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## 1 Subject of specification

This specification used in conjunction with other technical specifications of LOTOS Group S.A., establishes minimal requirements regarding design and execution of electric shock protection.

The specification deals with the following issues:

- electric shock protection in low voltage networks
- electric shock protection in medium voltage networks
- electric shock protection in direct current networks.

## 2 Scope of validity

This specification shall be used when preparing both quotations and Purchase Orders concerning planned LOTOS Group S.A. new investments and modernizations.

It shall also be a base for preparation of other detailed specifications and quotations relevant for package units or other equipment deliveries.

The Contractor is independently responsible for selection of equipment and materials to be purchased on the basis of technical design particularly in relation to instruments and equipment made in explosion – proof execution.

### 2.1 Deviations

Any deviations from this specification and relevant specifications, standards and documents, including the bidder's proposals indicating a more economic and/or technically better design or solution, shall be submitted in writing for checking and approval by LOTOS Group S.A. No deviation or modification shall be permitted unless confirmed in writing by LOTOS Group S.A.

The supplier must report in writing any ambiguity in this or any other specifications of Grupa LOTOS SA or non-compliance with the referred documents / standards and obtain a written explanation from Grupa Lotos SA.

### 2.2 Exclusions

Scope of this specification does not cover requirements regarding non-technical means of electric shock protection, and requirements regarding earthing installation, either.

The requirements regarding earthing installation are covered in electric branch specification – standard No 4500 „Lightning protection, earthing and static electricity protection systems"

## 3 Hierarchy of Documents

In case of conflicts existing between this specification and other documents, the following order of precedence shall govern:

- The current Polish legislation
- Terms of purchase order/contract and other requirements agreed in writing with GL SA
- Data Sheets approved by GL SA
- This Specification

- Other Specifications
- Drawings and other documents
- Standards

## 4 Definitions and designations

CUSTOMER: GL SA LOTOS Group S.A. / BUYER

SUPPLIER: BIDDER / VENDOR / CONTRACTOR

### 4.1 Designations

**GL SA** LOTOS Group S.A.

**LV –** low voltage

**MV –** medium voltage

**AC** – alternative current

**DC –** direct current

**KiA** – Control and Automatics (Instrument)

Shall – Indicate a mandatory requirement

# 5 Description

## 5.1 Ambient conditions

- Atmosphere — marine, aggressive industrial, chemical and dusty
- Ambient temperature (max/min) — +36°C/-25 °C
- Relative humidity (max/min) — 90%/70%
- Elevation above sea level — 1m
- Wind speed — 26 m/s
- Snowfall — 290 mm
- Work conditions — refinery, sea coast

## 5.2 Power network parameters

| | |
|---|---|
| Medium voltage | 15kV (LOTOS Railway, North Marine and Przejazdowo Water Supply Point), 3-phase, IT (isolated network)<br>10.5kV (GPZ3), 3-phase, IT (isolated network)<br>6kV (GPZ1, GPZ2), 3-phase, IT (isolated network) |
| Frequency | 50Hz with allowable tolerance +4% /-6% |
| Low voltage | 400V, TN-C-S with tolerance +/-10% |
| Low voltage (lighting, heating) | 230V, TN-S |
| Low voltage (emergency lighting) | 110V DC |
| Alternate current control voltage | 230V, single-phase |
| Direct current control voltage | 24V DC, 110V DC, 220V DC |

## 5.3 Main design requirements

5.3.1 General requirements

Because all electrical equipment, for which operating voltage values are higher than safe values, create hazard of electric current shock, therefore electric shock protection shall be applied in each network or electrical installation of power supply system, and for all electrical consumers connected to a power source.

Currently valid regulations of electric shock protection (PN-IEC 60364 standard) assume, that in networks of voltage up to 1 kV the voltage is safe, if it does not exceed values given in the following table:

| Type of current | Safe voltage **$U_L$ (V),** in conditions: | | |
|---|---|---|---|
| | normal | particular (high temperature, high humidity, conducting floor) | Extreme hazard (immersed in water) |
| Alternate current | **50** | **25** | **12** |
| Direct current | **120** | **60** | **30** |

For networks of voltage above 1 kV, the highest allowable touch voltages $U_{STP}$ are included in standard PN-E-50522.

