CODE OF PRACTICE 001

FOR

CUSTOMER SUBSTATION DESIGN

Version 1.0

Issued by: Transmission and Distribution Department

Date of Issue: 01 September 2022

1. Introduction

This Code of Practice details the principles to be applied to the civil design and construction of customer substations located at ground floor, first floor, special high level of buildings and at outdoor areas. For buildings with special requirements, other locations for customer substations may be adopted, if approved by CEM on a case-by-case basis.

2. Objectives

The objectives of this Code of Practice are to ensure that all customer substations provided by the customers are designed and constructed to the same standard, and fully comply with the statutory requirements of MSAR Government legislation and those requirements of Companhia de Electricidade de Macau (CEM).

The requirements in this Code of Practice may be changed as new equipment is made available, new techniques developed or because of new requirements from CEM or MSAR Government.

3. Main Considerations

The following items must be taken into consideration when designing a customer substation:

3.1. Customer substation shall be planned to have in mind the future loading and development of the area.

3.2. Many of the requirements are associated with the safety of the operational personnel, public and equipment. Always put 'SAFETY FIRST'.

3.3. A preliminary load estimation proposal shall be prepared so that the number and type of equipment to be accommodated can be determined.

3.4. Personnel access and equipment access (including power cables) shall be considered.

3.5. Adequate drawings and information from the customer or architect for the intended purpose and function of the buildings: e.g., site layout plan, ground floor, upper floors and basement plan, structural plans etc. shall be obtained

4. Design Criteria

Customer substation must be designed and built to comply with the criteria listed in this section. Customer substation equipped with two transformers, located at ground floor, must use non-flammable silicone fluid filled transformers or equivalent as a standard to avoid the installation of a fixed fire extinguishing system.

4.1. General

4.1.1. Customer substation need to be located at the periphery of the building, being readily accessible from non-covered and unrestricted public road, fully accessible to CEM and satisfy the requirement specified in Section 4.1.2 and 4.1.3.

4.1.2. Customer substation shall have proper access for CEM's personnel and equipment at all time. The access to the customer substation shall be of adequate height, width, gradient and of enough strength to withstand the combined weight of the transformer and the conveying vehicle.

4.1.3. The access to the customer substation shall be at least 3 m wide and 4 m high and the area in front of the customer substation should have a minimum height of 4.5 m for loading and unloading of equipment. In case the customer substation periphery is covered by a building canopy, the direct distance from the entry of the substation to the non-covered area should not be more than 2.5 m.

4.1.4. The minimum clear headroom of the customer substation shall be 4m.

4.1.5. For customer substation equipped with retractable lifting beam and hoist for the transportation of CEM equipment, the minimum clear headroom of the customer substation shall be 4.5m.

4.1.6. The optimal location of the customer's main switch room should be immediately adjacent to the customer substation.

4.1.7. In case the customer's main switch room cannot be adjacent to the customer substation, the customer must build a cable duct or cable tray running in common areas inside the building to connect the customer substation and the customer's main switch room.

4.1.8. The customer substation shall be of suitable waterproof construction to prevent water leakage into the customer substation.

4.1.9. A suitable waterproofing layer with appropriate protection shall be applied to the inner concrete surface of cable trenches by the customer. For the requirement of the waterproofing layer, see drawing E-565. The design drawings of the waterproofing layer should be submitted to CEM for review and approval.

4.1.10. In case the customer substation and manholes are located above basement, design consideration and measures (such as using of waterproof concrete, waterproofing layer application and drainage installation, etc.) must be taken to prevent water ingress to the substation as well as to prevent leakage into the basement.

4.1.11. Manholes which are located inside of development boundary shall be designed such that water can flow out of the manholes naturally to the terminal manhole outside the development boundary or can be drained out through drainage pipes to the public drainage system.

4.1.12. Where necessary, drainage points connecting to drainage system shall be provided at manholes for discharge of water out of the manholes.

4.1.13. No water pipes, drainage pipes or any kind of installations by customer shall be inside of or pass through any part of the customer substation.

4.1.14. No expansion joint shall be installed in any part of the customer substation.

4.1.15. Adequate and permanent ventilation to open air, completely segregated from the main building, must be provided.

4.1.16. The floor level of the customer substation shall normally be **150 mm** higher than the outside (pavement, access road) level to minimize the risk of water ingress into the customer substation due to flash flooding.

4.1.17. For new customer substations located in low-lying areas exposed to storm surge, all CEM equipment shall be installed at an elevation above +4.21 mSL (meter above mean sea level) unless otherwise approved by CEM. “Black Storm Surge” map provided by MSAR Government – Cartography and Cadastre Bureau should be referred to for the boundary of low-lying areas affected by storm surge.

4.1.18. The openings for cable inlet and outlet (distribution network manholes and customer side) shall be properly sealed by the customer to prevent water ingress into the customer substation and be of two hours fire resistance period (FRP) construction.

4.1.19. Neither exceed 3200 kVA for total capacity installation nor more than 2 oil-type transformers shall be accommodated within any room or enclosure.

4.1.20. Typical customer substation layouts shall be used wherever possible. Drawings C-096 and C-097 show typical layouts for housing 1 and 2 transformers together with the associated MV panels / Ring Main Unit for ground level customer substation.

4.1.21. Unless otherwise approved by CEM, the substation walls, ceiling and floor shall be made of reinforced concrete with a design strength class of B30 (28 days compressive cube strength of 30 MPa) or above.

