	Shall mean hand pickable soil and includes loose gravel, clay, back-filled soil, loose or soft shale, loose literati and rocks less than 75 mm diameter.
HARD MATERIAL:	Shall mean rock which is hand pickable including hard shale, dense literati and rocks exceeding 75 mm in diameter to 0,03 cubic metres volume.
ROCK:	Shall mean granite, quartz sandstone, slate and stone of similar hardness as well as rocks exceeding 0.03 cubic metre volume in general requiring the use of jack hammers and other mechanical means of excavations.
HARD ROCK:	Shall mean rock than can only be excavated by means of explosives.

ASPHALT SURFACE	shall mean existing asphalt road surfaces and compacted sub-layers requiring the use of jackhammers and other mechanical means of excavations.
CONCRETE SURFACE	shall mean existing concrete surfaces and compacted sub-layers requiring the use of jackhammers and other mechanical means of excavations.
PAVING BLOCKS	shall mean existing un-grouted concrete or clay paving and compacted sub-layers. Pavers must be carefully removed and replaced by skilled labourers after excavations are filled and sub- layers compacted to 95 % MOD. A.A.S.H.T.O. density.

Where rock and hard rock are encountered, the prior approval of the Engineer shall be obtained before proceeding with the excavation. This requirement is stipulated in order to afford the Engineer the opportunity to determine whether an alternative trench route is justified.

1.1.9 Joint Holes

Where cable joints are required to be made in the course of a cable run, a joint hole shall be excavated of sufficient size to enable the cable jointer to work efficiently and unimpeded.

1.1.10 Bedding

The bottom of the trench shall be filled across the full width with a 75mm layer of suitable soil sifted through a 6 mm mesh and levelled off.

Only sandy clay or loam soil with a satisfactory thermal resistivity (not exceeding 1.5°C m/w) may be used for this purpose. Sea or river sand, ash, chalk, peat, clinker or clayey soil shall not be used. The use of crusher sand is acceptable.

Where no suitable soil is available on site, the contractor shall import fill from elsewhere and make all the necessary arrangements to do so. The cost of importing soil for bedding purposes shall be included in the unit rates for excavations.

After cable laying a further layer of bedding shall be provided to extend to 75 mm above the cables.

The bedding under joints shall be fully consolidated to prevent subsequent settling.

1.1.11 Cable Sleeves

Where cables cross under roads, railway tracks, other service areas etc. and where cables enter buildings, the cables shall be installed in polyethylene (6mm thickness), asbestos-cement pipes or earthenware pipes. Pitch fibre and PVC pipes are not acceptable because of the adhesion that occurs after a period of time between the pipe and the sheathing or outer serving of the cables.

Pipes shall be joined in accordance with the manufacturer's instructions.

Sleeves shall cross roads and railway tracks at right angles.

Sleeves shall have a minimum diameter of 100 mm. They shall extend at least 2 m beyond the tracks of a railway line or of the outermost tracks where there is more than one line. In the case of roads, the sleeves shall extend at least 1 m beyond the road edge or kerb on both sides of the road.

All sleeves shall be graded 1:400 for water drainage.

Cable sleeves shall be installed to the spacings and depths as specified, as stated below.

Galvanised metallic sleeves up to and including 76 mm dia. shall be supplied and installed by the Contractor.

The ends of all sleeves shall be sealed with a non-hardening watertight compound after the installation of cables. All sleeves intended for future use shall likewise be sealed.

2. INSTALLATION OF CABLES

This section covers the installation of cables for the distribution of power in buildings, other structures and in ground for system voltages up to 11 kV, 50 Hz.

2.1 Cable types

- All cables and jointing and termination accessories used for power distribution shall comply with the relevant SANS Specifications.
- Cables with copper conductors shall be used throughout unless otherwise specified or approved.
- All unarmoured cables shall be installed in metal trunking, sleeves or conduit unless clearly specified to the contrary.
- XLPE Cables shall only be used in exceptional circumstances with the written permission of the Engineer.

2.2 Competence of Personnel

It is a definite requirement that the Contractor shall only employ personnel fully conversant with cable manufacturer's recommendations for joining and terminating cables.

2.3 Identification of Cables

Cables shall be identified at all terminations by means of punched metallic bands or marked with labels or tags. (Refer also to SANS 10142-1.)

The use of PVC tape with punched characters is not acceptable. The identification numbers of cables shall be shown on "as built" drawings of the installation.

3. INSTALLATION OF UNDERGROUND CABLES

3.1 Installation Depths

Cables shall be installed at the following minimum depths below final ground level:

- Up to 11kV: 800mm

All cable depth measurements shall be made to the top of the cable when laid directly in ground or to the top of the duct or sleeve where these are provided.

The above depths shall apply to the top layer where cables are installed in layers.

The Contractor may only deviate from the above depths provided prior authority in writing has been obtained from the Engineer. In this event the cables shall be protected with a suitable concrete covering.

The depth of cable pipes or ducts beneath railway lines or roads shall be not less than 1,1 m below the formation level.

3.2 Cable Spacings

Cables installed in the same trench shall be laid parallel to each other with the following spacings between cables (LV: up to 1 kV; MV: 1 kV to 11 kV):

- LV/LV: 2 cable diameters
- LV/MV: 150mm minimum
- MV/MV: 150mm minimum
- LV/MV/PILOT: 1 cable diameter

Where MV and LV cables have to be installed in the same trench, both shall be laid at a depth of 800 mm and then covered with 75 mm of soil. The soil shall then be compacted, and then backfilled and compacted in layers not exceeding 150mm until the trench is completely backfilled.

Cables for telephones, communication systems and other low voltage systems (less than 50 V) shall be separated from power cables by at least 1 m. All control or pilot cables without a lead sheath and steel armouring shall be laid at least 300 mm from power cables.

Cables shall not be buried on top of each other unless layers are specified. The minimum spacing between layers shall be 200 mm.

3.3 Cable Laying

Except where ducts, tunnels or pipes are provided, cables shall be laid directly in the ground.

The cable shall be removed from the drum in such a manner that the cable is not subjected to twisting or tension exceeding that stipulated by the cable manufacturer.

Cable rollers shall be used as far as possible to run out cables. Rollers shall be spaced so that the length of cable in the trench will be totally suspended during the laying operation and sufficiently close to prevent undue sagging and the cable from touching the ground. Rollers shall also be placed in the trench in such a manner that they will not readily capsize.

Cable rollers shall have no sharp projecting parts liable to damage the cables.

Where cables have to be drawn around corners, well-lubricated skid plates shall be used. The skid plates shall be securely fixed between rollers and shall constantly be examined during cable laying operations.

Where cables have to be drawn through pipes or ducts, a suitable cable sock shall be used and particular care shall be exercised to avoid abrasion, elongation or distortion of any kind. In the case of oil filled cables, a cable sock may never be used. Special eyes, giving access to the interior of the cable, must be utilised.

The maximum allowable tension when pulling a cable, is 70 N/mm2 of conductor area.

It will be assumed that the price or rates contained in the tender includes for the installation of cables in pipes and ducts or below existing or newly installed services.

The Engineer shall be informed timeously of the intention to carry out all cable laying operations to allow an inspection of the works by the Engineer if so required.

3.4 Backfilling

The Contractor shall not commence with the backfilling of trenches without prior notification to the Engineer so that the cable installation may be inspected. Should the Contractor fail to give a timeous notification, the trenches shall be re-opened at the Contractor's cost. Such an inspection will not be unreasonably delayed.

For medium voltage cables (1 kV to 11 kV) a coloured plastic marking tape shall be installed 400 mm above the cable. The tape shall be yellow, marked with the words "electric cable/elektriese kabel" in red. These markings shall not be more than 1 m apart from centre to centre.

Backfilling shall be undertaken with soil suitable to ensure settling without voids. The maximum allowable diameter of stones present in the backfill material is 75 mm.

The Contractor shall have allowed in his tender for the importation of suitable backfill material if required.

The backfill shall be compacted in layers of 150 mm and sufficient allowance shall be made for final settlement. The Contractor shall maintain the refilled trench at his expense for the duration of the Contract. Surplus material shall be removed from site and suitably disposed of.

On completion, the surface shall be made good to match the surrounding area.

In the case of roadways or paved areas the excavations shall be consolidated to the original density of the surrounding material and the surface finish reinstated.

3.5 Cable Markers (for MV cables only, except where otherwise specified)

Cable markers shall be provided along all MV cable routes but need only be provided along LV cable routes where specified.

Cable markers shall consist of concrete blocks in the shape of truncated pyramids, approx. 300 mm high, 150 x 150 mm at the top and 250 x 250 mm at the bottom.

Brass plates shall be cast into the tops of the blocks in such a manner that they cannot be prised loose. The wording "ELECTRIC CABLE " shall be stamped on the brass plates, as well as direction arrows and the cable voltage rating.