Electric shock protection shall be designed and executed according to PN-EN/PN-IEC standard, in a manner ensuring its proper functioning. For areas where IEC/EN standards have not been developed, but national standards exist, the latter shall be observed.

Type of employed electric shock protection shall be adjusted with GL SA.

### 5.4 Electric shock protection in low-voltage networks up to 1 kV

In order to protect persons against effects of electric current shock, the following technical means of electric shock protection shall be employed in low voltage networks up to 1 kV:

- Protection against direct contact (primary protection)
- Protection against indirect contact (complementary protection)
- Protection against direct contact accomplished by supplying with very low voltage (for non-earthed circuits – SELV, for circuits equipped with working earthing – PELV).
- Protective equipment

#### 5.4.1 Protection against direct contact

At least one out of the following protective means shall be employed:

- Isolation of live parts
- Use of enclosures or guards
- Use of fences
- Use of barriers and obstacles
- Placing active parts beyond arm's reach
- Protection by use of highly sensitive earth leakage current protecting devices, as supplementary protection resource.

#### 5.4.2 Protection in case of malfunction

Protection in case of malfunction have to limit of electric shock effects in case of touching accessible conducting parts, which unexpectedly turned on dangerous voltage (e.g. as result of insulation damage). Such action shall be accomplished by:

- making flow of electric current through human or animal body impossible, or

- limiting of electrocuting current value or time of its flow.

Protection in case of malfunction in low voltage electric appliances can be achieved by use of at least one out of the following means:

- automatic disconnection of supply
- II$^{nd}$ protection class equipment, or of equivalent insulation
- isolation of post
- non-earthed equipotential bondings
- electric separation

5.4.2.1 Protection by means of automatic disconnection of supply

Its use entails necessity of: leading of protective conductor to each exposed-conductive part, and use of automatic disconnection of supply device. The protection shall be executed in such manner, that in case of short-circuit between live part and exposed conductive part (e.g. conducting enclosure of electric equipment) or protective conductor, prospective touch voltage of value higher than given in p. 4.3.1 is switched off such quickly, that dangerous pathophysiological effects would not occur.

Such requirement will be met, if the short-circuit will result in current flow of such intensity that would bring about automatic action of switch-off device in sufficiently short time. Therefore adequate path for short-circuit current must be created, so-called short-circuit loop, composed of phase and protective wires – connecting all accessible conducting parts of electric equipment with neutral point of network or with earth, depending on network configuration.

The above is ensured when below given condition is met:

**For TN network arrangement -**

$$\mathbf{Z_s \times I_a \leq U_o}$$ where

$\mathbf{Z_s}$ stands for impedance of short-circuit loop, including supply source, active wire until fault point and protective wire between fault point and supply source

$\mathbf{I_a}$ stands for current causing automatic action of disconnecting device in time depending on rated voltage $U_0$, determined in PN-HD 60634-4-41 standard.

$\mathbf{U_o}$ stands for effective value of rated AC voltage in relation to earth.

The devices automatically disconnecting short-circuit current, can be:

- Over current protections (reacting to raise of current intensity in a circuit), e.g. fuses or automatic circuit breakers with trips or over current relays. Such devices shall properly operate at reduced value of supply voltage as well.
- Current differential protective devices, reacting to appearing of leakage current from a circuit.

Automatic disconnection of supply is effective, when the protection is adequately matched to supply circuit parameters, and maximum disconnection time meets requirements of PN-HD 60364-4-41 standard.

**As a general rule, the 0.4s required time of protecting devices' reaction is assumed for all installed on GL SA area receivers:**

**Conventional disconnection time, not longer than 5s, can be assumed (after agreement with GL SA) in long distribution circuits and for small transformers. Use of other cut-off time shall be each time adjusted with GL.**

**In case of TT network configuration –**

$$R_A \times I_a \leq 50V$$ where

**$R_A$ stands for sum of earthing resistance and resistance of accessible conducting parts protective conductor**

**$I_a$ stands for current intensity, causing automatic actuation of protective device.**

If over current protection is used in capacity of protective device, then it shall be:

- a device of dependent time-current characteristic, and $I_a$ current shall be the current ensuring automatic operation in time not longer than 5s, or
- an instantaneous action device, and $I_a$ current shall be the minimum current ensuring immediate cut-off.