4.1.22. Substation walls and ceiling shall be cement and sand plastered and finished with one coat of liquid prepolymer sealing and three finishing coats of white color acrylic resin-based coating in matt finish.

4.1.23. Substation floor shall be cement and sand rendered and applied with carborundum and red dan powder to enhance floor durability and better slip resistance.

4.1.24. For substation areas exposing to potential risk of falling, adequate fencing, cover or other suitable measures should be provided by the customer.

4.1.25. A 'DANGER' sign together with the customer substation nameplate with CEM logo, substation identification number and substation name are to be fixed to the customer substation door. The nameplate will be supplied by CEM and installed by customer.

4.1.26. Adjacent occupancies and adjoining hazards must be considered, particularly in respect to avoiding, as far as possible, "wet" environments above the customer substation – water tanks, kitchens, toilets, and the like; otherwise, double slab ceiling with waterproofing construction or equivalent water proofing solutions must be provided.

4.1.27. No storage of transformer or switchgear insulant is allowed in the transformer room or customer's main switch room.

4.1.28. All external steelwork shall be stainless steel of the low carbon type AISI 316L (equivalent to BS 970-316 S12). Appendix B gives details. This specification applies to doors, door's frames, louvers, rat guards, i.e., all steelwork exposed to open air. Welding for stainless steel should only by inert gas arc welding to BS7475.

4.1.29. Internal steelwork (air trunk, hangers, chequer plate, etc.), except the stainless-steel hanging rod for air duct, shall be hot dip galvanized to BS729 and finished with one coat of calcium plumbate or zinc phosphate primer and two finishing coats of grey synthetic paint. No welding and cutting would be allowed after the steelwork is being hot dip galvanized.

4.1.30. After casting the concrete, timber formwork should be totally removed from the customer substation and manholes to avoid breeding of organisms.

4.1.31. For laying of temporary supply cable from the customer substation, 3 x 150mm uPVC pipes shall be installed at high level on the perimeter wall of the customer substation. The openings shall be sealed by customer using removable plugs with sealing gasket according to drawing E-561.

4.1.32. When floor level changes, black/yellow color stripes shall be painted on the edge/step.

4.1.33. When a stair is necessary to access the customer substation, hand railing shall be installed along the stair and the front edge of the stair step shall be painted by durable yellow color reflective paint.

4.1.34. No external decorative louver should be installed, affixed or attached outside the customer substation, unless under special circumstances to be approved by CEM on a case-by-case basis. Furthermore, the customer shall be the owner of the external decorative louver and bear the maintenance responsibility.

4.1.35. Normally, cables pass between customer substation and customer's main switch room by cable ladder (refer to drawing E-515). Alternatively through cable trench inside of customer substation. Customer's main switch room should be designed to suit this arrangement. Minimum bending radius of cables must be satisfied.

4.2. Layout

4.2.1. General

4.2.1.1. The typical customer substation layouts presented in this handbook should be used whenever possible. If special requirements are necessary, other layouts can be adopted with approval by CEM in advance.

4.2.1.2. The typical architectural layout plans shown in this handbook represent only the functional requirements. The customer is encouraged to introduce adequate architectural design to harmonize the customer substation structure with the rest of the development.

4.2.1.3. To avoid or minimize civil works in customer substation that are in service, the layout shall be designed to be adequate for the lifetime of the customer substation and is subjected to the equipment being used. Such layout should take in consideration additional electrical equipment when necessary.

4.2.1.4. Access shall always be provided for the erection and removal of equipment.

4.2.1.5. The battery charger unit, remote terminal unit RTU, fiber optic marshalling box and service auxiliary board shall be wall mounted.

4.2.1.6. Adequate operating area must be provided for both MV and LV control equipment; a minimum of 1.2 m shall be provided in front of the operation side of the equipment.

4.2.1.7. Adequate working area must be provided; normally 750 mm clearance between different equipment must be allowed in the design of customer substation.

4.2.1.8. The clearance between transformer and any MV panel / RMU shall be a minimum of 750 mm. The clearance between transformer and any wall shall be not less than 600 mm to ensure good circulation of cooling air around the transformer cooling panels/ fins.

4.2.1.9. A low voltage cable trench shall be provided wherever possible.

4.2.1.10. Where possible the air intake associated with the transformer should be positioned such that the wire mesh at the intake mouth can be cleaned with the transformer energized, without endangering the person carrying out the work. Proper and adequate ventilation must remain as objective and no design that “short circuits” the airflow should be considered.

4.2.2. MV Equipment (MV Panel or Ring Main Unit)

4.2.2.1. The space allocated for 11 kV equipment shall be in accordance with the total demand required for each project. The associated trench shall be designed for MV panels / Ring Main Unit compatible (RMU) as far as possible for single transformer installation.

4.2.2.2. The separation between the rear of the 11 kV equipment and the substation wall shall be a minimum of 300 mm for RMU and 300 mm for MV panels.

4.2.2.3. A minimum clearance of 500 mm shall be provided when the Q.G.B.T. is placed beside the RMU.

4.2.3. Q.G.B.T.

4.2.3.1. The Q.G.B.T. will be secured on the floor against the substation wall. A minimum distance of 300 mm between the LV trench and the customer substation wall is required.

4.2.4. Transformer

4.2.4.1. The space allocated for any transformer shall be capable of accommodating the largest size of transformer that is L = 2500 mm, W = 1400 mm, H = 2600 mm.