Cable markers shall be installed on the surface along all the underground routes and shall project 35 mm above normal ground level unless the projected markers could be a hazard to pedestrian or other traffic in which case they shall be installed flush with the surface.

Cable markers shall be installed at the beginning and end of a cable run (e.g. where a cable enters a substation or building), at all changes of direction, above all joints, above cable pipe entries and exits and at intervals not exceeding 50 m along the cable route.

The position of cable markers shall be indicated on the "as built" drawings.

3.6 Transnet, Provincial Administration or National Road Crossings

The contractor shall not trench beneath any railway tracks without the Transnet administration's supervision. The Contractor shall request the Engineer timeously to arrange for the necessary supervision. The cost of such supervision will be paid for by the Employer.

The Engineer will arrange for the necessary wayleave and permission to cross Transnet property and railway tracks, or Provincial or National road reserves and Telkom Authority approval of proposed cable routes.

The Contractor shall carry out the crossing installation in strict accordance with the Transnet and Provincial administration's requirements and stipulations. Where these

requirements are in contradiction with this specification, the Engineer's ruling shall be sought.

The Contractor shall ensure that he will comply with the various administrations' requirements regarding crossing of provincial and national roads, especially with regard to the safeguarding of the public. The Contractor shall also provide proof of adequate insurance cover against any claim from any accident as a result of work done by the contractor during the crossing operation. The Engineer shall also be indemnified from all liability in this regard.

The Contractor shall liaise with the various administrations well in advance regarding the intended dates, times and expected duration of the crossing operations and obtain their approval of the programme and method of operation before commencing with the work.

4. INSTALLATION OF CABLES IN CONCRETE TRENCHES

4.1 General

This paragraph covers the installation of cables in building trenches, service ducts, etc. The trenches, ducts, etc. inside buildings will be constructed and installed by others.

4.2 Installation

Cables shall be installed in one of the following ways

- On horizontal cable trays
- On horizontal metal supports with suitable clamps
- On vertical cable trays or metal supports fixed to the side of the trench. The cables shall be clamped in position.
- Cables shall not be bunched and laid on the floor of the building trenches.

4.3 Covers

The covering of concrete trenches shall, as a rule, fall outside the scope of the electrical installation. The Contractor shall however be responsible for the cutting or drilling and smoothing of holes for cables through chequer plates, concrete or other coverings as required.

Cables shall enter and exit the trench through sleeves protruding 300 mm beyond the covering. The sleeves shall be permanently secured in position and the open space between the cable and sleeves shall be sealed with a non-hardening, watertight compound.

4.4 Filled trenches

Where specified, floor trenches shall be filled with fine crusher sand (no river or sea sand).

If a sand filling is specified, the cables shall be fixed to non-corroding supports.

Sand-filled trenches other than in substations shall be covered in one of the following ways:

- Unless otherwise specified allowance for a mass of 2 tons shall be made. Reinforced concrete covers. This shall be used where vehicular traffic may be encountered over trenches.
- Sand and cement screed.
- Removable chequer plates.

Method (a) above shall be used where vehicular traffic may be encountered over trenches. Unless otherwise specified, allowance for a mass of 2 tons shall be made.

5. FIXING OF CABLES TO TRAYS OR STRUCTURES

5.1 Installation

Cables -may be installed in one of the following ways:

- On horizontal cable trays
- Against vertical cable trays with suitable clamps
- Against horizontal or vertical metal supports or brackets with suitable clamps
- On clamps which are fixed to the structure

5.2 Clamps

Suitable clamps (cleats) which will secure cables without damage shall be used. Metal clamps or drilled hard wood blocks shall be used. Clamps shall consist of adjustable metal wings which clamp to a metal support, or consist of two halves that are bolted together. The correct clamp size to fit the cable shall be used. Cables of different sizes may only be fixed by a common clamp when the clamp is specially made to accommodate the various cables.

5.3 Spacing of Supports

Two methods of supporting cables are found in practice. The most generally known method is the restrained installation where the distance between supports is small enough to prevent any noticeable sag in the cable. The alternative method is the unrestrained installation where the distance between supports should be great enough to ensure that there will be obvious sag in each span between supports.

5.4 Spacing of Supports of Unrestrained Cables

Large single core cables shall always be installed according to this method. Generally, single core cables with conductors exceeding a cross sectional area of 185 mm^2 should be supported at spacings in excess of 2 m since the sag between supports will safely accommodate any thermal expansion.

Reducing the spacing between the supports to 1,5 m or less shall be avoided at all costs, as expansion cannot be taken up by a change of sag and chances of sheath failure become considerable.

5.5 Spacing of Supports of Restrained Cables

Additional cleats shall be installed at each bend or offset in the cable run. The maximum distance between supports or cleats for multi-core control cables shall be 20 times the outside diameter of the cable with a maximum spacing of 550 mm for unarmoured cables and 30 times the outside diameter of the cable with a maximum spacing of 900 mm for armoured cables. Spacing of supports for cables for high voltage lighting shall be in accordance with Table 8 of SANS 10142-1. A minimum of 20 mm ventilation clearance shall be maintained between cables and the wall to which they are cleated.

6. GROUPING AND SPACING OF CABLES IN BUILDINGS AND STRUCTURES

6.1 Spacing Correction Factors

Cables shall, as a rule, be spaced two cable diameters apart, for which no grouping correction factor need be applied.

6.2 Cables on Different Levels

Where parallel cable runs are installed at different levels (e.g. on parallel cable trays) and where the spacing of the layers is not specified, a minimum spacing of 300 mm shall be maintained.

6.3 Single Core Cables

Where single core cables are installed along a three-phase circuit, the cables shall be installed in trefoil formation and bound together at 300 mm intervals.

6.4 High Voltage Cables

High voltage cables shall be separated from other cables and services throughout the installation and shall as far as possible be installed in separate floor trenches, pipes or metal channels. Where this is not feasible a minimum spacing of 500 mm shall be maintained.

6.5 Cables for other Services

Cables for telephones, communication systems and other low voltage systems (less than 50 V) shall be separated from power cables. In building ducts a physical barrier shall be provided between power cables and cables for other services. Where armoured cables are used for such other services, they shall be installed on separate cable trays or shall otherwise be at least 1 m away from power cables.

Where unarmoured cables are used for these other services, they shall be installed in separate conduits or metal channels.

CROSS-SECTIONAL AREA OF CABLE CONDUCTORS (MM^2)	MAXIMUM SPACING OF SUPPORTS (CLEATS) (MM) FOR RESTRAINED CABLES			
	WIRE ARMOURED CABLES		OTHER THAN WIRE ARMOURED CABLES AND UNARMOURED CABLES	
	HORIZONTAL CABLE ROUTES	VERTICAL CABLE ROUTES	HORIZOBNTAL CABLE ROUTES	VERTICAL CABLE ROUTES
1,5	450	750	300	400
2,5	450	750	300	400
4,0	600	750	300	400
6,0	600	750	300	400
10,0	750	900	400	450
16,0	750	1 000	400	550
25,0	900	1 000	450	550
35,0	900	1 000	450	550
Bigger than 35,0	900	1 000	450	550

For larger cables the spacing shall be 10 x outside diameter of the cable.

7. TERMINATION AND JOINTING OF CABLES

7.1 General

Cable ends shall be terminated with glands or in cable boxes with the associated accessories such as clamps, shrouds, etc. complying in all respects with the manufacturer's instructions.

Connection of cables to switchgear shall always be effected in such a way that the various phases, seen from the front of the switchgear, will be in the following positions:

- No.1 conductor: left (red) (A)
- No.2 conductor: centre (white) (B)
- No.3 conductor: right (blue) (C)

Exposed armouring shall be covered with bitumen-base paint.

All cable ends shall be supplied with the necessary earth connection.

A channel or other approved means of support shall be provided to remove mechanical stress from the glands.

Cable cores shall be marked with heat-shrunk sleeves where necessary to identify the phases. Refer to SANS 10142-1.

The current-carrying capacity and breakdown voltage of the cable end shall be the same as for the complete cable.

Cables shall be terminated in accordance with the recommendations laid down by the manufacturers of the cables and glands employed.

7.2 Termination of Paper-Insulated Cables

The ends shall be terminated in cable end boxes filled with bituminous, cold filling or resin oil semi-fluid compound or heat-shrinkable terminations in accordance with the manufacturer's recommendations.

Heat-shrinkable materials shall only be used in exceptional circumstances with the written permission of the Engineer.

Before terminating or jointing paper-insulated cables, a test to establish the presence of moisture must be carried out.

All cut cable ends which will be exposed to the atmosphere for more than two hours shall be sealed and wiped to prevent penetration of moisture.

