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1. Introduction

1.1 Scope

[INFO-EED-5] The present specification describes the electrical and electronic design requirements applicable to systems and subsystems to be installed or integrated to the E-ELT. This document presents a subset of requirements from RD1. The main goal of this document is to provide design rules in order to achieve electrical and electronic compliance of such systems and the parts it consists of.

1.2 Glossary, Conventions and Definitions

[INFO-EED-7] Definitions may be found in IEC 60050 (International Electrotechnical Vocabulary).

1.2.1 General

[INFO-EED-9] **Machinery, machine -** assembly of linked parts or components, at least one of which moves, with the appropriate machine actuators, control and power circuits, joined together for a specific application, in particular for the processing, treatment, moving or packaging of a material. The term "machinery" also covers an assembly of machines which, in order to achieve the same end, are arranged and controlled so that they function as an integral whole.

1.2.2 Definitions related to EMC

[INFO-EED-11] **Burst** - A sequence of a limited number of distinct pulses or an oscillation of limited duration.

[INFO-EED-12] **Electromagnetic compatibility (EMC)** - The ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

[INFO-EED-13] **Electromagnetic interference (EMI)** - Degradation of the performance of an equipment, transmission channel or system caused by an electromagnetic disturbance.

[INFO-EED-14] Note. Disturbance and interference are respectively cause and effect.

[INFO-EED-15] **Emission level (of a disturbing source)** - The level of a given electromagnetic disturbance emitted from a particular device, equipment or system in a specified way.

[INFO-EED-16] **Emission limit** - The specified maximum emission level of a source of electromagnetic disturbance.

[INFO-EED-17] **Enclosure port** - The physical boundary of the apparatus through which electromagnetic fields may radiate or impinge.

[INFO-EED-18] **Harmonic (component)** - A component of order greater than one of the Fourier series of a periodic quantity.

[INFO-EED-19] **(Total) harmonic factor** - The ratio of the r.m.s. value of harmonic content to the r.m.s. value of an alternating quantity.

[INFO-EED-20] **Immunity (to a disturbance)** - The ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

[INFO-EED-21] **Immunity level** - The maximum level of a given electromagnetic disturbance incident on particular device, equipment or system for which it remains capable of operating at a required degree of performance.

[INFO-EED-22] **Immunity limit** - The specified minimum immunity level.

[INFO-EED-23] **Machinery -** An assembly of linked parts or components, at least one of which moves, with the appropriate actuators, control, and power circuits, etc., joined together for a specific application.

[INFO-EED-24] **Port -** Particular interface of the specified apparatus with the external electromagnetic environment.

[INFO-EED-25] **(Electromagnetic) susceptibility** - The inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

[INFO-EED-26] **Interharmonics** - Discrete or wide-band spectrum frequencies which are not integer multiples of the power frequency fundamental.

[INFO-EED-27] **Short (supply) voltage interruption** - The disappearance of the supply voltage for a period of time not exceeding 3 min.

[INFO-EED-28] **Voltage dip** - A sudden reduction of the voltage to a value of less than 90% of the reference voltage at a point in an electrical system, followed by voltage recovery after a short period of time, from half of a cycle to a few seconds.

[INFO-EED-29] **Voltage fluctuation** - A cyclical variation of the voltage envelope or a series of random voltage changes.

[INFO-EED-30] **Voltage surge** - A transient voltage wave characterized by a rapid increase followed by a slower decrease.

[INFO-EED-31] **Voltage unbalance (imbalance)** - In a polyphase system, a condition in which the r.m.s. values of the phase voltages or the phase angles between consecutive phases are not all equal.

1.2.3 Abbreviations and Acronyms

[INFO-EED-33]

AC	Alternating Current
CB	Circuit Breaker
CE	Conformité Européenne
CEN	European Standards Coordinating Committee
CENELEC	European Committee for Electrotechnical Standardisation
COTS	Commercial Off-The-Shelf (product)
DC	Direct Current
DOC	Declaration of Conformity