4.2.4.2. The separation between the support for LV cable and the facing substation wall shall be a minimum of 800 mm.

4.2.4.3. The separation between the support for MV cable and the facing substation wall shall be a minimum of 700 mm.

4.3. Requirements for First Floor Customers Substations (maximum 5m above ground level)

The following specific requirements must be satisfied:

4.3.1. First floor customer substation should be located at the periphery of the building and should be accessible any time by CEM staff by a separate and independent staircase directly from the public road. The vertical distance between the floor level of substation and ground level of the equipment loading and unloading area shall not be greater than 5m unless otherwise approved by CEM.

4.3.2. The access and exit route of the first-floor customer substation shall always lead to the ground level of the building. Lockable door or gate along the route is not permitted unless otherwise approved by CEM.

4.3.3. Direct vehicular access to the customer substation must be provided from the public road. The access to the customer substation shall be at least 3m wide and 4m high and the area in front of the customer substation equipment access door shall be clear from the ground to the first-floor access door for loading and unloading of equipment.

4.3.4. The loading and unloading area for the delivery of equipment in or out of the substation should be within the development or building area where it is owned or managed by the customer. Using the public pavement or road outside the substation as loading and unloading area can be accepted on a case-by-case basis, subject to the review and approval by CEM.

4.3.5. Adequate exit signage and emergency lights shall be provided along the corridor/staircase and should operate for not less than two hours. For signage and lights installed inside the customer substation, the batteries should be charged from the customer substation auxiliary services board.

4.3.6. Clear signage plate shall be provided by customer to indicate the locations of the substation and the cable riser(s) when deemed necessary by CEM. The template of the signage plate shall be agreed with CEM.

4.3.7. Considering higher fire safety standards, special types of transformers such as dry-type or SF_6 gas insulated must be used.

4.3.8. If possible, multiple customer substations on the same floor should be in close proximity to use only one separate and independent staircase instead of one staircase for each customer substation.

4.3.9. The capacity of all structural elements shall be adequate to support the operational weight of the customer substation equipment, the related operational activities and hoisting loads.

4.3.10. When the access route, including the staircase, from the exit of the customer substation to the public road is longer than 10m, mechanical ventilation with manual control shall be provided by the developer, according with CEM specifications following a case-by-case study. For mechanical ventilation system installed in common areas, the power supply of the ventilation system should be provided by the customer.

4.3.11. Independent enclosed cable riser(s) with associated manhole(s) must be built and maintained by the customer, together with working platforms to facilitate cable installation and connection to the first-floor customer substation. All access door(s) and opening cover(s) of the independent enclosed cable riser shall be of 2-hour FRP. Inside the cable riser, opening of the floor and ceiling slab shall be provided for installation of cables.

4.3.12. The design of the cable riser(s) will be provided by CEM according to the power demand, location of the customer substation and building layout. The associated manhole(s) shall be located at ground level inside the boundary of the development and shall be adjacent to the terminal manhole outside the boundary to allow cable connection between the two manholes.

4.3.13. The cable riser and the associated manhole shall be readily accessible by CEM staff for operation purposes.

4.3.14. A retractable lifting beam, together with a manual or electrical hoist for lifting minimum 7500kg shall be provided and maintained by the customer. The design drawings and calculation of the retractable lifting beam and hoist must be submitted to CEM for review and approval.

4.3.15. The use of non-retractable lifting beam is generally not permitted unless the entire hoisting system is installed within the site boundary of the development. The design drawings and calculation of the non-retractable lifting beam and hoist must be submitted to CEM for review and approval.

4.3.16. As a general requirement for the lifting beam and hoist, the proposed lifting system shall be designed to transport the largest transformer specified under Section 4.2.4.1. Unless otherwise approved by CEM, the clear height of the hoist lifting hook to the substation floor shall be minimum 3.6 m and the clear distance between the hoist lifting hook (after full extension of the retractable beam) and the substation wall shall be minimum 1.5 m.

4.3.17. Appropriate safe load test certificate by an accredited testing laboratory must be submitted to CEM before the loading and unloading of equipment.

4.3.18. The Operation and Maintenance (O&M) Manual for the lifting beam and hoist must be displayed inside the customer substation and submitted to CEM before the loading and unloading of equipment.

4.3.19. The minimum clear headroom requirement for first floor customer substation equipped with retractable lifting beam and hoist should refer to Section 4.1.5.

4.3.20. For circumstance where the front of the customer substation can be freely accessed by vehicle and have sufficient space to park, transport, lift and remove the equipment using the lifting device mounted on conveying vehicle. The retractable lifting beam and hoist can be omitted on a case-by-case basis, subject to the review and approval by CEM. The minimum clear headroom requirement for first floor customer substation without retractable lifting beam and hoist should refer to Section 4.1.4.

4.3.21. For circumstance where a lift in the public area inside the building is provided for operational and maintenance purposes, the retractable lifting beam and hoist can be omitted on a case-by-case basis, subject to the review and approval by CEM. The minimum clear headroom requirement for first floor customer substation without retractable lifting beam and hoist should refer to Section 4.1.4. As a general requirement, the lift in the building shall be capable to carry the heaviest equipment and the largest equipment in the substation. The loading capacity, power supply (normal and backup supply) and other details of the lift should be further submitted to CEM for review and approval.

4.3.22. Building façade design must not affect the ventilation of the customer substation, must not obstruct the substation door and must not block the lifting path for loading and unloading of equipment.

4.3.23. For buildings with arcade where the distance between the entrance of the transformer room and the public road is more than 2.5 m, a service platform capable of supporting a weight of 7.5 tons should be installed for loading and unloading equipment.