7.3 Termination of XLPE Cables

Cross-linked polyethylene cables (XLPE) shall be terminated in accordance with the manufacturer's recommendation.

The copper tapes of the earth screen on the cable shall be bonded to the main earth bar of the switchgear or transformer, but the bond shall be easily removable for testing purposes.

The cable shall be firmly secured on the switchgear by means of a clamp to prevent mechanical stress on the cable and terminations.

7.4 Termination of PVC-insulated Cables

Cable ends shall be terminated by means of adjustable glands in accordance with the the manufacturer's specification.

The glands shall be fitted in accordance with the cable and gland manufacturer's instructions.

The correct size and type of gland shall be used for the particular cable and application.

7.5 Connection of Cable Conductors

Suitable lugs shall be used, preferably solidly sweated to the cable conductor ends. Lugs may be crimped, using mechanical or pneumatic tools designed for this purpose, on condition that evidence is submitted that the method used complies with the performance requirements of BS 4579.

Contact surfaces shall be thoroughly cleaned and smoothed and fixing bolts shall match the hole size of the lug.

Cables that are connected to clamp type terminals where the clamping screws are not in direct contact with the conductor, need not be lugged but the correct terminal size shall be used.

Ferrules shall be used as far as possible where cable conductors are connected directly to equipment with screws against the conductor strands.

When cutting away insulation from cable conductors to fit into lugs, care shall be taken that no strands are left exposed. Under no circumstances may any of the conductor strands be cut away to fit into lugs.

7.6 Joints

Joints in cable runs will not be allowed unless specified in the Detail Technical Specification or authorised by the Engineer.

Jointing shall be carried out strictly in accordance with the manufacturer's instructions and by personnel competent in jointing the types of cables used.

During outdoor jointing operations, the joint bays shall be adequately covered by tents of waterproof material suitably supported. Where necessary a trench shall be excavated around the bay to prevent the ingress of moisture. The sides of the hole shall be draped with small tarpaulin or plastic sheeting to prevent loose earth from falling in during jointing operations.

The joint shall not impair the anti-electrolysis characteristics of the cable.

The Contractor shall notify the Engineer timeously of the day on which jointing is to be carried out in order than an inspection may be arranged if so required. Any cable joint not inspected by the Engineer because of insufficient notice being given, shall be opened for inspection and redone at the discretion of the Engineer at the cost of the contractor.

MV cable joints on paper insulated cables shall be of the compound cast type and the compound used shall comply with the manufacturer's specification

MV cable joints on XLPE-insulated cables shall be of the heat shrinkable type or shall be based on a prefabricated system utilising pre-moulded slip-on stress cones and shall comply with the manufactuer's recommendations.

LV cable joints shall be of the epoxy-resin type.

Joints shall be fully water and air tight and shall be free of voids and air pockets.

The crossing of cores in joints will not be permitted under any circumstances.

8. TESTING

Each cable shall be tested after installation in accordance SANS 1507 (up to 1 kV) and SANS 97 (up to 11 kV) as well as the requirements of the Local and Supply Authorities.

LV Cables shall be tested by means of a suitable megger at 1 kV and the insulation resistance shall be tabulated and certified.

MV Cables shall be high voltage tested and the exact leakage current shall be tabulated and certified.

The Contractor shall make all arrangements, pay all fees and provide all equipment for these tests. The cost of testing shall have been included in the tender price.

The Contractor shall notify the Engineer timeously so that a representative of the Engineer may witness the tests.

On completion of the tests on any cable, the Contractor shall without delay, submit three copies of the certified Test Reports to the Engineer.

9. COMPLETION

The Engineer reserves the right to inspect the installation at any stage during the course of construction. Such inspections will however not deem the portions inspected as being complete or accepted and the Contractor shall remain responsible for completing the installation fully in accordance with the Contract Documents.

The Contractor shall carry out a final "as built" survey of the cable routes and present to the Engineer "as built" route plans of the complete installation. The following information shall be reflected on the plans or submitted as separate schedules with the plans:

- Overall length of each cable
- Locations of all joints (if any) in relation to permanent reference points. Dimensions shall be shown and the method of triangulation i.e. two dimensions to each joint, shall be used
- Identification of each cable

The works will be deemed to be incomplete until all tests have been conducted successfully and all "as built" drawings and schedules have been handed to the Engineer.

PFC (POWER FACTOR CORRECTION) PANEL SPECIFICATION

PFC (POWER FACTOR CORRECTION) PANEL SPECIFICATION

1. INTRODUCTION

This specification covers the new PFC panel to be manufactured, tested, installed and commissioned at Sundumbili Magistrates Court.

The tenderer must sign and return the compliance document. Failure to do so will automatically lead to dis-qualification of the tenderer and his/her tender will not be considered regardless of tendered value.

2. SCOPE OF WORK

The scope of work comprises of the design, manufacture, testing, delivery, installation, commissioning and maintenance (if required) during the liability period.

The following items will form part of the scope of work:

a) Design to relevant standards: SANS & IEC and indicated below
b) Issue drawings (general arrangement & control wiring diagram) for approval prior to construction
c) Manufacture of the PFC Panels
d) Internal testing and quality control
e) Delivery
f) Installation
g) Commissioning, testing and verification (with PQ meter c/w report)
h) Routine test report & declaration of conformity to relevant standards

3. STANDARDS

The design of the low voltage capacitor bank and accessories shall comply with the requirements of the latest current edition of following IEC standards and with the specific requirements of this specification

IEC 60831: Parts 1&2- Shunt power capacitors of the self-healing type for AC systems

having rated voltage up to and including 1 kV

IEC 61921: Power factor capacitors. Low voltage capacitor banks

IEC 61439-1/2: Low Voltage Switchgear and Control gear Assemblies

IEC 60947: Low Voltage Switchgear, Part 2: Circuit Breakers, Part 4: Control gear for voltages up to and including 1kV AC

IEC 60076-6: Reactors

IEC 60529: Degree of protection provided by enclosures

4. SITE SPECIFIC SUPPLY

The supply to which the panels are to be connected is 3 phase (4-wire) & earth, 400/230V (+/- 10%) with a frequency of 50 Hz

5. RATINGS AND GENERAL REQUIREMENTS

5.1 RATINGS:

Voltage (operational): 400V
Insulation voltage: 1000V
Impulse voltage: 8000V
Current: 320A
Fault level: 15kA
Frequency: 50Hz
PFC Var rating: 150kVAr (at 400V)
Capacitor voltage rating: 480/525V
De-tuned reactors: 14% (135Hz) Class H
Level of contamination: 3
IP rating: IP54
Form of separation: 1
Maximum ambient temperature: 35°C degree Celsius
Relative humidity: 85%
Control voltage: 230V

5.2 GENERAL REQUIREMENTS:

Main Switch: 320A circuit breaker with door interlocked handle & shaft (MCCB type)
Configuration: 6 x 25kVAr steps (only rack mounted solutions will be accepted)
Configuration: capacitor-reactor racks will have a dedicated circuit breaker as protection
Configuration: the circuit breaker will have overload and short-circuit protection
Capacitor voltage: to suite supply voltage and de-tuned reactor
Controller: door mounted
Temperature sensors: 2 (1 x fan control, 1 x over-temperature)
Ventilation: fans and filters based on enclosure size and equipment heat dissipation
Siren: Audible
BMS provision: potential free contact rated at 230V, 1A
Fire suppression: 2 x Stat-X Thermal Aerosol Generator, 100g c/w bracket & thermal head
Mounting: Floor standing
Enclosure: Mild steel (2mm doors, 3mm mounting plates)

Colour: RAL7035
Cable entry/exit: Top

6. ENCLOSURE, BUSBARS, WIRING & LABELLING

Enclosure to be made up of modular construction fully type tested assembly

All joints between enclosures to be fitted with purpose made gaskets

All doors to be earthed

Particular attention shall be given to the ventilation of panels, to eliminate build-up of excessive heat caused by the sun or internal heat generation. All necessary precautions shall be taken to ensure that the temperature of the air in any portion of the assembly does not rise more than 15°C above ambient air temperature

Every board shall be fitted with a suitable gasket incorporated onto the door to ensure that the arrangement is in accordance with the required degree of protection. Gaskets shall be made of durable, non-hardening rubber, neoprene or other synthetic material, suitably fixed to the door to ensure that the seal does not become dislodged during normal operation

The lock and door catch shall comprise of a combination unit. Door latching and de-latching operations shall be smooth and quick, whilst ensuring proper compression of the sealing gaskets. Repeated opening and closing of the hinged doors and operations of the door locks and catches shall not cause chipping or scratching of the painted surfaces or any other blemishes to the finished boards

Lifting lugs shall be provided

Due care shall be taken to ensure that the live side of the MAIN SWITCH is suitably protected so that no live conductors are exposed when the panel door is opened

The panel shall be equipped with a set copper busbars. The busbars shall be continuously rated for the full load of the incoming supply circuit breaker. An earth bar shall be rated to fault current and touch voltage and will be installed for the full length of the panel

Busbar rating shall be 1.6A/mm2

Busbar temperature shall not exceed a 40°C temperature rise

The busbars shall be adequately braced and supported. The busbars shall be covered with a sufficient number of layers of high quality insulating tape or heat

shrink and finished in standard colours (red, white & blue)

Busbars shall be suitable enclosed in a busbar chamber or behind a protective barrier for protection against inadvertent contact with "live" busbars with panel door opened for inspections during operation

Inter-connectors between the busbars and control units shall be by means of fully insulated, adequately rated conductors firmly bolted to the busbar and secured to the appropriate terminals of the control units using crimped-on terminal lugs. No conductor of less than 16mm2 shall be used between busbars and control units. All conductors shall be suitably rated for the fault level

The power and control wiring must be installed in PVC trunking by neatly arranged vertical and horizontal runs. Wire looms not in trunking must be strapped to rails and must be wrapped with spiral band to protect the conductors.

