Contents

Definitions/Abbreviations

COMPANY / OWNER	
CONTRACTOR	The entity which has been contracted to supply goods and/or services to the COMPANY.
SUPPLIER	The party which manufactures or supplies equipment and/or services to perform the duties specified by COMPANY or CONTRACTOR.
SUB-SUPPLIER	Any party which manufactures or supplies equipment and/or services to the SUPPLIER to perform the duties specified by COMPANY or CONTRACTOR

AC	Alternating Current
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
HV	High Voltage – voltages over 52kV in AC
MV	Medium Voltage – voltages over 1kV in AC and up to 52kV in AC
LV	Low Voltage – voltages below 1000V in AC
RK	Republic of Kazakhstan
SDRS	Supplier Documentation Requirement Schedule
SNiP	Russian Construction Codes and Regulations
TRCU	Technical Regulation Customs Union

1 PURPOSE

The purpose is to set the standard for good design and engineering practice to be applied on facilities to achieve maximum technical and economic benefit from standardisation.

2 SCOPE

This document defines the Electrical and Instrument Earthing and Lightning Philosophy that shall be applied for the instrumentation, electrical distribution, utilisation and emergency generation systems on installations.

3 REFERENCES

-00-ENG-SPC-00026	Climatic, Environmental and Utility Data
-00-ELT-SPC-00022	Electrical Basis of Design
-00-ELT-SPC-00023	Electrical Installation and Testing

4 ROLES AND RESPONSIBILITIES

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5 CODES AND STANDARDS

Earthing and Lightning Protection equipment shall be designed, manufactured, installed and tested in accordance with the latest applicable sections of international, federal, state or local codes, regulations, ordinances and rules of Kazakhstan as detailed in Appendix A.

The word 'should' shall be replaced by 'shall' wherever it appears in the reference standards.

Kazakhstan is a member country of the Eurasian Customs Union (EAC), equipment shall meet the requirements of the technical regulations of the Customs Union. Attention should be paid to:

- Electromagnetic compatibility
- Low voltage equipment
- Machinery
- Safety
- EAC marking

Where the data sheet indicates that the equipment is for use in a hazardous area, the equipment and all its associated parts shall comply with the requirements of Technical Regulation Customs Union (TR CU) 012/2011.

6 PRECEDENCE

The order of precedence shall be as follows (unless stated otherwise in the project documentation):

1) National and/or Local Regulations;
2) Purchase Requisition;
3) Data sheets and drawings;
4) Project specifications;
5) This specification;
6) Industry codes and standards referenced.

CONTRACTOR is responsible for satisfying all technical and certification requirements for and on behalf of the COMPANY with the local Kazakh authorities.

Any apparent conflict between documents in the same level of the hierarchy shall be brought to the attention of the COMPANY for clarification. However, as a general rule, where such conflict exists, the most onerous requirement shall govern.

CONTRACTOR shall identify and detail any deviations and/or exclusions to the documents during the Tendering phase. Unless such deviations/exclusions are specifically identified, the CONTRACTOR shall be deemed to have confirmed full compliance with all the documents listed.

7 DESIGN CRITERIA – EARTHING

7.1 General

Earthing shall be provided to protect personnel against electric shock, protect equipment against damage due to earth fault currents, static discharge and lightning, and to ensure signal integrity and provide a reference point for instrumentation systems.

Earthing is the provision of a specific return path for fault currents to operate protective devices in the shortest possible time.

Bonding is the interconnection of two adjacent pieces of conducting material to prevent a potential difference between them, which could be a hazard to people, or capable of causing an ignition. The reasons for earthing and bonding are:

- To provide a dedicated reliable low impedence return path for fault currents.
- To prevent potential differences which could cause a possible electrocution hazard.
- To minimise the effect of lightning strikes.
- To prevent or control the build up of electrostatic charges.
- To minimise the effect of electrical interference.
- To provide a signal reference for instrumentation systems.
- To satisfy the requirements necessary to ensure the safety of explosion proof apparatus.

Earthing shall be designed in accordance with the standards listed in Appendix A.

Design of underground earthing installations shall take account of the Basic Civil Engineering Design Data Doc. No. -00-CVS-SPC-00006.