4.3.24. For substation areas exposing to potential risk of falling, adequate fencing, cover or other suitable measures should be provided by the customer. For areas where provision of fencing or cover is not suitable, anchor point(s) for fastening of independent lifeline should be provided by the customer at the ceiling or walls of transformer room for the installation of personnel fall protection equipment. See drawing F-071 for the typical requirement of the anchor point.

4.3.25. For area near the double leaf door used for loading and unloading of equipment, a working zone shall be designated and painted with anti-slip material in yellow/black color stripes. The minimum length of the working zone shall be the same as the customer substation door or lifting area and the minimum width shall be 1000 mm (see drawing F-071).

4.3.26. Additional specific requirements may be necessary on a case-by-case basis.

4.4. Requirements for high level Customers Substations (above 5m above ground level)

4.4.1. Equipment access shall be by a lift in the public area inside the building. The lift in the building shall be capable to carry the heaviest equipment (at least 7500Kg) in the substation such as transformer. The entrance from the public road to the lift should have enough space for the In and Out of the transformer (at least Wide = 2000 mm, H = 3000 mm). This lift shall be able to change - over to the essential supply of the building when its normal supply fails. The lift designer should coordinate with CEM on the loading requirement of the lift. The loading capacity, power supply (normal and backup supply) and other details of the lift should be further submitted to CEM for review and approval.

An individual switch should be equipped at the ground floor to shut down the transformer for emergency and RMU.

4.4.2. Subjected to the configuration of the 11kV supply network, provision of a 11kV switch room(s) on ground level will be required as a switching along the route shall be avoided.

4.4.3. Adequate exit signage and emergency lights shall be provided along the corridor/staircase and should operate for not less than two hours. For signage and lights installed inside the customer substation, the batteries should be charged from the customer substation auxiliary services board.

4.4.4. Clear signage plate shall be provided by customer to indicate the locations of the substation and the cable riser(s) when deemed necessary by CEM. The template of the signage plate shall be agreed with CEM.

4.4.5. Considering higher fire safety standards, special types of transformers such as dry-type or SF_6 gas insulated must be used.

4.4.6. If possible, multiple customer substations on the same floor should be in close proximity to use only one separate and independent staircase instead of one staircase for each customer substation.

4.4.7. The capacity of all structural elements shall be adequate to support the operational weight of the customer substation equipment, the related operational activities and hoisting loads.

4.4.8. When the access route, including the staircase, from the exit of the customer substation to the public road is longer than 10m, mechanical ventilation with manual control shall be provided by the developer, according with CEM specifications following a case-by-case study. For mechanical ventilation system installed in common areas, the power supply of the ventilation system should be provided by the customer.

4.4.9. Independent enclosed cable riser(s) with associated manhole(s) must be built and maintained by the customer, together with working platforms to facilitate cable installation and connection to the high-level substation. All access door(s) and opening cover(s) of the independent enclosed cable riser shall be of 2-hour FRP. Inside the cable riser, opening of the floor and ceiling slab shall be provided for installation of cables.

4.4.10. The design of the cable riser(s) will be provided by CEM according to the power demand, location of the customer substation and building layout. The associated manhole(s) shall be located at ground level inside the boundary of the development and shall be adjacent to the terminal manhole outside the boundary to allow cable connection between the two manholes.

4.4.11. The cable riser and the associated manhole shall be readily accessible by CEM staff for operation purposes.

4.4.12. Appropriate safe load test certificate by an accredited testing laboratory must be submitted to CEM before the loading and unloading of equipment.

4.4.13. Building façade design must not affect the ventilation of the customer substation, must not obstruct the substation door and must not block the lifting path for loading and unloading of equipment.

4.4.14. For buildings with arcade where the distance between the entrance of the transformer room and the public road is more than 2.5 m, a service platform capable of supporting a weight of 7.5 tons should be installed for loading and unloading equipment.

4.4.15. For substation areas exposing to potential risk of falling, adequate fencing, cover or other suitable measures should be provided by the customer. For areas where provision of fencing or cover is not suitable, anchor point(s) for fastening of independent lifeline should be provided by the customer at the ceiling or walls of transformer room for the installation of personnel fall protection equipment. See drawing F-071 for the typical requirement of the anchor point.

4.4.16. For area near the double leaf door used for loading and unloading of equipment, a working zone shall be designated and painted with anti-slip material in yellow/black color stripes. The minimum length of the working zone shall be the same as the customer substation door or lifting area and the minimum width shall be 1000 mm (see drawing F-071).

4.4.17. Additional specific requirements may be necessary on a case-by-case basis.

4.5. Requirements for Outdoor Customer Substation

4.5.1. Stand-Alone

4.5.1.1. To avoid water leakage / seepage into the substation from the ceiling, double slab ceiling with waterproofing construction with slope of 2 degrees and/or drainage system shall be constructed by the customer. The design drawings and design specification of the double slab ceiling, drainage and ceiling waterproofing must be submitted to CEM for review and approval.

4.5.1.2. Decorative structure or any add-on material applied on the ceiling surface of the customer substation will not be allowed.

4.5.2. Stand-Alone for temporary construction

4.5.2.1. All external steelwork shall be hot dip galvanized to BS729 and finished with one coat of calcium plumbate or zinc phosphate primer and two finishing coats of grey synthetic paint. No welding and cutting would be allowed after the steelwork is being hot dip galvanized. This requirement includes doors, door's frames, louvers, rat guards, i.e., all steelwork exposed to open air.