All control wiring must be numbered with Legrand Memocab system

Power wire: minimum 16mm2 from busbars to equipment
Up to 16mm2 must be red/white/blue
Above 16mm2 colour coded at ends with high quality heat shrink

Control wire: minimum 1mm2
230V – red
Neutral – black

All components must be labels that can be clearly read in conjunction with the wiring diagrams

The panel shall be fitted with the following labels as needed in suitable positions:

- Live busbars
- Main label (always required)
- Voltage rating
- Current rating
- Fault level and time
- IP rating
- Job number
- Reference number
- Date of manufacture
- Form of separation
- Fed from

The panel shall be supplied with a test certificate that indicates compliance with SANS 1973-1

7. CAPACITORS

The capacitors shall be low-losses units, tested in accordance with IEC 60831 part 1

Each element is to be of a dry self-healing metallised polypropylene film and to be housed in a three phase assembly in one aluminium casing

A double protection system shall be fitted to each three phase assembly which shall comprise an integral discharge resistor and an overpressure disconnect device.
This over pressure device must disconnect the 3 phases

Each element forming the three phase capacitor shall be fitted with an internal discharge resistor to ensure that the capacitor is discharged to a voltage not exceeding 50 V measured at the capacitors terminals, one minute after disconnection from the power supply

The use of polychlorinated biphenyl (PCB) and oil as capacitor impregnation is not acceptable

The capacitor losses in Watts shall not exceed 0.5W/kVAr, discharge resistor included

The group of elements forming a three phase capacitor unit shall be installed in an aluminium casing

Each capacitor shall be provided with three locking terminal pads and shall not require earth connection. The earth connection shall be done with the mounting stud and a locking contact ring

The three-phase capacitor shall be designed and manufactured in an ISO 9001 and ISO 14001 certified manufacturing plant. Certificates shall be available on request

Tolerance on capacitance value: -5%, +10%

Insulation level: 50/60 Hz, 1 minute withstand voltage: 4 kV & Vimp: 6 kV

Temperature class: - 25°C / 55°C (class D)

Admissible voltage overloads: 8 h in any 24 h period: 10 %

8. REACTORS:

The detuning reactor shall be three phase iron core with copper or aluminium winding

All the parts of the reactor protected against corrosion with varnish

The detuning reactor shall be equipped with thermal protection device used for step disconnection under over load condition

Tolerance: +/- 5 %

Permissible overload fundamental current: 1.1 time the nominal current (I1)

Insulation level: 1.1 kV according to IEC 60076-6

Test voltage (coil to core & coil to earth): 4 kV 1 minute

9. AUTOMATIC PFC CORRECTION CONTROLLER:

The power factor controller shall be a micro-processor based unit complete with a LCD display capable of switching capacitor contactors in 12 steps

The technical specification should be as follows:

Rated voltage (Un) : 110V–220V / 240V–415 V

Display: LCD screen

Alarm output contact

The controller shall have a built-in temperature sensor

Separated output contact to control the fans in the capacitor banks

Accuracy class: 1.5 %

Operating Temperature: 0 to 60°C

Connection type: Line to line or Line to neutral

Connection features: Insensitive to CT direction / Insensitive to phase rotation polarity

Current input: CT 800A/ 5A class 1

Potential free output contacts: 1A / 400V; 2A / 250V; 5A / 120V

Programmable step configuration: automatic or disconnected

Power factor setting range: Digital, 0.85 lagging to 0.90 leading

The controller shall provide the following information, alarms and warnings:

- Cosine phi
- Connected steps
- Switching delay
- Real and reactive current
- Total voltage harmonic distortion
- Voltage , temperature, Power (S,P,Q)
- Voltage harmonic spectrum (3,5,7,11,13)
- Low power cosine phi
- Hunting
- Abnormal cosine phi
- Overcompensation
- Frequency not detected
- Over current
- Under voltage
- Over voltage
- Over temperature
- Total voltage harmonic distortion
- Capacitor overload

10. DRAWINGS

Within one week of the receipt of order the successful tenderer shall submit drawings (general arrangement & control wiring diagram) for approval

11. PROGRAM

The manufacturer will strictly adhere to the customer's program

12. GUARANTEE

The tenderer shall guarantee the panel for a period of 1 year after commissioning.

13. RETURNABLE POWER FACTOR CORRECTION DATA SHEET

SCHEDULE OF INFORMATION / COMPLIANCE DOCUMENT (RETURNABLE DOCUMENT)

The tenderer must sign and return the compliance document. Failure to do so will automatically lead to dis-qualification of the tenderer and his/her tender will not be considered regardless of tendered value

Item	Description	Required	Offered
Enclosure	Supplier	Rittal or approved equivalent	
Enclosure	Type testing	to IEC 61439-1	
Enclosure	Material	Mild steel	
Enclosure	Door thickness	2mm	
Enclosure	Mounting plate thickness	3mm	
Enclosure	Colour	RAL 7035	
Enclosure	Voltage rating	400V	
Enclosure	Current rating	320A	
Enclosure	1s kA rating	15kA	
Enclosure	IP rating	54	
Enclosure	Fire protection	2 x 100g Stat-x unit c/w bracket & thermal head	
Switchgear	Circuit breaker	ABB	
Switchgear	PFC racks	Schneider	
PFC Racks	Configuration	6 x 25kVAR	
Reactors	Tuning	14%	
Reactors	Temp class	H	
Controller	PFC Controller	Schneider	
Other	Fans	Rittal	
Other	Filters	Rittal	
Other	Thermostats	Rittal	
Other	Siren	Eagle S2	
Other	Control transformer	1000VA (400V/230V)	
Copper	Copper	Copalcor	
Wiring	Wiring	Abedare / Alvern	
Enclosure	Dimensions	1200w x 2100h x 600d	

Date	Tenderer authorised signature
Name & Surname	Position

GENERATOR SPECIFICATION

GENERATOR SPECIFICATION

1. INTRODUCTION

The stand-by generating set herein specified is to be installed at the Sundumbili Magistrates Court in KwaZulu Natal. The generating set will be installed within a building and will require sound attenuation, louvers and acoustic doors (1 x single door & 1 x double door)

The generating set shall generally comprise of a diesel engine coupled to an alternator mounted on a common base, a set of starting batteries, automatic charging unit, interconnecting cables, a control panel housing the generator switchgear and generator controller and all necessary control gear.

The tenderer must sign and return the compliance document. Failure to do so will automatically lead to dis-qualification of the tenderer and his/her tender will not be considered regardless of tendered value.

2. SCOPE OF WORK

The contract comprises of the manufacture, testing, delivery, rigging, commissioning and hand-over of the generating set (diesel engine coupled to an alternator mounted on a base mounted fuel tank).

This includes the items below and details further mentioned.

a) 500kVA **Prime** diesel generating set (diesel engine coupled to alternator, complete with base tank, generator controller and switchgear)
b) 800 litre base mounted tank complete with all hoses and fuel level indicator
c) Sound attenuation for the room for the inlet and outlet
d) Louvers (inlet and outlet)
e) Single acoustic door
f) Double acoustic door
g) Drawings for approval prior to construction
h) Wiring diagrams indicating generator controller, switchgear and other auxiliary equipment for approval prior to construction
i) Factory acceptance test at the manufacturer's facility
j) Inspecting and liaising concerning concrete plinth provided with builder on site
k) Delivery, offloading and rigging into position on site
l) Site acceptance test after delivery
m) First fill of diesel after site acceptance test
n) Routine test report and declaration of conformity to SANS 10142-1 & SANS 61439

3. SITE SPECIFIC SUPPLY

The supply to which the generating set is to be connected is 3 phase, 4 wire, 400/230V with a frequency of 50 Hz

4. SOUND ATTENUATION & ACOUSTIC DOORS C/W INLET AND OUTLET LOUVERS

Inlet and outlet sound attenuation c/w inlet and outlet louvers will be supplied and installed by the generator suppliers. The acoustic doors (1 x single and 1 x double), inlet & outlet sound attenuation as well as the inlet and outlet louvers must not be ordered without approval / sign off by the engineer. Drawings as well as data sheets must be sent for approval.