If earth leakage current protective device is used in capacity of protective device, then $I_a$ current is rated differential actuating current $I_{\Delta n}$.

**In case of IT network configuration –**

After occurrence of first earth fault, conditions of disconnection of supply in case of the second earth fault depend on that, if accessible conductive parts are connected one with another by means of protective wire (collective earthing), or are they group or individually earthed.

If neutral conductor is not used, then the following condition shall be met:

$$Z_s \leq (\sqrt{3} \times U_o) / 2 I_a$$

or, if the neutral conductor is used

$$Z'_s \leq U_o / 2 I_a$$ where

**$U_o$** stands for rated AC voltage between phase wire and neutral point

**U** stands for rated AC line-to-line voltage

**$Z_s$** stands for impedance of fault loop including phase conductor and protective conductor of the circuit

**$Z'_s$** stands for impedance of fault loop including neutral conductor and protective conductor of the circuit

**$R_A$** stands for resistance of exposed conductive parts' earthing

**$I_a$** stands for current causing automatic actuation of protective device in time determined by PN-HD 60364-4-41 standard.

In IT network configurations, it is necessary to use devices controlling insulation condition, in order to detect first earth fault between live part and exposed conductive part or earth.

5.4.2.2 Protection by means of earth leakage current devices

The earth leakage current-devices shall be used for protection of electrical consumers in the following cases:

- If fulfilling of electric shock protection requirements by means of quick disconnection of supply accomplished by over current devices is impossible
- If such requirement is imposed by adequate norms and regulations
- In cases indicated by GL SA.

Usage of earth leakage current-devices aims at increase of protection effectiveness for direct contact. Application of current differential devices of rated actuation earth leakage current not exceeding 30 mA, is considered supplementary mean for direct contact protection.

**The devices cannot be the only means of protection .**

In case, where use of earth leakage current devices is necessary, such devices shall be used in serial connection with over current protective devices. It is allowed to use compact type current differential breaker switches with over current breaker switches, or current differential breaker switches with over current module.

It is required that for receivers protected in this manner, condition of quick disconnection of supply effectiveness is satisfied.

The residual current breaker switches shall be used for protection of the following receivers:

- Repair plug-in sockets
- Electric heating circuits (heat tracing)
- Annealing furnaces
- Vom's panels
- Transportable equipment, operated in harsh environmental conditions (humidity, high temperatures)
- Transportable equipment on construction site

5.4.2.3 Protection by application of II$^{nd}$ protection class equipment

Protection by application of II$^{nd}$ protection class equipment, or of equivalent insulation, is achieved by furnishing the equipment with one of below listed solutions:

- double insulation, consisting of primary insulation, and independent from it, additional insulation, equivalent in terms of electrical and mechanical strength. Such insulation is used, for example, in household equipment, hand tools, etc.
- reinforced insulation, which is, in fact, the primary insulation, but equivalent to the double insulation in terms of electrical and mechanical strength,
- insulating enclosures, which are guards made of insulating material of adequate mechanical strength and resistance to environmental factors' influences, providing at least IP2X protection degree. In such enclosures installation equipment is, for example, fabricated (box type switchgears, plugs, sockets, etc.).

5.4.2.4 Protection accomplished by insulation of post

This requirement can be satisfied by means of:

- covering of floor with insulating material, or making the floor and walls of insulating material, which does not subject to moisture influence, as well as by increasing distance of exposed conductive parts from extraneous conductive parts beyond the arm's reach.
- locating adequate barriers, made, within the realms of possibility, of insulating materials, not connected to earth nor to exposed conductive parts,
- insulating of extraneous conductive parts.

Insulation of post can be used in such situations, where application of other means is difficult to accomplish, for example, quick enough supply switch-off or touch voltage reduction cannot be done.