4.5.3. Outdoor Compact Substation (Monoblock)

4.5.3.1. Outdoor compact substation (Monoblock) should be installed for temporary construction sites.

4.5.3.2. The dimension and details for the foundation of the monoblock as well as the surrounding area should follow CEM specifications. The typical arrangement is shown in C-101 for reference.

4.6. Foundations

4.6.1. The transformer foundation shall be capable of withstanding a minimum load of 7000 kg. The minimum loading of the passage for delivery of the transformer shall be enough to support the transformer weight.

4.6.2. The dimensions for the transformer plinth would be 2.35 m × 1.55 m for customer substation housing one transformer (see drawing C-096) and 2.55 m × 1.45 m for customer substation housing two transformers (see drawing C-097) and leveled with finished floor level.

4.6.3. Normally, the transformer is supported by four steel wheels which stand on two metallic frames in form of U-channels on the transformer foundation plinth. The plinth strength and the U-channels, to be installed by the customer, shall be calculated to support the pressure of the transformer wheels.

4.6.4. The 11 kV equipment foundations shall be capable of withstanding a Dead Load of 600 kg per RMU and 300 kg per panel and an Impulse Load of 750 kg per RMU and 400 kg per panel. The floor surface shall be smoothed and leveled.

4.6.5. The minimum dimensions for the 11kV equipment base shall be 675 mm × 1375 mm for type A RMU, 675 mm × 1910 mm for type B RMU, 750 mm × 820 mm for GBC-B panel and 375 mm × 820 mm for each IM or QM panel.

4.7. Cable Trench and cable tray

The cross-section area of cable trenches shall not be reduced by ground beams or other civil structures. If there are ground beams at the boundary of a customer substation, the clearance under the beams shall be 500 mm minimum. The cables of different level of voltage should be installed in different cable trenches. An appropriate sump pit shall be built at the lowest level of the trench to allow the installation of a sump pump. Suitable waterproofing layer with appropriate protection shall be installed according to the requirement specified in Section 4.1.9.

4.7.1. MV Cable Trenches

4.7.1.1. All MV cable trenches shall be generally 800 mm deep and:

4.7.1.2. 800 mm wide for MV panels or ring main unit compatible,

4.7.1.3. 450 mm wide for 11 kV cables from MV equipment to transformers; the final section leading to the transformer MV terminal can be 300 mm wide.

4.7.2. LV Cable Trenches

4.7.2.1. LV cable trenches shall be generally 1000 mm wide × 800 mm deep.

4.7.2.2. Trench for LV single core cables from the transformer to the

Q.G.B.T. shall be 800 mm wide × 800 mm deep.

4.7.2.3. LV single core cables from transformer to customer's main switch room shall be used cable tray and the minimum height shall be 1.5 m about ground. The maximum length of this section cannot be more than 30 m.

4.7.3. Cable Trench Construction

All cable trenches shall be covered with 5 mm thick hot dip galvanized plates, built according to drawing E-105.

4.7.4. Cable Trench Outlet and cable tray Outlet

4.7.4.1. The connection between the cable trench and customer substation exterior are through uPVC pipe. The invert level of the trench outlet to be 850 mm minimum for MV cable trench and 650 mm minimum for LV cable trenches below the pavement level.

4.7.4.2. To avoid water leakage / seepage into the substation from the cable trench. All the trench outlet between inside and outside should keep the slope of 22.5 degrees.

4.7.4.3. The typical cable trench outlet for MV cable required 4 × 150 mm uPVC pipes, but additional uPVC pipes might be required to accommodate additional cables.

4.7.4.4. The typical cable trench outlet for fiber optic required 2 × 70 mm uPVC pipes.

4.7.4.5. The typical cable trench outlet for normal LV cable required 12 × 150 mm uPVC pipes for each transformer.

4.7.4.6. The typical cable tray outlet to the customer's main switch room required 800 mm x 400 mm for each transformer.

4.7.4.7. The minimum separation between each uPVC pipes must be 80 mm.

4.7.4.8. For the installation of uPVC pipes for trench outlet, it is forbidden to install the required uPVC pipes until the substation walls are fully constructed and reached the design strength specified under Section 4.1.21. Therefore, the uPVC pipes should not be installed during concrete casting stage and wall openings between the cable trench, customer's main switch room and customer substation exterior must be provided. The wall openings shall be constructed and sealed using non-shrink grout and water stop according to drawing E-566.

4.7.4.9. Referring to Section 4.1.18, all cable openings shall be sealed by customer according to drawing E-105. The sealant used to seal the trench outlets must be specified and approved by CEM. BASF STYRODUR 3035S + expandable PU foam or equivalent products can be used as sealant to prevent water ingress; Hilti CP670 fire stop coating or equivalent products can be used as fire resistance sealant.

4.8. Earth System

4.8.1. For every installation, the customer is required to provide its own earthing system by which the exposed conductive parts of the installation are connected to earth.

4.8.2. Where the supply is taken directly from a transformer or via underground cable, a bonding conductor may be allowed between customer's main earthing terminal and CEM power transformer earth or the metallic sheaths of LV supply cable to minimize the rise of potential between CEM and customer installation exposed conductive parts.

4.8.3. In each customer substation it will be installed one earth bar terminal (provided with test link) connected to the main earthing system of the building. The minimum size of the earthing conductor should be 95 mm^2 copper cable or 25 × 3 mm^2 copper tape.