5. RATING & OPERATIONAL REQUIREMENTS

The rating of the diesel generating set shall be based on operation of the set when equipped with all necessary accessories such as radiator fan, air cleaners, lubricating oil pump, fuel transfer pump, fuel injection pump, water circulating pump, and battery charging alternator.

The diesel generating set and its ancillary equipment shall normally operate as an automatic mains failure unit. It shall be capable of delivering its full rated output at any time and any ambient conditions likely to occur at the site.

The generator will be used to start (and run) various motors and other loads. It is the tenderers responsibility to familiarize himself/herself with the motor list and starting methods at time of tender. Should the tenderer feel that the 500kVA generator is not suitable for starting and running the motors and other loads, the tenderer shall offer a bigger generating set. The tenderer will not offer a smaller generating set. Should the tenderer choose to offer a 500kVA generating set, the engineer will automatically assume that the motor list, starting and running currents of the motors and other loads have been considered. The starting, running of motors and other loads will be verified during the site acceptance test.

6. SITE SPECIFIC SUPPLY

The system to which the generating set is to be connected is 3 phase, 4 wire, 400/230V with a frequency of 50 Hz.

7. DIESEL ENGINE

The engine shall be of the multi cylinder, four stroke cycle, cold starting, direct injection, compression ignition type, suitable for operation on diesel fuel.

The engine shall be of the water cooled type and the cooling system shall be of sufficient capacity to cool the engine when the set is delivering its full rated load in the ambient site conditions specified under item 1 above.

The engine shall be equipped with a heavy duty type radiator complete with engine driven fan and centrifugal water circulating pump and a thermostat to maintain the engine at the manufacturer's recommended temperature level.

A thermostatically controlled immersion heater shall be provided and fitted in the engine cooling circuit to ensure easy starting of the engine at any ambient temperature.

The heater shall be so fitted that it can easily be withdrawn without having to drain the system. The heater shall be suitable for a 230 volt 50 Hz supply. The heater shall be supplied from a dedicated MCB in the control panel.

The engine speed shall not exceed 1 500 R.P.M. at normal full load conditions.

The engine shall be capable of satisfactory performance on a commercial grade of distilled petroleum fuel (commercial grade diesel fuel).

The engine shall be suitable for continuous running at the specified speed, delivering its rated output at the specified site conditions.

In addition the engine shall be capable of delivering 110 % load for one hour, after the set has been running at full load for a period of six hours and shall, after the overload period of one hour be capable of maintaining the rated output continuously without any undue mechanical strain, overheating, incomplete fuel combustion or other ill effects.

The engine shall have sufficient capacity to start up and shall within 15 seconds from mains failure, supply the full rated load at the specified voltages and frequency.

The engine shall be controlled by an electronic governor to maintain governed speed for 50 Hz operation.

The engine shall be provided with a forced feed lubricating system with a gear type lubricated oil pump for supplying oil under pressure to the main bearings, crank pin bearings, pistons, piston pins, timing gears, camshaft bearings, valve rocker mechanism and all other moving parts.

The engine shall be provided with one or more dry type air cleaners which shall provide positive air filtration.

The engine shall be fitted with an efficient stainless steel exhaust system. Flexible bellows shall be fitted between the exhaust outlet and the silencer. The flexible

piping will not be used to form a bend or compensate for misalignment. The silencer and discharge piping shall be of the high efficient type and shall be suitably supported. The internal and external part of the exhaust pipe shall be suitably lagged.

The flywheel shall be designed to limit the cyclic irregularities within the required limits.

The engine shall be equipped with a 24 volt starting system of sufficient capacity to crank the engine at a speed, which will allow starting of the engine.

The starting equipment shall include a 24 volt D.C. starter motor engaging directly on the flywheel ring gear. A heavy duty battery charging alternator and maintenance free batteries shall be supplied.

The batteries shall be connected to the engine with suitably rated P.V.C. insulated flexible leads. The batteries shall have sufficient capacity to provide three automatic attempts to start immediately followed by three manual attempts without any appreciable drop in voltage. The automatic attempts to start shall each be of not less than 10 seconds duration with 10 second intervals between and the manual attempts shall be based on the same cranking period.

A device shall be provided to limit the cranking time of each automatic attempt to start, to the 10 seconds specified above and to provide three automatic attempts after which the automatic starting mechanism will cut out until manually reset. The engine driven battery charging alternator shall have sufficient capacity to recharge the batteries back to normal starting requirements in not more than six hours.

A battery charging unit of the trickle charge type shall be provided to maintain the batteries at full capacity. The charging equipment shall be connected so that the battery is normally charged from the mains, but is also charged under mains failure conditions from the diesel generating set and if required via an inhibitor relay to prevent dual charging. The charging unit shall be incorporated in the diesel generator control cabinet.

8. ALTERNATOR / AC GENERATOR

The alternator / AC generator shall be a 400/230 volt, 3 phase, 4 wire 50 Hz machine rated 500kVA at 0.8 power factor. The generator rating shall be applicable for continuous service application.

The alternator / AC generator shall be a revolving field type, coupled directly to the engine flywheel through a flexible disc for positive alignment. The alternator / AC generator housing shall bolt directly to the engine flywheel housing and shall be equipped with a heavy duty ball bearing support for the rotor. The motor shall be

dynamically balanced up to 25 % over-speed.

The alternator / AC generator shall be of heavy duty compact design and insulation shall be Class H

The alternator / AC generator field excitation shall be performed by a rotating exciter mounted on the generator motor shaft through a brushless rotating diode system. The voltage regulator shall be of the static-magnetic type with silicon diode control. It shall be mounted on the top or side of the generator and enclosed in a drip proof enclosure. A built in voltage adjusting rheostat shall provide 10 % voltage adjustment.

The alternator / AC generator shall be capable of continuously delivering the full rated load specified and of providing a 10 % overload for the period and in the manner specified for the engine.

The alternator / AC generator shall be self-regulated and shall incorporate an automatic voltage regulator.

The voltage regulation shall not exceed ±2½%, from no load to full load, including cold to hot variations at any power factor between 0,8 lagging and unity and inclusive of speed variations.

Upon application of full load at a power factor of 0,8 lagging the alternator voltage shall recover to within 2½% of the steady state value within approximately 300 milliseconds.

Upon application of any load specified in transient, maximum voltage dip shall not exceed 20% of the nominal voltage when measured at the alternator terminals.

The alternator / AC generator stator windings shall be star connected with the star point brought out and connected to the neutral terminal in the terminal box on the generator to provide a 400/230V, 50Hz supply.

The terminal box shall be sized to suit the interconnecting cables between the alternator and canopy mounted control panel.

The alternator / AC generator shall be suitably suppressed against radio and television interference.

9. BASE / FUEL TANK

A steel fabricated base-frame (incorporating the day fuel tank) with anti-vibration mounts. The day tank shall be an integral part of the base frame of the generator set. The tank shall have sufficient capacity to run the engine on full load for a minimum period of 8 hours between the engine-alternator combination and base

shall be provided and must be able to be placed directly on the concrete slab.

The tank shall be fitted with a suitable filter, electronic gauge, removable inspection cover, drain and filler cap.

The set shall be supplied with a hand operated pump and suitable length of oil resistant hose. The hose shall be of the "push lock" type and shall be sufficient in length to extend for filling from 200 litre drums.

A tank mounted breather pipe shall be installed

10. CONTROL PANEL

A fully automatic change-over system must be provided to isolate main supply and connect standby set to the load in case of main failure. This procedure must be reversed on return of mains supply.

The switchgear for this system must be electrically and mechanically interlocked in a safe and fail-proof way to prevent the alternator from being switched onto mains and vice versa.

The control panel shall be of robust construction, totally enclosed and dust proof. Special attention shall be given to vermin proofing and dust sealing.

It shall be of folded 1,6 mm 3CR12 thick cold rolled sheet steel construction suitable for front entry through hinged doors. Internal chassis plates, circuit breaker pans and gland plates shall be provided.

All bus-bars and wiring shall be adequately rated and suitably supported, and control wiring shall be neatly laced and numbered with durable plastic ferrules, for easy tracing. Suitable terminals are to be provided for incoming and outgoing cables.

Busbars will be rated at 1.6A/mm2. This will include the phase, neutral and earth busbars. Neutral and earth busbars will be of the same rating as the phase busbars.