5.4.2.5 Protection by use of non-earthed equipotential bondings

If fulfilling of electric shock protection by means of quick disconnection of supply in effect of overcurrent devices application is impossible, then additional equipotential bondings, conforming to PN-IEC 60364 standard, shall be made.

5.4.2.6 Protection by means of electrically separation

Protection by means of electrically separation consists in supplying (one or more) protected appliance from separating source, which most frequently is adequate transformer or converter, in order to reduce possibility of earth faults.

Voltage value in secondary circuit cannot exceed 500V.

5.4.3 Simultaneous protection against direct and indirect contact

Simultaneous protection against direct contact and indirect contact consists in supplying appliances with very low voltage, not posing hazard for human, but satisfying adequate conditions for energy source, such as:

- protecting transformer or equivalent device (converter)
- electrochemical source (e.g. battery).

The circuit is to be separated from earth (SELV), or be equipped with functional earthing (PELV). Plugin sockets and plugs used in circuits of very low voltage cannot match to plugs and plug-in sockets used in other circuits.

5.4.3.1 Protection degree provided by enclosures

Protection degree provided by enclosures (so-called **IP Code**), constitutes measure of protection provided by enclosures against access to dangerous parts contained in them, as well as against penetration of foreign matters and/or water into them.

## 5.5 Electric shock protection in networks of voltage above 1 kV

Power engineering systems for voltages above 1 kV shall be such constructed, that unintentional touching of live parts, or unintentional access to dangerous zone, adjacent to voltage, is made impossible.

The protection shall incorporate live parts, the parts having only functional insulation, as well as parts that can carry dangerous potential.

The following parts can be included among them:

- Accessible live parts
- The parts of system, in which earthed metallic sheaths or conducting screens of cables have been removed
- Cables and accessories without earthed metallic sheaths or earthed conducting elastomeric screens, as well as flexible insulated leads without conducting elastomeric screens.
- Conducting terminals of cable jackets, if they are able to carry dangerous voltage
- Isolating bodies of insulators and other similar parts, e.g. electric instruments with insulation made of cast resins, if dangerous touch voltage can occur on them
- Bases or enclosures of capacitors, converters and converting transformers, which can carry voltage during normal operation
- Windings of electric machines, transformers and reactors.

The protection shall be realized by use of various means, depending on that if the device is located within closed area of electric operations, or within public access area. Furthermore, the protection shall be verified on the grounds of assessment prepared basing on results of completed measurements and analyses.

5.5.1 Measures of direct contact protection

The following protection types are acknowledged:

- Protection by use of enclosure
- Protection by use of barrier
- Protection by use of obstacle
- Protection by placement beyond reach

The elements employed in capacity of direct contact protection, such as: walls, guards, obstacles, etc., shall be mechanically rugged and securely mounted.

Door to cubicles or fields of switchgear, constituting part of enclosure, shall be designed in such a way, that can be opened only with use of tools or key.

Outside of closed areas of electric operations, such door shall be equipped with safety locks.

Removable, conducting elements of protection shall be such secured, that distance required respectively for barriers or obstacles is maintained, if properly used. Otherwise, the protecting elements shall be made of insulating materials or dried timber.

It is allowed that railing can be removed without use of tools. The railing shall be rigid.

In areas or premises open to the public, protective elements shall not be easy to remove from outside with use of common tools.

5.5.1.1 Protection by use of enclosure

The requirements regarding application of enclosure as reliable measure of electric shock protection, are covered in p. 5.4.3.1 of this specification.

The enclosures can be removed only from internal side of installation, that is through intentional action and with observance of safety measures, as well as by means of adequate tools.

Degree of protection shall meet at least IP 2X requirements. Special means of protection against effects of electric arc impact may be, however, necessary.

5.5.1.2 Protection by use of barrier

The barriers shall be made in such a way, that removing them shall not proceed towards field centre, i.e. towards live parts.

It is possible to use full walls, door or guards (wire mesh) of minimum height 1800 mm in capacity of barriers, ensuring that no part of human body can reach dangerous zone in vicinity of live parts.

Within the installation area minimum proximity distances shall be kept near barriers, from active parts to internal side of the barrier surface, specified in PN-EN-61936-1 standard.