4.8.4. The overall earth resistance shall be lower than 10 ohm.

4.8.5. The typical arrangement of the earthing system is shown in Appendix D.

4.8.6. At least three earthing pits (earth electrode) should be installed for each customer substation. Earthing pit can be either exterior or interior or a combination of both to obtain the best earthing resistance value (see drawing G-023).

4.8.7. The spacing between earth electrodes should not be less than the length of the electrode under the soil in any circumstance and should be as large as possible.

4.8.8. The optimum resistance value for each earth electrode inside each earth pit is 10 ohm or below. The main earth terminal of customer substation should also be 10 ohm or below. Measurement condition is 10 days after dried weather conditions.

4.8.9. Earth electrodes must be installed in such a way that their resistance does not exceed the required value under climatic conditions such as soil drying or freezing or from corrosion, etc.

4.8.10. The earth electrode in each earth pit should be connected to the earthing conductor through a copper clamp that can be disconnected when testing the earth electrode. Warning notice for earthing connection is necessary.

4.8.11. The diameter of copper rod (earth electrode) is 15 mm and its minimum length is 2 meters.

4.8.12. Using chemicals like salt and other corrosive materials to improve the earth resistance is forbidden. Salt, which can be drained away easily, would cause the earth resistance to rise later. Corrosive chemicals that corrode the earth electrode would eventually reduce the reliability of the earth system and shorten the life of the earth system.

4.8.13. Earth system checking and measurement declaration must be signed by CEM Electrical Engineer and must be included in the civil customer substation works acceptance.

4.8.14. All exposed conductive parts must be bonded to the earth bar, equal potential bonding conductor shall have a cross-sectional area not less than 16 mm^2.

4.8.15. Transformer neutral point should connect to the main earth bar directly with copper bar and the distance should be as short as possible.

4.8.16. Every joint in the earth system of the customer substation must be properly done by using copper bolt / brass bolt / cad weld.

4.8.17. Only copper or better conductive material can be used for earth system.

4.9. Doors

All customer substation doors shall open outwards into an unobstructed space with 110^{o} swing and shall be of stainless-steel construction. For doors where it is necessary that their integrity is resistant to fire for at least two hours, they must follow the requirements defined by Fire Services Regulations.

4.9.1. Type of Door

4.9.1.1. For customer substation located at ground floor, double leaf door shall normally be 1800 mm wide × 2800 mm high for transformer, MV equipment and Q.G.B.T. access and for personnel access when customer substation has only one door for equipment and personnel access. For customer substation located on the first floor, the door size shall be confirmed by CEM on a case-by-case basis. See drawing D-349, D-350 and D-351 for the typical details of double leaf door.

4.9.1.2. For customer substation located at ground floor, single leaf door 1000 mm wide × 2170 mm high shall be provided for personnel access and exit when necessary. For customer substation located on the first floor, the door size shall be confirmed by CEM on a case-by-case basis. See drawing D-233 and D-234 for the typical details of single leaf door.

4.10. Ventilation

4.10.1. Indoor substations housing transformers shall be sufficiently well ventilated with a fixed ventilation system to cope with the total heat dissipated at full load, with a margin to provide for cyclic overloads.

4.10.2. The minimum height of the ventilation outlet to free air shall be 2.15 m above ground level.

4.10.3. Inlet louver area shall be a minimum of 1.1 m^2 for each transformer.

4.10.4. Exhaust fan, ventilation duct and outlet louver assembly shall normally be installed according to drawing D-326.

4.10.5. One exhaust fan and associated ventilation duct shall be provided for each transformer. The exhaust fans shall be provided by CEM to customer.

4.10.6. The exhaust fan should be controlled by temperature monitoring devices to avoid unnecessary operations.

4.10.7. The ventilation trunk shall be constructed with the minimum of bends and in such a way as to efficiently remove hot air directly from above each transformer.

4.10.8. The inlet louvers and extraction duct shall be designed to ensure the passage of cooling air "through" the transformer and eliminate any possible 'short circuit' of the airflow.

4.11. Vermin Proofing

4.11.1. To avoid problems of hygiene, corrosion and risk of equipment damaged by vermin, the customer must provide adequate vermin proofing measures including but not limited to the followings: -

- Sealing of cable trench openings, cable riser openings and temporary supply cable openings.
- Sealing of cable ducts between customer substation and customer's main switch room.
- Provide rat guards (net) at ventilation louvers.
- Provide rodent barrier of appropriate height.

4.12. Customer's Main Switch room

The foundation level of the customer's main switch room must follow CEM requirements. Normally, the foundation level of the customer´s main switch room is the same as the foundation level of the customer substation. For details refer to Appendix A.

5. Provision and Installation of Customer Substation Buildings & Accessories

The developer/constructor/customers are responsible for providing all the necessary material and the civil construction works of the customer substation (including terminal manholes and earth pits as shown on CEM drawings). They also need to provide a one-year civil construction guarantee to CEM against any defect in the customer substation after they receive the taking over certificate from CEM.

CEM shall not be held responsible for any defects of works carried out by the customers.

6. Drawings

List of drawings specified in this Code of Practice.