Suitably sized holes shall be punched in the gland plates for the required number of cable terminations for both incoming and outgoing cables. The gland plate shall be suitably braced to prevent distortion after the cables are glanded thereto.

Tenderers must give an assurance with their tender that replacements for the equipment, switchgear and instruments used in the construction of the panel are readily available from stock held in the Republic of South Africa.

11. ELECTRICAL INSTALLATION

All cables to and from the generating set panel will be supplied and installed by others.

Allowance for correspondence and site meetings must be allowed for by the tenderer.

The tenderer shall ensure that the mains and generator phase rotations are identical before the site acceptance test and must be confirmed during the test.

12. FAT (FACTORY ACCEPTANCE TEST)

A factory acceptance test shall be carried out at the manufacturer's facility to establish that the diesel generating set and its ancillary equipment meets with the requirements of the specification.

The fuel required for the FAT must be allowed for in the tendered value.

The manufacturer must provide the required load for all the testing listed below. The cost of hiring load banks etc. to comply with the testing listed below must be included in the tendered value.

The manufacturer shall give the engineer at least seven working day notice prior to testing the generating set.

In the event of the generating set failing the test and having to be re-tested, at some future date, all expenses (including time, meals and travelling) incurred by the engineer in attending the second test will be to the manufacturer's account.

FAT must include the following:

- Simulate a mains failure to automatically start the generating set from cold to test its ability to attain full rated speed and voltage and assume the full load in the specified time of ten seconds.

- Run the generating set at full load per phase for a period of one hour.

- Immediately after the above specified run, without stopping the generating set, run it for a further hour at 110 % load per phase.

- Test the generating set with regards to voltage dip, voltage and frequency recovery, with a sudden application of various loads.

- Test and demonstrate (by simulation only where actual Conditions could damage the generating set and its ancillary equipment) the correct operation of the engine safety controls and alarms.

- Any other tests the client may consider necessary to establish that the diesel generator and its ancillary equipment as a whole is functioning correctly and in accordance with the specification.

- The manufacturer will have a dedicated test sheet for testing generating sets that must be completed during the FAT. This test sheet should include voltage, currents, frequency, temperatures, pressures etc.

13. SAT (SITE ACCEPTANCE TEST)

The fuel required for the SAT must be allowed for in the tendered value. Further to this, the generating set shall be filled to 100% capacity after the SAT for hand-over. The cost for this must also be included in the tendered value.

On completion of the electrical installation of the generating set on site, the following tests shall be carried out:

- All tests done during the FAT

- Any other tests the client may consider necessary to establish that the diesel generator and its ancillary equipment as a whole is functioning correctly and in accordance with the specification.

14. OPERATING AND MAINTENANCE MANUALS

The Contractor shall supply three complete comprehensive sets of operating and maintenance manuals complete with schematic control diagrams and complete spare parts list for both engine and generator.

The above manuals are to be handed to the authorised representative on completion of the site acceptance test.

In addition a complete schematic diagram of the power and control circuitry is to be left inside the control panel.

15. DRAWINGS

Within one week of the receipt of order the successful tenderer shall submit prints of each of the following drawings for approval:

- General arrangement of the generating set switchboard front panel

- Schematic of the complete electrical systems, including starter motor, battery and automatic battery charger

- Dimensioned layout of the generating set in the canopy

16. SPARE PARTS

Tenderers must give with their tender an assurance that spare parts for the plant offered by them as a whole are readily available within the Republic of South Africa and to state where these are available.

A spare parts list must form part of the hand-over documentation

17. GUARANTEE

The tenderer shall guarantee the generating set for a period of twelve months after first delivery of the plant. During the guarantee period the tenderer shall repair any defective material, equipment or workmanship (excepting proven, wilful or accidental damage, or fair wear and tear). These shall be made good with all possible speed at the tenderer's expense and to the satisfaction of the client.

When called upon by the client the tenderer shall make good on site and shall bear all expense incidental thereto including making good of work by others, arising out of removal or reinstallation of equipment. All work arising from the implementation of the guarantee of equipment shall be carried out at times which will not result in any undue inconvenience to users of the equipment or occupants of premises.

If any defects are not remedied within a reasonable time the client may proceed to do the work at the tenderer's risk and expense, but without prejudice to any other rights which the client may have against the tenderer.

The client reserves the right to demand the replacement or making good by the tenderer at his own expense of any part of the tender which is shown to have any latent defects or not to have complied with the specification, notwithstanding that such work has been taken over or that the guarantee period has expired.

Should any specified materials or equipment in the tenderer's opinion be of inferior quality, or be unsuitably employed, rated or loaded, the tenderer shall prior to the submission of his tender advise the engineer accordingly. His failure to do so shall mean that he guarantees the work including all materials or equipment as specified.

18. RETURNABLE GENERATOR DATA SHEET

SCHEDULE OF INFORMATION / COMPLIANCE DOCUMENT (RETURNABLE DOCUMENT)

The tenderer must sign and return the compliance document. Failure to do so will automatically lead to dis-qualification of the tenderer and his/her tender will not be considered regardless of tendered value.

Component	Description	Required	Offered
Generating set	Output	500kVA @ 0.8PF - Prime	
Generating set	One step loading	65%	
Generating set	Second step loading	35% within 4s	
Generating set	Overloading	10% for 1 hour every 12 hours	
Room	Inlet sound attenuation	Trox	
Room	Outlet sound attenuation	Trox	
Room	Single acoustic door	Trox	
Room	Double acoustic door	Trox	
Engine	Make	Volvo / Perkins / Iveco	
Engine	Governor	Electronic	
Engine	Cooling system	Water cooled	
Engine	Injection system	Direct	
Engine	Cycles	4 cycle	
Engine	Speed	1500 rpm	
Engine	Exhaust	Flexible bellows	
Alternator	Make	Marelli / Syncro	
Alternator	Bearing	Single	
Alternator	Pitch	2/3 pitch winding	
Alternator	Insulation class	H	
Alternator	Voltage regulation	1.50%	
Alternator	IP rating	21	

Fuel tank	Capacity	800 litre	
Fuel tank	Fuel gauge	Electronic	
Fuel tank	Filler cap	included	
Fuel tank	Dished bottom	included	
Fuel tank	Drain	included	
Fuel tank	Plug	included	
Control panel	Controller	Deepsea 7320 c/w Modbus RS485	
Control panel	Switchgear	ABB	
Control panel	Alternator circuit breaker	ABB	
Control panel	MCB's & relays	ABB	
Control panel	Current transformers	on load side of change-over	
Component	**Description**	**Required**	**Offered**
Control panel	Emergency stop	included	
Control panel	Battery charger	3A c/w short-cct protection	
Control panel	Battery	maintenance free lead calcium	
Control panel	Battery	ampere / hour rating	
General	Manufacturer in RSA	Yes	
General	Back-up	24h, 7 days a week in KZN	

Date

Tenderer authorised signature

Name & Surname

Position

public works

Department:
Public Works
REPUBLIC OF SOUTH AFRICA

TECHNICAL SPECIFICATION PHC

PARTICULAR SPECIFICATION EARTHING AND LIGHTNING PROTECTION SYSTEMS

DEPARTMENT OF PUBLIC WORKS
SUNDUMBILI MAGISTRATES COURT

WCS 044999 : SUNDUMBILI MAGISTRATES COURT

PHC LIGHTNING PROTECTION SYSTEM

TECHNICAL SPECIFICATION PHC

PHC PARTICULAR SPECIFICATION EARTHING AND LIGHTNING PROTECTION SYSTEMS

Table of Contents

PART THREE - INSTALLATION REQUIREMENTS

WCS 044999 : SUNDUMBILI MAGISTRATES COURT
PHC LIGHTNING PROTECTION SYSTEM

PART ONE - GENERAL REQUIREMENTS

1.1 INTRODUCTION

The specification covers the soil survey, risk analysis, design of LPS, supply, installation, testing and issue of a Certificate of Compliance (CoC) for lightning protection systems (LPS) comprising either or all of air termination systems (ATS), down conductor systems (DCS) and earth termination systems (ETS) as specified below. The earthing and or lightning protection systems shall be installed and used at specific locations as indicated in the relevant scope of work.

This specification contains general performance requirements necessary for the design, manufacture, transport, installation, testing and final documentation requirements for earthing and or lightning protection systems.

The requirements of the SANS 62305 Series, SANS 10313 and SANS 725 (IEEE80-2000) include earthing and lightning protection which could pose life hazard forms an integral part of this specification. Tenderers need to ensure that they have a clear understanding of the respective Standards to design, install and test the installation to function in accordance with the respective Standards.