The earthing system shall comprise the following sub-systems that shall be connected only at the earth electrode system in the unit substation:

- Plant Earth System
- Instrument Clean Earth System
- Intrinsically Safe Earth System

7.2 Electrical System Earthing

The existing system earthing philosophy at each voltage levels as follows:

- 35kV ± 6%, 3 phase, 3 wire, 50Hz, earthing transformer and resistance earthed.
- 110kV +6% to -10%, 3 phase, 3 wire, neutral solidly earthed.
- 11kV ± 10%, 3 phase, neutral high impedance earthed (Main Power Generator).
- 6kV ± 6%, 3 phase, 3 wire, 50Hz, resistance earthed.
- 690V ± 6%, 3 phase, 3 wire, 50Hz, solidly earthed.
- 400/230V ± 6%, 3 phase, 4 wire, 50Hz, solidly earthed.
- 230V ± 6%, 1 phase, 2 wire, 50Hz, solidly earthed.
- 230V +6% -1%, 1 phase, 2 wire, 50Hz from a UPS system, solidly earthed.
- 110V DC +10% -20%, 2 wire from a rectifier /battery system, unearthed.

The method of system earthing at each voltage level shall be shown on the single line diagrams and earthing layout drawings.

Generally, main power system distribution transformer and generator neutrals shall be connected to the Plant Earth System either solidly or via a resistor, depending on voltage level. For solidly earthed systems, the maximum resistance of the earthing system shall be 1 ohm. For resistance earth systems, the maximum resistance of the earthing system (excluding the resistor) shall be 0.5 ohm.

7.3 Earthing Arrangement

The earthing system shall consist of a common earthing grid with earth rods (electrodes) as required and tied into the existing plant earth grid at several points.

For each generator and transformer star point, all electrical equipment, mechanical equipment, support steelwork and lightning protection systems within the plant, a connection to earth shall be provided via protective conductors.

The underlying philosophy is to determine an earth grid design which reduces step and touch voltages to allowable/tolerable levels as per the relevant codes and regulations - to be confirmed by calculations. Earth loop impedances shall also be checked by calculation.

Underground earthing conductors which are run independently from a main cable trench shall be run at a minimum depth of 450mm below grade.

All earthing cable shall be green/yellow Poly Vinyl Chloride (PVC) sheathed. All cable to cable joints in the earthing system shall be Thermite welded.

7.4 Plant Earth System

The Plant Earth System shall comprise of a series of $70mm^2$ PVC sheathed copper conductors with a cross sectional area calculated in accordance with IEC 60364-5-54 laid directly in the ground or PVC sheathed copper conductors installed on cable tray rack forming closed loops around the various plant areas. These earth loops shall be connected to earth electrodes as necessary to ensure that the resistance to earth at any point connected to the Plant Earth System shall not exceed 1 ohm.

7.5 Instrument Clean Earth System

Control buildings and instrument equipment room shall contain a dedicated Instrument Clean Earth System for earth connections associated with instrumentation systems. The Instrument Clean Earth System shall be isolated from the Plant Earth System and from building structures except at its point of connection to the Plant Earth System at the earth electrode in the substation from which its power supply is provided. The arrangements for instrument earthing are depicted in schematic form on the Earthing Philosophy Diagram, Typical Earthing Arrangement of Instrument Equipment, Doc. No. 4TPFC-00C-EG0-9450-00002.

The resistance to earth at any point connected to the Instrument Clean Earth System shall not exceed 1.0 ohm.

While Plant earth (Protective earth) is intended to give protection to personnel. Clean earth is used to eliminate “noise" pick-up on instrument signal wiring between field and control room equipment.

Cable screening, both overall and twisted pair (or triple) screening shall be insulated from earth at the field connection and connected to Clean earth on one side only at the panel terminal rail. Integrity of signal cable screening shall be maintained through all junction boxes or loop connections.

To distinguish from Plant earth (Yellow/green) the colour for Clean earth sleeving shall be Green.

Cable armouring is not intended to provide signal screening.

7.6 Intrinsically Safe Earth System

An Intrinsically Safe Earth System shall be provided for earthing signal systems. The Intrinsically Safe Earth System shall be isolated from the Plant Earth System and the Instrument Clean Earth System and from building structures except at its point of connection to the Plant Earth System at the earth electrode in the substation from which its power supply is provided.