Drawing	Title
TYPICAL LAYOUT	
C-096	Standard size of PT room for one transformer
C-097	Standard size of PT room for two transformers
C-098	Standard size of PT room for one transformer on 1st floor
C-099	Standard size of PT room for two transformers on 1st floor
C-101	Standard size of area for Outdoor Customer Substation
TRANSFORMER PLINTH	
D-117	Support for Transformer Type I
D-119	Support for Transformer Type II
SUBSTATION DOOR	
D-349	Double leaf stainless steel door with louver for 1st floor
D-350	Double leaf stainless steel door with louver
D-351	Double leaf stainless steel door without louver
D-234	Single leaf stainless steel door with louver
D-233	Single leaf stainless steel door without louver
LOUVER	
D-330	Typical details of stainless-steel louver for air intake
D-331	Stainless steel louver for air outlet
AIR DUCT	
D-245	Air duct for stand-alone outdoor customer substation for temporary construction
D-326	Air Duct with silencers
D-328	Aerofoil Climafan

CABLE TRENCH	
D-334	Cable trench and metallic cover for Q.G.B.T.
E-105	Steel cover for cable trench
E-238	Cable trench for support LV & MV from transformer
E-421	Cable trench for MV panels
E-556	Cable trench for RMU
E-565	Typical water proofing for cable trench
EARTH SYSTEM	
G-023	Exterior earthing pit
CABLE LADDER	
E-515	Cable ladder
E-521	Direct cable ladder
OTHERS	
E-561	Outgoing for temporary cables
E-566	Typical details of trench outlet
F-071	Typical upper-level PT work at height – safety measure

Appendix A

Design of Customer's Main Switch room

The purpose of establishing a customer's main switch room in a building is to receive supply from CEM service equipment and accommodate the main switch and the distribution board for controlling and distributing electricity supply to all parts of the building. Hence, in designing a customer's main switch room, the following requirements must be taken into consideration.

1. Position of switch room in relation to service position

   Where the supply is taken directly from a transformer located within the building, the main switch room must be located immediately adjacent to the customer substation so that the length and bending of CEM cables connecting the transformer to the main switch are kept to a minimum.

   Where the supply is taken from a low voltage network via multi-core cables, the main switch room shall be as close to the building entrance as possible.

2. Access

   The main switch room must always be readily accessible from a communal area without passing through any individual customer's premises.

3. Routing of outgoing circuits

   The outgoing circuits from the main switch room such as rising mains and landlord's services shall not pass through any individual customer's premises. Where this cannot be avoided, suitable concrete ducts must be provided so that the cables installed therein can be replaced without the need to enter any individual customer's premises at any time.

4. Dimensions

   The main switch room shall not only be large enough to accommodate all the associated switch gear, distribution board and CEM metering equipment but also have adequate working space to facilitate installation, operation and maintenance. Figures 1.1, 1.2 and 1.3 in NCEM C14-100 section 4.4 show the detail dimensions.

Appendix B

Stainless Steel for Substation External Steelwork

1. Material used shall be grade 316L stainless steel.

2. The Japanese standard for this steel is SU 316L and the American equivalent is TP 316L.

3. The following notes relate to all external steelwork, in particular to the doors:

   3.1. The hinges of each door leaf must be designed and constructed to withstand the weight of the door plus 50 kg and be not less than four in number per leaf.

   3.2. Welding treatment must be suitable for grade 316L stainless steel and must not create weak spots at the weld. After welding, the weld surface must be brushed clean to remove all welding flux and surface dirt. The surface shall then be solvent cleaned to remove all residual dirt and grease. Welding should only by inert gas arc welding to BS7475.

   3.3. The doors and other external steelwork shall be covered with plastic sheets at the time of installation and such plastic sheets shall not be removed until the building construction work is completed, in order to avoid staining and damage to the steelwork by site construction work.

Appendix C

General Notes to Design Criteria

1. Internal clear headroom of the customer substation under ceiling/ceiling beams should follow the requirements presented in Section 4.1.4 and 4.1.5.

2. For new customer substations located in low-lying areas exposed to storm surge, all CEM equipment shall be installed at an elevated level to mitigate the risk of flooding. See Section 4.1.17 for the elevation requirement.

3. For first floor customer substation, the special requirements under Section 4.3 must be satisfied.

4. Invert level of trench at inlet to be 850 mm minimum below pavement level for MV cables and 650 mm below pavement level for LV cables. All cable trenches to be covered with 5 mm thick hot dip galvanized plate. The cable trench outlet must be free of obstructions.

5. For the installation of uPVC pipes for trench outlet, it is forbidden to install the required uPVC pipes during concrete casting stage. For the installation requirements, see Section 4.7.4.8.

6. All substation walls, ceiling and floor shall be made of reinforced concrete with a design strength class of B30 (28 days compressive cube strength of 30 MPa) or above.

7. Minimum thickness of reinforced concrete floor slab to be 200 mm, and to withstand a 'superimposed load' of 5 kPa. Where appropriate, the substation floor shall be laid on well-compacted subsoil.

8. Area hatched for MV equipment erection to withstand 'dead load' of 600 kg and 'superimposed load' of 750 kg per equipment. Finished top surface shall be smoothed and level.

9. The dimensions for each transformer foundation should be 2.35 m × 1.55 m for customer substation housing one transformer (see drawing C-096) and 2.55 m × 1.45 m for customer substation housing two transformers (see drawing C-097). The transformer foundation should withstand 7000 kg and be leveled with finished floor level.

10. Substation walls and the ceiling shall be cement and sand plastered and finished with one coat of liquid prepolymer sealing and three finishing coats of white color acrylic resin-based coating in matt finish.