1.2 ABBREVIATIONS AND DEFINITIONS

- ATS – Air Termination System
- DCS – Down Conductor System
- ETS – Earth Termination System
- IEC – International Electro-technical Commission
- OEM – Original Equipment Manufacturer of a component
- LEMP – Lightning electromagnetic impulse
- LPS – Lightning Protection System
- PE – Protective Earth Conductor
- RCC – Regulatory Certificate of Compliance
- SABS – South African Bureau of Standards
- SANS – South African National Standard
- SHEQ – Safety of Environment and Quality
- SPD – Surge Protective Device
- VC – Compulsory safety specification
- Employer – Legal Person on whose behalf the enquiry is issued.
- Employer's Engineer – Engineer responsible for specification and approval of the earthing or lightning protection systems
- Competent Person – A person who is competent to express an opinion on the safety and functionality of the earthing and lightning protection system.

1.3 SOUTH AFRICAN AND INTERNATIONAL STANDARDS

- SANS 1063 – Earth rods, couplers and connections
- SANS 10142-1 – The wiring of premises - Part 1: Low-voltage installations
- SANS 10142-2 – The wiring of premises – Part 2: Medium-voltage Installations
- SANS 10199 – The design and installation of earth electrodes

- SANS 10313 – Protection against lightning - Physical damage to structures and life hazard
- SANS 62305-1 – Protection against lightning - Part 1: General principles
- SANS 62305-2 – Protection against lightning - Part 2: Risk management
- SANS 62305-3 – Protection against lightning - Part 3: Physical damage to structures and life hazard
- SANS 62305-4 – Protection against lightning - Part 4: Electrical and electronic systems within structures
- SANS 10225 – The design and construction of lighting masts
- SANS 61643-12 – Low-voltages surge protection devices – Par 12: Surge protective devices connected to low voltage power distribution systems – Selection and application principles
- SANS 725 – IEEE80-2000 Guide for safety in AC Substation Grounding

1.4

1.5 STATUTORY REQUIREMENTS

1.5.1 Earthing and lightning protection systems shall meet the requirements of the Acts or the legislative requirements applicable to the place of installation.

1.5.2 Earthing and Lightning Protection Systems shall comply with the fundamental safety requirements of Clause 5 of SANS 10142-1.

1.5.3 Earthing and Lightning Protection Systems shall as a minimum be designed, constructed and tested in accordance with the requirements of SANS 10313 and a certificate shall be issued to this effect.

1.5.4 All components and electric conductors fitted to the ASSEMBLY shall be certified as safe by means of valid RCC certificates in accordance with SANS 10313 or identified by an SABS 'Mark of Approved Performance'.

1.5.5 Each completed Earthing and Lightning Protection System shall be certified in terms of the requirements of SANS 10313 and this specification by a person who is competent to

express an opinion on the safety and functionality of the Earthing and Lightning Protection System (hereinafter referred to as the 'Competent Person').

1.6 ASSEMBLY DESIGN AND CONSTRUCTION COMPETENCIES

1.6.1 Tenderer shall be required to demonstrate their competency to interpret the requirements of SANS 62305-2 to perform a risk analysis by submitting such an analysis for the installation.

1.6.2 For substation earthing, the GPR (Ground Potential Rise) shall be determined in accordance with the requirements of IEEE-80.

1.6.3 A proposed layout of the Earthing System shall be submitted for approval.

1.7 PROJECT IMPLEMENTATION

1.7.1 The design, manufacture, installation and testing, of the earthing and/or lightning protection system shall include all necessary items to complete the installation.

1.7.2 The successful Tenderer shall be responsible for supply and transport and where specified for installation of the earthing and/or lightning protection system to final commissioning.

1.8 ENGINEERING DRAWINGS AND INFORMATION

1.8.1 All drawings, circuit or schematic diagrams prepared by or on behalf of the successful Tenderer for submission to the Employer's Engineer in terms of the requirements of the ADS and any revisions thereto, shall have been thoroughly checked, corrected where necessary and signed as approved by the successful Tenderer, prior to such submission.

1.8.2 The Employer's Engineer's approval of any drawings will be of a conceptual nature only. Such approval will not release the successful Tenderer from his responsibility for the proper operation of the installation or for its full compliance with the specification,

drawings, local authority and Statutory requirements, or for ensuring that the equipment can be physically accommodated within the space and via the access provided.

1.8.3 The following information must be included for approval:

a) General arrangement, dimensions, layout of all earth points, trenches etc.,
b) Types of cables and conductors used, compliance standards, etc.

1.9 OPERATING AND MAINTENANCE MANUALS

1.9.1 The Operating and Maintenance Manual shall comprise of a single document containing the following information:

a) All calculations and risk assessments,
b) Supplier of masts, name of company and contact address,
c) Technical data for all components,
d) Schedule of all engineering drawings,
e) Copies of all test certificates and commissioning data in terms of SANS 10313,
f) Annual maintenance procedures for the ETS and/or LPS.

1.9.2 One copy of each document and drawing shall be provided for the Employer's Engineer to check and comment if necessary, allowing sufficient time for review and re-issue before completion of works.

1.10 INSPECTION AND TESTING

1.10.1 Tests shall be performed by a person who is fully trained to perform such final inspections and routine tests in accordance with the requirements of SANS 10313-1 and the prescribed certificate shall be used (refer SANS 10313 Annex A).

1.10.2 A Competent Person appointed by the successful Tenderer shall inspect and routine test the completed ETS and or LPS.

1.10.3 The successful Tenderer shall timeously inform the Employer's Engineer in writing when the ETS and/or LPS shall be ready for inspection and test.

1.10.4 The test certificate as per SANS 10313 Annex A shall be used and duly completed and signed by the successful Tenderer.

1.11 SCHEDULE OF INFORMATION AND BILL OF QUANTITIES

1.11.1 Tenderers are to submit detailed information regarding their proposals. These proposals shall incorporate all detailed schematics, component brochures and proposed layouts and proposed schedule of manufacture.

1.11.2 A bill of quantities and schedule of information must be issued for each installation.

PART TWO - DESIGN OF A LIGHTNING PROTECTION SYSTEM (LPS)

2.1 PURPOSE OF THE LPS

2.1.1 The purpose of the Lightning Protection System is

a) To intercept a lightning flash with an Air Termination System (ATS)
b) To conduct the lightning current safely to earth with a Down Conductor System (DCS)
c) To disperse the lightning current safely into the earth with an Earth Termination System (ETS)

2.1.2 At completion of the design, installation and testing in terms of SANS 10313:2008 by the successful Tenderer of the ETS and / or the LPS will prevent the following sources of damage:

• S1	– Flashes to the structure.
• S2	– Flashes near to the structure.
• S3	– Flashes to the services connected to the structure.
• S4	– Flashes near the services connected to the structure.

2.1.3 The following types of damage are to be avoided after the ETS and or the LPS has been designed, installed and commissioned by the successful Tenderer in terms of the requirements of SANS 10313:

• D1	– Injury to living beings due to touch and step potentials.
• D2	– Physical damage (fire, explosion, mechanical destruction) due to lightning current effects including sparking.
• D3	– Failure of internal systems due to LEMP

2.2 PERFORMING THE RISK ANALYSIS

2.2.1 Prior to initiating design of an LPS or an ETS, Tenderers shall perform a risk assessment in terms of SANS 62305-2 and determine the risk of human life R_1 and the risk of

economic value R_4. The tolerable risk for loss of human life or permanent injuries R_T is assumed to be 10^{-5}.

2.2.2 Tenderers shall calculate the total risk R. If $R \leq R_T$ the Tenderer shall submit proposed protection measures. The cost effectiveness of the proposed protection measures shall be performed as per Fig 2 of SANS 62305-2 and the most suitable protection measure shall be proposed by the Tenderer (refer Table 9 of SANS 62305-2).

2.2.3 The nature of the earth termination system (ETS) will depend on whether the structure contains only electrical equipment (Type A) or whether electronic equipment is functional in the building (Type B). Tenders shall indicate which type of earthing arrangement their design is based on.

2.2.4 The ETS shall be designed in accordance with the requirements of SANS 62305-3.

2.2.5 Most recent ground flash densities to be obtained from the SAWS (South African Weather Service).

2.2.6 Air termination conductors shall be designed in accordance with SANS 62305-3 and the conductors shall be indicated on the building drawing.

2.2.7 Tenderer shall clearly indicate all parts of the ETS required in accordance with the ADS.

2.2.8 The size and lengths of bonding conductors shall be selected in accordance with SANS 62305-3 Table 1. and reported in the ADS.
Table 1 can be used by the Tenderer as a quick reference to the values used in the Lighting Risk Calculator. All correction factor tables are sourced from SANS 62305-2.