5.5.1.3 Protection by use of obstacle

The obstacles shall be made in such a way, that removing them shall not proceed towards field centre, i.e. towards live parts.

Protective railings, serving as obstacles, can be considered sufficiently rigid, if under action of 500N force their deflection would not exceed 20 mm.

The obstacles can be coverings, railings, chains and ropes, as well as walls, door and screens of height less than 1800m, which for this reason cannot be considered to be a barrier.

Within the installation area minimum proximity distances shall be kept near obstacles, from live parts to internal side of an obstacle surface, specified in PN-EN-61936-1 standard.

5.5.1.4 Protection by placement beyond reach

The protection consisting in locating beyond reach, is accomplished by placing active parts outside the area, which extends from the surface that persons can usually stand or move on, until limit that can be reached by hands in arbitrary direction.

Minimum proximity distances to active parts are given in PN-EN-61936-1 standard.

In order to obtain detailed requirements, concerning external fences, transport roads, crossroads and proximities to buildings, refer to PN-EN-61936-1 standard.

5.5.2 Measures of indirect contact protection

The main measure for indirect contact protection, in power engineering systems of voltage above 1 kV, is protective earthing.

Single earthing electrode or earthing system shall limit touch or step voltage by means of achieving low value of earthing resistance, or adequate distribution of potential on ground surface.

The requirements regarding earthing system are covered in electrical branch specification – standard N° 4500 „Lightning, earthing and static electricity protection systems". Prospective touch voltages shall not exceed values of safe levels specified in PN-EN 50522 standard, drawing 4.

Moreover, one can use measures of additional electric shock protection, which task is to prevent dangerous touch and step voltages appearing during earth faults.The following belong to them:

- Insulation of post
- Electroinsulating coating
- Protective insulation
- Insulating insert

- Protective fence or barrier

5.5.2.1 Protective earthing

Earthing system shall be such selected, that values of effective touch voltages $U_T$ within area covered with this earthing system, would not exceed allowable $U_{TP}$ values.

$$\mathbf{U_T \leq U_{TP}}$$

It is allowed to acknowledge this condition fulfilled without computing or measuring of the highest effective touch voltage $U_T$, if:

- the system being considered constitutes part of combined earthing system
- earthing voltage, determined by means of measurement or computations, does not exceed double value of allowable effective touch voltage, specified in PN-EN-50522 standard ($\mathbf{U_E \leq 2U_{TP}}$)

  or

- specified, acknowledged supplementary M measures are in place, adequate for value of earthing voltage and earth fault time. Such measures are given in PN-E-05115 standard,
- earthing voltage, determined by measurement or calculated, does not exceed four times allowable touching voltage given by code and not exceed allowable value of current flowing through human body (acc. to IEC 6047901 annex B, C2 curve)

Earthing voltage $\mathbf{U_E}$ can be calculated basing on calculated resistances $\mathbf{R_E}$ of earthing, and earthing currents $\mathbf{I_E}$ ($\mathbf{U_E = R_E \times I_E}$).

Apart from assessment of electric shock hazard that can occur on earth fault condition in the station, hazards resulting from earthing voltage being transferred from the station to other stations shall also be checked. This applies in particular to hazards in low voltage systems supplied from the station (the switchgear), by lines working in TN configuration. Assesment shall be done in accordance to PN-EN 61936-1 code.

Connection of neutral point of low voltage network operating in TN configuration, to earthing of supplying station, may, in case of earth fault occurrence in high voltage equipment, may result in appearance of $U_{TP}$ touch voltage on conductive parts of accessible low voltage equipment, equal to $U_F$ interference voltage, which in turn is equal to $\mathbf{U_E}$ earthing voltage (transferred by PE or PEN wire).
In such circumstances, the value and time of interference voltage or touch voltage hold up, during earth fault in high voltage network, shall not exceed values given in PN-IEC 60364-4-442 standard.

5.5.2.2 Insulation of post

Insulation of post consists in post covering with high resistance layer. Reduction of shock current is thus achieved, by increasing of path resistance between foot and the post.

This method can be used only in dry rooms, and insulating elements shall constitute permanent outfit.