The resistance to earth at any point connected to the Intrinsically Safe Earth System shall not exceed 1.0 ohm.

To distinguish from Plant Earth (yellow/green) the colour for Intrinsically safe earth sleeving shall be yellow in line with COMPANY practice.

The arrangements for intrinsically safe instrument earthing are depicted in schematic form on the Earthing Philosophy Diagram, Typical Earthing Arrangement of Instrument Equipment, Doc. No. 4TPFC-00C-EG0-9450-00002.

7.7 Cable Terminations

All earthing cables terminating at equipment or earthing bus-bars shall use a compression type cable lug.

Cable armour shall be earthed via the cable gland and the equipment at both ends.

For terminating high voltage cables, the design of the cable gland or termination shall incorporate a lug for bonding the cable armour to earth, or to the equipment enclosure.

Where a low-voltage cable enters a metallic enclosure, a bonding connection between the gland and the enclosure is not required, providing there is no electrical discontinuity of the enclosure. Tapped entry holes are preferred, but where entry is through a clearance hole a “star” washer shall be fitted under the backnut to ensure good electrical contact.

Where plastic/non-metallic enclosures are used, means shall be provided to preserve the electrical continuity of the armouring and/or metallic sheaths of cables. This should be provided either internally or externally for bonding the cable armour to each other and to earth - normally achieved with an earth continuity plate inside the enclosure.

7.8 Protective Conductors

All plant equipment items and exposed conductive parts of the plant shall be connected to the Plant Earth System, by protective conductors, to form an equipotentially bonded system.

Protective conductors may consist of one or a parallel combination of the following:

- Cable armouring or metallic sheath
- Earth core within a multicore cable
- Separate conductor
- Structural steelwork

Sole reliance on cable armouring and/or metallic sheathing shall only be made if it is adequately fault rated as a protective conductor.

Structural steelwork may be considered as a protective conductor provided it is part of the common static and lightning earthing system and there is a permanent metallic path for fault current via such steelwork and other earthing conductors back to the source of the power supply.

The cross sectional area of every protective conductor and bonding connection between exposed and extraneous conductive parts shall be such that they can carry the earth fault current, or an appropriate fraction of the total fault current, for the duration of the fault without damage to the conductor or associated insulation.

The required minimum cross sectional area may be determined by the following formula:

$$S = \frac{I\sqrt{t}}{k} \text{ mm}^2$$

where,

S = Cross-section of protective conductor (mm)

I = Total earth fault current through the protective device (amperes)

t = Operating time of the disconnecting device (seconds)

k = Factor dependent on the material of the conductor, the type of insulation, the assumed initial temperature and the maximum allowable temperature of the insulation

Note:
Where the "protective conductor" consists mainly of a large steel structure such as an extensive mesh of interconnected copper earthing conductors, the impedance of the earth return path may generally be ignored for fault current calculation.

Values of k for typical types of protective conductor are given in the table below. For conditions and conductor types not covered by the table below, reference should be made to IEC 60364-5-54 Tables A54-2 to A54-6.

Typical values of K for Protective Conductors and Fault Rated Bonding Connections (based on IEC 60364-5-54) are as follows.

Material of Protective Conductor	Assumed Initial Temperature °C	Final Temp.°C	K
Copper with PVC sheath	30	160	143
Bare copper	30	200	159
Copper as a core of a PVC cable	70	160	115
Steel armour in contact with PVC	60	200	51
Lead sheath in contact with PVC	60	200	26
Bare steelwork	30	200	58

The minimum size of earth cable connecting equipment and structures to the main earth grid shall be in accordance with the following table.

Main Earth Grid	$70mm^2$
Earth Pits	$70mm^2$
Metallic enclosures of MV equipment	$70mm^2$
Metallic enclosures of LV equipment rated greater than 90kW	$70mm^2$
Metallic enclosures of LV equipment rated up to 90kW	$35mm^2$
Motor control stations	$35mm^2$
Structures, tanks and vessels	$35mm^2$
Instrument stands & junction boxes	$35mm^2$
Perimeter fencing	$35mm^2$

Joints in protective conductors should be avoided. If this is not possible, effective measures shall be taken to prevent inadvertent disconnection, corrosion or other forms of deterioration at all such joints.