Program Section	Section Value	Table Reference SANS 62305-2
Structure Attributes	Risk of Fire or Physical Damage	Table C.4 Page 121
	Risk of Dangerous Discharge	Table B.2 Page 107
	Internal Wiring Type	Table B.5 Page 111
Environment	Ground Flash Density	Annex B from SANS 10313
	Environmental Factor	Table A.2 Page 97
	Service Line Density	Table A.5 Page 101
Service Lines	Service	Table A.3 Page 99
	Cable Type	Table D.1 Page 127
	Transformer at Structure	Table A.4 Page 101
Protection Measures	Efficiency of Building Protection	Table B.2 Page 107
	Fire Protection	Table C.3 Page 121
	Surge Protection at Point of Entry	Table B.2 Page 107
	Surge Protection on All Equipment	
Loss Categories		
Category 1 - Loss of Human Life	Special Hazard	Table C.5 Page 121
	Fire Damage Factor	Table C.7 Page 125
	Overvoltage Damage Factor	
Category 2 - Loss of Essential Services	Fire Damage Factor	Table C.6 Page 122
	Overvoltage Damage Factor	
Category 3 - Loss of Cultural Heritage	Fire Damage Factor	Table C.7 Page 125
Category 4 - Economic Loss	Fire Damage Factor	Table C.7 Page 125
	Overvoltage Damage Factor	
	Acceptable Risk of Economic Losses	Tenderer chooses best situation from given parameters
	Step & Touch Potential Damage Factors	Table J.3 Page 213
Overall Risk	Acceptable Risk (Ra)	Table 7 Page 59

Table 1: Lightning risk calculator factor sources.

2.3 ESTABLISH PROTECTION PARAMETERS

2.3.1 Tenderers shall ensure that full detail regarding the required levels of protection is defined and fully described prior to undertaking the risk assessment of the installation.

2.3.2 The following protection measures shall be considered by the Tenderer to reduce injury to persons due to touch and step voltages:

a) Adequate insulation of exposed conductive parts,
b) Equipotentialization by means of a meshed earthing system, and
c) Physical restrictions and warning labels.

2.3.3 The following protection measures shall be considered by the Tenderer to reduce failure of electrical and electronic systems:

a) Earthing and bonding of the installation,
b) Magnetic shielding,
c) Line routing, and
d) Coordinated surge protection device (SPD) protection.

2.3.4 Selection of the most suitable protection measures shall be the responsibility of the successful Tenderer according to the type and amount of each type of damage and to the technical and economic aspects of the different protection measure.

2.4 AIR TERMINATION SYSTEMS

2.4.1 Tenderers shall design the air termination system from one or more of the following components:

a) free-standing masts,
b) catenary wires,
c) meshed wires.

2.4.2 The air termination system shall be positioned according to SANS 62305-3, with the methods specified and the surfaces on which the ATS is to be positioned.

2.4.3 The tenderer shall take into account the height of the structure when designing the air termination system for flashes to the side of the structure, and shall incorporate the required air termination components into the design.

2.4.4 Air termination components not isolated from the structure shall be installed by the method determined by the roof and structure material type as specified in SANS 62305-3.

2.4.5 The tenderer should consider structural metal components, from the structure to be protected, as possible natural air terminators in accordance with SANS 62305-3.

2.5 DOWN CONDUCTOR SYSTEMS

2.5.1 Tenderers shall ensure that the down conductors are arranged in a specific way in accordance with SANS 62305-3.

2.5.2 A single down conductor shall be needed at each supporting structure for an isolated LPS when the air termination system:

a) Consists of separate mats not constructed from steel and/or interconnected reinforcing steel,
b) Consists of catenary wires,
c) Forms a network of conductors

2.5.3 More than one down conductor shall be used in non isolated LPS systems and spacing of the conductors shall be in accordance with SANS 62305-3.

2.5.4 Tenderers shall consider the following parts of the structure as natural down conductors:

a) Metal installations in accordance with SANS 62305-3,

Concrete reinforcing shall NOT be used as a natural downconductor. A dedicated galvanised cable shall be installed within the columns secured with suitable clamps and flush fittings.

b) Interconnected steel framework,

c) Facade elements, profile rails and metallic sub-constructions of facade in accordance with SANS 62305-3.

2.5.5 A test point shall be fitted on each down conductor at the earth termination connection, in the case of natural down conductors the test points shall be combined with foundation earth electrodes.

2.6 EARTH TERMINATION SYSTEMS FOR STRUCTURES

2.6.1 Tenderers shall install a single integrated structure earth termination system

2.6.2 Tenderers shall offer either a type A or a type B arrangement:

a) The number of earth electrodes for type A arrangement shall be more than two,

b) The number of earth electrodes in a type B arrangement shall be equal but not less than the number of down conductors,

c) Electrodes are connected to ring earth electrode at points where down conductors are connected,

d) Construction of earth electrodes are in accordance with SANS 62305-3.

2.6.3 Tenderers shall ensure the installation of the earth electrodes are in accordance with SANS 62305-3.

2.6.4 Interconnected reinforcing steel or other suitable underground structures shall be used as a natural earth electrode.

2.6.5 The successful Tenderer shall take preventive measures for mechanical splitting of concrete when using the metallic reinforcement in concrete.

2.7 EARTH TERMNATION SYSTEMS FOR SUBSTATIONS

2.7.1 The earth termination system for substation shall be designed in accordance with IEEE-80 incorporating the following steps:

a) The field data, including the soil resistivity shall be taken into account.
b) The size of the conductor shall be
c) Step and touch voltage criteria shall be calculated.
d) A preliminary design for the entire area shall be performed.
e) Initially estimated grid resistances for the preliminary grounding system shall be determined, but for the final design, a complete computer analysis shall be necessary.
f) The design shall take the grid current into account as to not over design the system.
g) If the touch voltage criteria can be met, the design is complete. Alternatively, the following additional steps shall be taken for the design:
   - The mesh and step voltages shall be determined.
   - If the mesh voltage is larger than the touch voltage the design shall be modified, if not the design is complete.
   - If the calculated step voltage is smaller than criteria the design is completed, if not, the design shall be modified.
h) For the cases where the mesh and step voltages are larger than the criteria, the design shall be modified.
i) When the touch and step criteria are met, additional grounding shall be included in accordance with SANS 725.

2.7.2 The preliminary design shall be expanded if the possibility of dangerous potential differences may exist by consideration of the following:

a) Reduction in ground resistance,
b) Alteration in grid spacing,
c) Diversion of the fault current,
d) Placing a limit on the fault current,

e) Controlling access to the area.

2.8 LIGHTNING PROTECTION SYSTEMS FOR EXPLOSIVE INSTALLATIONS

2.8.1 In the case of explosives present in the structure to be protected, Tenderers shall ensure when the Type A or B arrangement is selected that the earth resistance is less than 10 Ω according to 5.4.2.2 of SANS 62305-3.

2.8.2 The Tenderer shall ensure that the distance between the storage place of explosives and installation of the LPS is a minimum of 1 m or greater if determined so from SANS 62305-3.

2.8.3 When the reduction factor, r_f, efd is used for risk evaluation, the successful Tenderer shall accurately determine this factor (see Annex C, SANS 62305-2).

2.8.4 The successful Tenderer shall not utilise piping carrying explosive material for natural components in the earth down conductor system according to SANS 62305-3.

2.8.5 The sensitivity of the explosive material contained in the structure shall be taken into account by the Tenderer in the design of the LPS according to Annex D.4, SANS 62305-3.

2.8.6 When explosive material is stored in underground structures an additional LPS shall be required such as an isolated LPS with the earth termination systems connected as in E.5.2.4.2.8 in SANS 62305-3.

2.8.7 The requirements of SANS 10313:2008 shall apply when LPS installations for explosives installations are designed.

PART THREE - INSTALLATION REQUIREMENTS

3.1 PROTECTION AGAINST LIGHTNING FOR INTERNAL INSTALLATIONS

3.1.1 An earth termination system comprising a bonding network shall be installed by the successful Tenderer.

3.1.2 External metal parts and incoming services shall be electrically bonded by the successful Tenderer.

3.1.3 The internal earthing system shall be incorporated into the bonding system of the complete ETS.

3.1.4 An external down conductor system (DCS) shall be required if the resistance of the reinforcing steel over the full distance is higher than 0.2 Ω.

3.1.5 Requirements for a coordinated SPD design shall be determined by the Employer's Engineer.

3.2 EARTH TERMINATION SYSTEM COMPONENTS

3.2.1 Bare copper conductors are buried in trenches of not less than 500 mm below finished ground level.

3.2.2 Earth rods shall be driven into undisturbed soil using special impact-resisting steel driving pipe or mechanical hammer.

3.2.3 Earth rods shall be spaced a minimum of 1 000 mm from the structure and the top of the rod shall be not less than 300 mm below finished ground level.

3.2.4 Joints and terminations of copper and copper-clad steel conductors shall be performed with mechanical clamps.