5.5.2.3 Insulation coating

Covering of conducting accessible and foreign parts with high resistance layer, brings about reduction of shock current in result of increasing of path resistance between hand and conducting part.

5.5.2.4 Protective insulation

Application of insulation of increased electric strength, in form of additional or non-punch through insulators, precludes creation of earth fault and emerging of touch or step voltage.

5.5.2.5 Insulating insert

Application of single or several insulating inserts in conducting parts, protruding outside the area predestined for power engineering purposes, precludes taking out of earthing voltage from areas separated for power engineering purposes, and therefore forming of touch or step voltage outside this area.

5.5.2.6 Protective fence or barrier

Fencing of equipment and posts precludes, or renders difficult, access to equipment or posts, on which touch or step voltages, forming dangerous effective touch voltages, are likely to emerge.

## 5.6 Protection in direct current networks

In direct current networks one shall use measures of electric shock protection, protecting against direct contact and indirect contact.

Direct contact protection measures have been given in p. 5.4.1 of this specification.

Protection in case of malfunction(indirect contact) measures have been discussed in p. 5.4.2 of this specification.

In capacity of basic measures of protection in case of malfunction in direct current networks, the following measures are used:

- quick disconnection of supply
- protective earthing.

Complementary measure of protection in case of malfunction can be **application of highly sensitive protective earth leakage current devices** (of tripping current intensity not greater that 30 mA), which increase effectiveness of basic protection, but cannot constitute its only measure.

Rules of proceeding in case of protecting receivers by means of current differential breaker switches, have been given in point 5.4.2.2 of this specification.

The requirements concerning earthing system are included in electric branch specification – standard No 4500 „Lightning protection, earthing and static electricity protection systems”.

## 5.7 Protection of receivers supplied from galvanically separated systems

5.7.1 Protection of receivers supplied from converters

In capacity of basic protection (direct contact protection) for converters, the following shall be used:

- primary insulation of live parts
- enclosure of adequate IP protection degree.

In capacity of complementary protection in case of malfunction (indirect contact protection), on shall use:

- automatic disconnection of supply, accomplished by use of earth fault or current differential protections adapted for this purpose

  or

- reduction of occurring touch voltages to level not exceeding of allowable values.

Power electronic converters are characterised by high leakage current, and have to be adequately earthed. For this purpose all foreign conducting parts, present in the converter, shall be connected to earthing bus bar. A multipoint protective earthing is achieved in such manner.

Except of multipoint protective earthing, current differential breaker switches destined for protecting of converters can be used, as complementary electric shock protection.

Application of current differential breaker switches of ordinary design is forbidden.

5.7.1.1 Protection of receivers supplied by frequency converters

One shall borne in mind, that in case of converters time curve of short-circuit current depends on place of short circuit occurrence, and that interpolar short circuit, as well as earth fault in the same place, may be characterised with different course of short-circuit current.

On earth fault state, a current of value and course the same as in case of each another circuit of TN configured system, is flowing in supply circuit of frequency converter.

In case of earth fault, distorted alternate current is flowing in output circuit. Output circuit is asymmetrically loaded, and asymmetry degree is very high if supplied from TN system. Intermediate direct current circuit causes, that supplying circuit of frequency converter is still symmetrically loaded despite of this. Symmetrization of currents on supply side of the converter causes, that in effect of single-phase earth fault in output circuit, the current flowing in one of the supply circuit phases is such low, that actuation of overcurrent protection is impossible. Therefore the frequency converter is equipped with protection against effects of interpolar and earth faults in output circuit. Actuation of the converter protections gives no intervention chances for any upstream overcurrent protection.

Effectiveness of complementary protection shall be attained by execution of the following, local equipotential bondings:

- PE protective conductors of adequate cross-section area shall be led to frequency converter and to consumer; the cross-section area shall in no case be less than 10 $mm^2$ (of copper), because of high leakage current value
- Equipotential bonding of PE bus bar to adjacent extraneous conductive parts shall be executed in upstream switchgears
- If the frequency converter and/or receiver are distant from the switchgear with local Equipotential bondings, than execution of equalizing connections between converter protective bus bar and/or consumer' enclosure, and closest extraneous conductive parts is recommended.
- Effectiveness of complementary protection accomplished by means of local equipotential bondings shall be analytically proven according to PN-HD 60364-4-41 standard.