7.9 Earth Electrodes

Earth electrodes shall normally consist of a number of rod sections coupled together and driven vertically into the ground. Several such rods may need to be connected in parallel to obtain the required electrode resistance. The distance between rods should be greater than their depth.

Earth rods may be of the following materials if they are entirely suitable for the application and ground conditions:

- solid hard drawn copper
- phosphor bronze
- copper clad steel
- stainless steel
- galvanised steel
- cast iron pipe

Each earth rod shall be protected against corrosion and terminated in an inspection pit.

The resistance of an earth electrode of given dimensions and geometry is dependent on the soil resistivity, which varies according to the type of soil, moisture content, degree of compaction and chemical composition. Minimum resistance of single earth electrode should not be more than 10 ohms.

Resistivity measurements shall be made at the proposed electrode Locations. These measurements and the subsequent electrode design should be carried out at an early stage of the project so that the electrode locations are compatible with plot layouts, foundations, etc.

The effect of possible seasonal increases in electrode resistance due to drying out or freezing of the ground shall be considered. Wherever possible, the earth electrode should be installed deep enough to reach the water table or permanent moisture Level, deeper than frost is likely to penetrate and to reach stable ground conditions.

7.10 Grounding Conductors and Connections

Where specified connections can be made by means of irreversible compression type grounding connectors or, cable to cable connections may be made using copper oxide and aluminium powder welding (exothermic) process using trade name CADWELD or THERMOWELD. This method provides a permanent connection, eliminates contact resistance, and is relatively corrosion free. It does however require above ground bolted joints for disconnect purposes (as for testing) and cannot be used in the presence of volatile or explosive mixtures.

In some instances, mechanical fittings may be used. These have a history of satisfactory operation although more susceptible to corrosion. Therefore, it is recommended if this type is used, to treat the joint with a corrosion inhibitor.

Connections of devices or fittings that depend solely on solder shall not be used.

7.11 Earthing Conductor Theft Prevention

The plant suffers from continuous theft of copper bar and cable used for earthing and lightning protection. One solution to the problem employed by other worldwide owners is the substitution of copper with materials with essentially no scrap value. To this end, the use of copper clad or electroplated steel has been successful in eradicating earthing conductor theft and should be considered as an option. Steel on its own is technically viable but it requires heavy sections for equivalent rating to copper and becomes costly to install. Aluminium has been used as a copper substitute but is itself subject to theft and is not suitable for buried earthing applications due to corrosion. Copper clad steel has been used in other parts of the world e.g. USA for many years.

7.12 Sub-stations and Generator Rooms

The electrical substation building and all other electrical equipment rooms shall contain a dedicated earth loop, which shall be connected to the Plant Earth System and to a dedicated earth electrode system.

A bar of high conductivity hard drawn copper shall be installed in the substation, to which the earth bars of all switchboards and the metallic enclosures of all low-voltage ancillary equipment (e.g. Lighting distribution boards, etc.) shall be connected.

The main substation earth bar shall be connected to one or more earthing busbars to form a complete ring. Alternatively, stranded copper cable may be used to connect each item to the earthing busbars.

Electrodes shall be installed in the ground near each substation. Connections to the electrodes and rods shall be made using conductors of 70 mm^2 minimum cross-sectional area.

At least one more than the required minimum number of electrodes shall be installed. By this means, each electrode can be disconnected one at a time for testing without affecting the integrity of the power earthing system.

All main switchboards shall be connected to the substation earthing system at two separate points.

The star points of all-star connected transformers and all alternator generator windings shall be connected to the earthing system, either, directly or via a current Limiting impedance and/or earthing switchgear, as required. Hard-drawn high•conductivity copper bar or stranded copper cable shall be used and in either case the conductor shall have a green/yellow PVC covering.

Solidly earthed transformer star points should be connected directly to earth pit(s) in addition to earth grid to ensure they cannot be disconnected in error.

The neutral of Low-voltage three phase four wire systems shall be connected to earth via the relevant main switchboard earth bar. A bolted link shall be provided between the neutral bar and the earth bar.