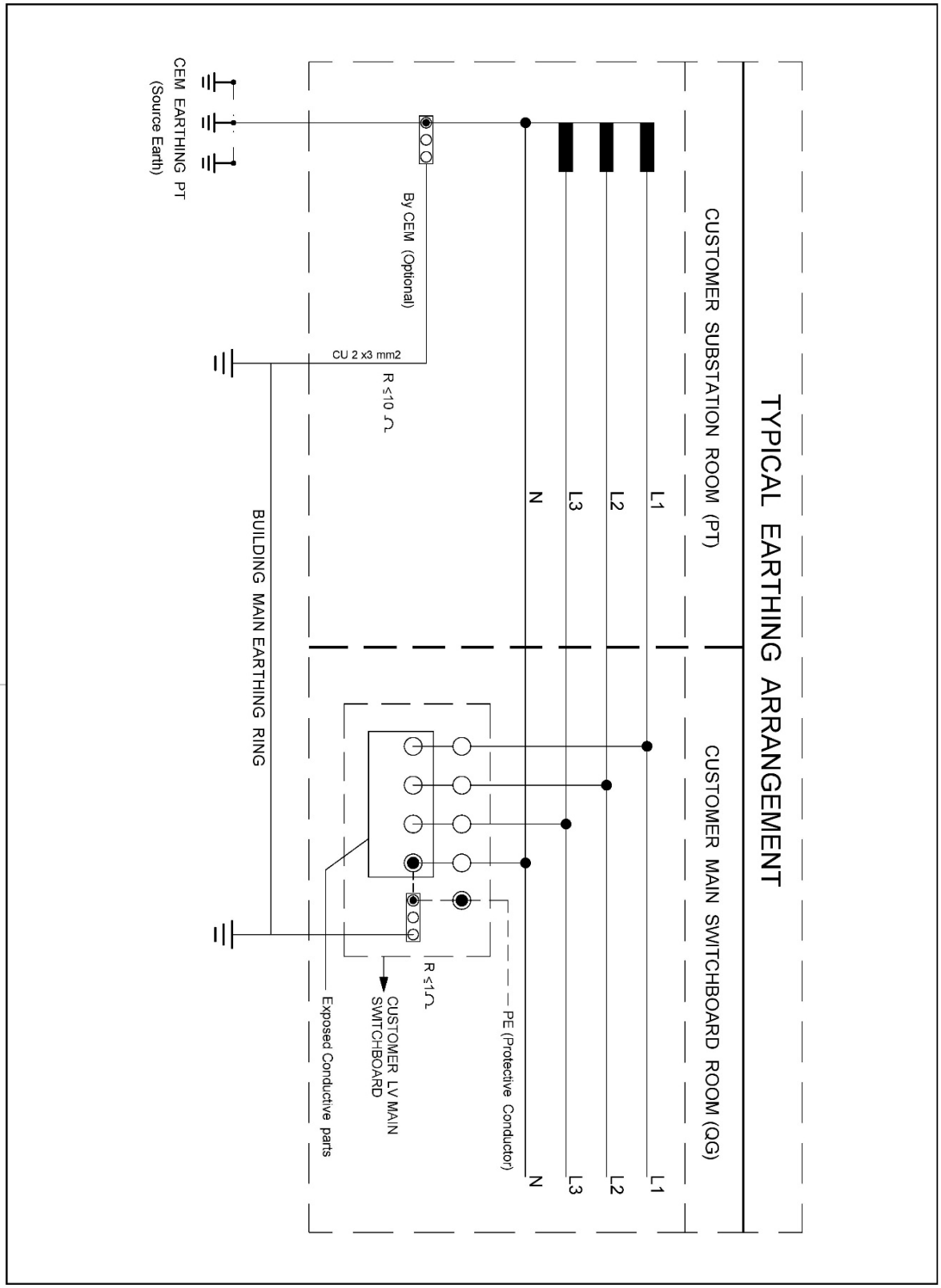
11. Substation floor shall be cement and sand rendered and applied with carborundum and red dan powder to enhance floor durability and better slip resistance.

12. The layout drawing is prepared from building plans submitted. Companhia de Electricidade de Macau – CEM, S.A. must be informed immediately of any modifications to the building plans which may affect the drawing.

13. The following drawings and information related to the customer substation should be prepared by customer and submitted to CEM during design stage: -

- Relevant site layout plan, floor plan, elevation and section of the customer substation;
- Location and details of cable riser, manhole and main switch room of the development;
- Waterproofing layer for the inner surface of cable trenches (Section 4.1.9);
- Waterproofing and drainage system for customer substation located above basement (Section 4.1.10);
- Double slab ceiling with waterproofing construction or equivalent water proofing solutions (Section 4.1.26);
- Manholes located inside the development boundary and associated drainage connection, if applicable (Section 4.1.11 & 4.1.12);
- Retractable lifting beam (Section 4.3.14) or non-retractable lifting beam (Section 4.3.15);
- Lift inside building for operational and maintenance (Section 4.3.21); and
- Ceiling waterproofing system and drainage system (Section 4.5.1.1).

Appendix D


TYPICAL EARTHING ARRANGEMENT
CUSTOMER SUBSTATION ROOM (PT)
CUSTOMER MAIN SWITCHBOARD ROOM (QG)
CEM EARTHING PT
(Source Earth)
By CEM (Optional)
CU 2 x3 mm2
R ≤10 Ω
BUILDING MAIN EARTHING RING
L1
L2
L3
N
R ≤1Ω
CUSTOMER LV MAIN SWITCHBOARD
Exposed Conductive parts
PE (Protective Conductor)