Use of earth leakage circuit breakers in capacity of devices providing automatic disconnection of supply shall be avoided, because transient increase of leakage current can cause unnecessary consumer switch-off. The earth leakage circuit breakers of relatively high rated earth leakage current of

actuation shall have to be used then, and moreover – such circuit breaker, which actuation at actually existing earth leakage current course is not fully recognized.

Taking into consideration that earth leakage current can have various time curve, can have spectrum including direct current and alternating components of wide frequency range, B tripping type current differential devices, with two systems of earth leakage current detection are required in circuits supplying frequency converters.

Classic earth leakage circuit breaker of B type tripping, and 30 mA sensitivity, can only be used in supply circuit of low power frequency converter, e.g. up to 5 kW, and of short output circuit.

In industrial equipment with high power frequency converters and longer output circuits, classic B type earth leakage circuit breaker of sensitivity 300 or 500 mA may subject to ceaseless, unnecessary actuations.

In such case one shall consider possibility of DOEPKE brand earth leakage circuit breakers application. These are circuit breakers of B tripping type, operating independently on network voltage, predestined to operate in circuits of 30 up to 400 V AC voltage, short-delay and delay type (Selective – S), overcoming transient earth leakage current accompanying frequency converters switching on.

As direct contact protection devices with IP65 and cables with 1kV minimum insulation voltage shall be designed. As a protection in case of malfunction for direct starting motors switch off by fuse in time shorter than 5s shall be used. Due to lack of possibility to ensure anti-shock protection in form of self switch off in circuits which supply fan motor and converters additional equipotential connections shall be made in place of their (motors) installation. Those connections shall be made by means of steel zinc coated tape FeZn 30x4 and LYżo 16mm$^2$ cable and cover all conducting elements around motors within touching range. Maximum measured touching voltage between available conducting parts shall not exceed 50V. Resistance of cable insulation shall be measured on 2.5kV level and its value shall not be lower than 1 megaohm.

5.7.2 Protection of electrical consumers supplied from UPS

In capacity of primary indirect contact protection for receivers supplied from UPS unit, quick disconnection of supply shall be employed.

Furthermore, earthing bar of the UPS shall be connected to earthing network. UPS earthing, except of electric shock protection function, performs function of false interferences drain as well. The earthing shall be designed and executed in such a way, that prospective touch voltages would not exceed value of safe voltages given in PN-IEC 60364 standard.

Earth leakage circuit breakers can be used in capacity of complementary electric shock protection.

During normal UPS operation, continuous earth leakage current of value reaching several tens mA emerges. This earth leakage current shall be taken into consideration while selecting earth leakage circuit breakers on input. Earth leakage current makes in general impossible the use of earth leakage circuit breakers of low actuating current (30 mA), which are recommended as complementary measure for direct contact protection. Such circuit breakers may be unnecessarily tripped. Therefore it is necessary to use short-delay breaker switches, selective or immune to surge currents, and sensible to alternating and pulsating currents.

Electric shock protection shall then be realized with use of fuses or over current breaker switches. In course of input protection selection, one shall take into account starting current of power supply, which is usually limited, and does not exceed rated value, but some UPS models exist, however, for which it can be even several times higher than rated current. In order to achieve selectivity of protections, the protection in switchgear shall be higher **1.6 times** than local protection in UPS unit.

The fuses on by-pass system input must be rated **at least 1.6 times higher**, than most powerful fuses in output switchgear (guaranteed).

While selecting protections for UPS supplied receivers, one shall assume most disadvantageous operating conditions, that is battery mode of operation, during which by-pass route is inaccessible because of network voltage failure, so that only output power of frequency converter is at disposal. Electric shock protection, accomplished by means of quick disconnection of supply with use of fuses, or circuit breakers with over current releases, shall take into account reduced fault currents and required times of UPS switch-off.