The armouring and metallic sheath (if provided) of all multicore cables shall, be bonded to the switchboard earth bar, via the termination or the gland and gland plate.

For single core cables where single point bonding is necessary unearthed terminations shall be insulated and shrouded for the maximum possible touch voltage for the application. The earthed end should be at the hazardous area end (if any). Single core cables in substations e.g. transformer secondary cables, shall be earthed at the supply end.

7.13 Medium Voltage Motors

The enclosures of all medium voltage motors shall be connected directly to the local static and lightning earthing system, or to local earth electrodes. A common earth electrode system may be used for several motors in the same area. If medium-voltage motors are already in permanent electrical contact with steelwork forming part of the common earthing system, no additional copper bonding connections are required.

Metallic enclosures of the local control station and any other associated electrical devices local to the motor shall be bonded to the motor enclosure or to the earthing system. If the enclosure is not in permanent direct metallic contact with earthed plant steelwork or pipework, it shall be bonded to the static and lightning earthing systems or to the adjacent earthed steelwork by means of a $35mm^2$ copper conductor.

7.14 Low Voltage Equipment

If the enclosure is in permanent direct metallic contact, e.g. via pump skid, vessels, piping, structures, etc., with the general mass of earthed plant steelwork, there is no necessity for any further connection to any earthing system.

If the enclosure is not in permanent direct metallic contact with earthed plant steelwork or pipework, it shall be bonded to the static and lightning earthing systems or to the adjacent earthed steelwork by means of a $35mm^2$ copper conductor.

7.15 Cable Tray Bonding

Earth continuity of cable tray shall be maintained over the length of run, this may be achieved be through mechanical contact or additional bonding across joints. The electrical path through the cable tray to the protective earth (Plant earth) shall be arranged by earth bonding as required, using a copper conductor of no less than $4mm^2$.

8 DESIGN CRITERIA – LIGHTNING AND STATIC EARTHING PROTECTION

8.1 General Requirements

Lightning protection shall be provided in accordance with Public Utility Easements (PUE), Rules for the Arrangement of Electrical Installations, and RoK SNiP 2.04-29-2005, Guide: Protection of Structures against Lightning.

ALL equipment and parts of equipment which are liable to accumulate potentially dangerous levels of static shall be in effective metallic contact with adjacent metal and with 'earth'.

The resistance to earth from all parts of fixed metal equipment shall not exceed 10 ohms.

Normal pipe and equipment flanges, unless specially insulated, provide a sufficiently low resistance to dissipate static electricity and do not require bonding connections across them. Similarly, any equipment which is in metallic contact with an earthed metal structure does not require any other earthing connection.

Note: Earthing of fixed plant does not in all cases remove the risk of static discharge. Other precautions are also necessary such as connecting an earthing clamp to road tankers before filling, control of pumping rates, avoidance of splash filling, etc.

To protect against a direct Lightning strike, as a minimum, the tallest structure on the plant shall be directly earthed as close to the base as possible with a minimum of two electrodes and the individual resistance of each shall not exceed 10 ohms.

Directly earthed items shall, where possible, also be connected to the general earthing system.

Structures which are made of metal and which are electrically continuous do not require a separate down conductor for Lightning protection; a connection to earth at a point near the base is sufficient.

Lightning protection shall be provided for all non-metallic structures over 20 metres high.

8.2 Steel Structures

A 50 x 6mm copper earth bar shall be bolted to supports of the main columns at approximately 600 mm above ground level and at intervals of not more than 20 m.

Steel structures shall be directly connected from each earth bar by 35mm^2 PVC covered copper conductor cable to the adjacent earth grid.

8.3 Concrete Structures

The reinforcement bars of concrete structures and foundations shall be bonded to a 50 x 6 mm copper earth bar. The bar shall be mounted on insulating supports approximately 600 mm above ground level and at intervals of not more than 20 m.

Each earth bar shall be directly connected to the earth grid by 35 mm^2 PVC covered copper conductor cable.

8.4 Vessels

When mounted directly on and in metallic contact with an earthed steel structure, no further bonding is necessary other than that which may be necessary for lightning protection.

When the mounting is insulated from steelwork by materials having poor conductivity such as wood, concrete, rubber etc., two earthing connections (M10 earth boss) shall be taken from the vessel to the common earthing system. Where the vessel is so remote from the plant as to make connection to the common earthing system impractical, two connections shall be taken from the vessel to separate earth electrodes and the resistance to earth of each electrode shall not exceed 10 ohms.

Looping of earthing conductors between vessels is permitted provided a connection is taken from each end of the 'looped' system to the general earth system or earth electrodes.

Earthing connections shall be 70 mm^2 copper conductors except for all applications including lightning protection.

Where a vessel has insulation and an outer metal cladding or wire reinforcement, the metal cladding or reinforcement shall be electrically continuous and bonded to the vessel.

The armouring of cables which enter the vessel shall be bonded to the shell at the point of entry.

8.5 Storage Tanks

Tanks up to 30 m diameter shall be provided with two, and tanks over 30 m diameter shall be provided with three, equally spaced M10 earthing bosses. The bosses shall be positioned near the base of the tank.

The earthing bosses on the tank shall be connected to the same number of separate earth electrodes as there are bosses, either individually or on a shared basis. The earth electrodes should preferably be close to the tank base.

For a group of tanks, earth electrodes common to the group may be installed if each tank has, as a minimum, two paths to earth. This ensures that during testing of one electrode, the tank will remain earthed by a system with an earth resistance not exceeding 10 ohms.

All tank internals, e.g. mixers, gauge floats and sling arms, shall be bonded to the tank shell at one or more locations depending on the size of the internal object.

8.6 Pipelines and Valves

Flanges of metallic piping systems that have insulated linings shall be bonded to ensure electrical continuity. A bond shall also be applied at any equipment connection. Flanged joints in other metallic piping systems shall be considered to be inherently electrically continuous unless the earth resistance of any length line is greater than 10 ohms.

Pipelines shall only be connected to the Plant Earthing System where they enter and leave a hazardous area. The requirements of cathodic protection systems shall be observed.

8.7 Fences

The perimeter gate and fence should be earthed by direct connection to the main earthing grid. The earth grid should therefore extend a distance of at least 1 metre outside the main boundary fence.

All gates and fences within the site area e.g. fences for transformer enclosures, switchyards and substations shall be bonded directly to the main earth grid.

All connections to earth shall be minimum 35mm^2 stranded copper conductor.

8.8 Static Electricity

To minimise the risk from electrostatic discharge, the resistance to earth from all parts of fixed metal equipment should not exceed 1 Megohm.

Where conductive parts are earthed in accordance with the above requirements, Sections 8.1 to 8.7, the resistance to earth should therefore not exceed 10 ohms and consequently will provide protection against the build up of static charge.

APPENDIX A – CODES AND STANDARDS

CODES AND STANDARDS OF THE REPUBLIC OF KAZAKHSTAN

Code of Practice for Earthing	BS 7430
Electrical Safety Code, Model Code of Safe Practice in the Petroleum Industry Pt 1	
Electrical Apparatus for Explosive Gas Atmospheres	IEC 60079
Electrical Installations of Buildings	IEC 60364
Short Circuit Current Calculations in Three Phase Systems	IEC 60909
Protection of Structures against Lightning	IEC 61024
Safety in AC Substation Grounding	IEEE Std 80
Protection of Structures against LightningGuide for the installation of lightning protection of buildings and structures	RoK SNiPSN RK 2.04-29-2005 GUIDE
PUE Regulations for use in Kazakhstan (Electrical Code)	PUE 2015

INTERNATIONAL CODES AND STANDARDS

EUROPEAN STANDARDS

Code of Practice for Protective Earthing of Electrical Installations - AMD: August 2015	BS 7430 + A1-2011
Model Code of Safe Practice for the Petroleum Industry Part 1 - Electrical Safety Code	ISBN 9780852932254
Electrical Apparatus for Explosive Gas Atmospheres	IEC 60079
Electrical Installations of Buildings	IEC 60364
Short Circuit Current Calculations in Three Phase Systems	IEC 60909
Protection of Structures against Lightning	IEC 61024

AMERICAN STANDARDS

Safety in AC Substation Grounding	IEEE Std 80