It must be borne in mind, that maximum power supply output current is being actively limited, and shall never exceed 300% of rated value. After exceeding of given load and time corresponding to it, switch over to by-pass mode takes place. In case of overload in range of 150% - 1000%, and after expiration of time corresponding to those overloads (e.g. 40 ms), switching over to by-pass mode takes place. Shall by-pass mode is inaccessible, the inverter continues operation for 0.2s, and only after that time is switched off.

In case of failure consisting in fault between conducting active part and enclosure, fault current flow will proceed. The current shall be limited to value equal to **300%** of power supply rated current value.

While selecting of protections for UPS supplied receivers, it is necessary to:

- calculate value of phase current drawn from power supply (taking into account present load of power supply)
- calculate maximum output current of power supply
- calculate the current, that has to bring about actuation of protection (the current is equal to difference between maximum output current and phase current being drawn from the power supply)
- check, basing on time-current characteristics of fuses, which rated value of fuse link guarantees actuation in time required by valid regulations.

One shall borne in mind that protection of electrical consumers shall be such matched, that faults would not result in power supply switching off (switch off time shall be shorter than 0.2s), as well as they shall protect in case of UPS protections' failure and UPS itself not being switched off (which is, however, extremely improbable).

Because supply continuity assurance for all receiving appliances, that are free from damage is of key importance, so allowable interruption in energy inflow shall be taken into account in course of consumers' protection selection.

Over current breaker switches can be used for protecting consumers supplied from UPS, but in case where very short switch-off times are required (order of 10 ms), fuses are of much greater reliability, and they shall be used.

### 5.8 Protection of equipment on construction site

Quick disconnection of supply shall be used in capacity of primary indirect contact protection. In such case, and adequately to earthing system type, allowable long-term touch voltage $U_L$ shall be limited to 25V AC voltage, or 60 V DC voltage.

All transportable construction site equipment shall be supplied from typical construction switchgears, containing set of repair sockets protected with earth leakage circuit breakers, of actuating current not exceeding 30 mA. Supply cable between construction switchgear and specific equipment shall not be longer, than 30 m.

Socket outlets in construction switchgears may also be supplied with SELV voltage, or from separation circuit, each socket outlet being supplied from separate isolating transformer.

All switchgears used in electrical systems on construction site shall fulfil requirements of PN-EN 60439-4 standard. Permanent equipment, installation equipment and fittings, shall have at least IP 40 protection degree.

In case of IT systems utilization, earth fault control shall be employed.

## 6 Relevant documents

- Other Technical Specifications, shown on delivered List of Technical Specifications for GL S.A

## 7 Codes and standards

Electric shock protection shall be executed according to below listed Polish Standards PN-EN, PN-IEC, as well as European equivalents of IEC/CENELEC standards.

| | |
|---|---|
| PN-IEC 60050-195 | International electrotechnical vocabulary. Earthing and electric shock protection. |
| PN-HD 60364-4-41 | Electrical installations of buildings. Part 4-41:Protection for safety. Protection against electric shock. |
| PN-HD 60364-7-704 | Low-voltage electrical installations. Part 7-704:Requirements for special installations or locations - Construction and demolition site installations |
| PN-EN 60071-1 | Insulation co-ordination. Part 1: Definitions, principles and rules |
| PN-EN 60071-2 | Insulation co-ordination. Application guide. |
| PN-EN 50110-1 | Operation of electrical installations. |
| PN-EN 50110-2 | Operation of electrical installations. Part 2: National annexes |
| PN-EN 61936-1 | Power installations exceeding 1kV a.c. Part 1: Common rules |
| PN-EN 50522 | Earthing of power installations exceeding 1kV a.c. |
| PN-EN 50178 | Electronic equipment for use in power installations. |
| PN-EN 60439-4 | Low-voltage switchgear and controlgear assemblies. Part 4: particular requirements for assemblies for construction sites (ACS) |

Protection against electric shock, executed according to other norms and standards, shall be submitted to GL SA for approval.

## 8 Record of changes

| No. | Date | Description | Introduced by |
|---|---|---|---|
| 1 | 30-11-2013 (rev.1) | Review, update, standardize and changes to the Standard within scope of order No. OK/990/2012 | Editorial board coordinated by T.Wróbel |
| - | 31-08-2015 | Page layout corrections, no content changes. | T. Wróbel |