EHSR	Essential Health and Safety Requirements
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EN	European Norm
ESD	Electrostatic Discharge
ESO	European Organisation for Astronomical Research in the Southern Hemisphere
EU	European Union
EUT	Equipment Under Test
HF	High Frequency
HFT	Hardware Failure Tolerance
I/O	Input/Output
IEC	International Electrotechnical Commission
ILS	Interlock and Safety System
IP	International Protection
ISO	International Organisation for Standardisation
ITE	Information Technology Equipment
LAN	Local Area Network
LCU	Local Control Unit
LCS	Local Control System
LED	Light Emitting Diode
LEMP	Lightning ElectroMagnetic imPulse
LPZ	Lightning Protection Zone
LRU	Line Replaceable Unit
LSZH	Low-Smoke Zero-Halogen
LV	Low Voltage
N/A	Not applicable
n.c.	Normally closed
n.o.	Normally open
PBC	Protective Bonding Circuit
PCB	Printed Circuit Board
PELV	Protective Extra Low Voltage
PFD	Probability of Failure on Demand
PFH	Probability of dangerous Failure per Hour
PE	Protective Earth
PLC	Programmable Logic Controller
PoE	Power over Ethernet
RCCB	Residual Current Circuit Breaker

RCD	Residual Current Device
RF	Radio Frequency
rms / r.m.s.	root mean square
ROHS	Restriction of Hazardous Substances
SELV	Safety Extra Low Voltage
SIL	Safety Integrity Level
SPD	Surge Protective Device
SRCF	Safety Related Control Function
SRECS	Safety-Related Electrical, electronic and programmable electronic Control System
SRS	Safety Requirements Specification
TBC	To be confirmed
TBD	To be defined
TCF	Technical Construction File
UPS	Uninterruptible Power Supply

2. Related Documents

2.1 Applicable Documents

[INFO-EED-36] The following documents, of the exact issue shown, form part of this Specification to the extent specified herein. Where no issue or date is indicated, the latest edition of the referenced document (including any amendments) at the start of design applies. In the event of conflict between the documents referenced herein and the content of this document Specification, the content of this document Specification shall be considered as a superseding requirement.

2.1.1 ESO Documents

[INFO-EED-38] AD1 ESO Safety Conformity Assessment Procedure;
SAF-GEN-MAN-3444 Version 5
https://kronosrv.hq.eso.org/kronodoc/HQ/ESO-193497/5

[INFO-EED-39] AD2 Control System Development Standards;
ESO-193358 Version 4
https://kronosrv.hq.eso.org/kronodoc/HQ/ESO-193358/4

2.1.2 ESO Drawings

2.1.3 Standards

[INFO-EED-42] AD3 Safety of machinery – Electrical equipment of machines – Part 1: General requirements;
EN 60204-1

[INFO-EED-43] AD4 Electrical Installations for buildings;
EN 60364 series

[INFO-EED-44] AD5 Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors;
EN 60445

[INFO-EED-45] AD6 Electromagnetic Compatibility (EMC);
EN 61000 series

[INFO-EED-46] AD7 Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements;
EN 61010-1

[INFO-EED-47] AD8 Safety of machinery, Functional safety of safety-related electrical, electronic and programmable electronic control systems;
EN 62061

[INFO-EED-48] AD9 Safety of Machinery – Emergency Stop – Principles for design;
EN ISO 13850

[INFO-EED-49] AD10 Mechanical structures for Electronic Equipment – Dimensions of mechanical structures of the 482.6 mm (19 in) series;
EN 60297-3

2.2 Reference Documents

[INFO-EED-51] The following documents, of the exact version shown herein, are listed as background references only. They are not to be construed as a binding complement to the present document.

[INFO-EED-52] RD1 Technical Specification Electrical and Electronic Design;
GEN-SPE-ESO-50000-5401 Version 3
https://kronosrv.hq.eso.org/kronodoc/HQ/ESO-044295/3

[INFO-EED-53] RD2 Technical Specification – Power Quality (compatibility levels);

GEN-ESO-SPE-50000-5044 Version 2
https://kronosrv.hq.eso.org/kronodoc/HQ/ESO-193391/2

[INFO-EED-54] RD3 Technical Specification – Earthing, Bonding and Protection against Lightning and LEMP of ESO Buildings and Structures;
GEN-ESO-SPE-50000-0072 Version 2
https://kronosrv.hq.eso.org/kronodoc/HQ/ESO-193873/2

[INFO-EED-55] RD4 Tests on electric and optical fibre cables under fire conditions;
EN 60332 series

[INFO-EED-56] RD5 Functional safety of electrical/electronic/programmable electronic safety-related systems;
EN 61508 series

[INFO-EED-57] RD6 Adjustable speed electrical power drive systems - Part 5-2: Safety requirements – Functional;
EN 61800-5-2

[INFO-EED-58] RD7 Electromagnetic Compatibility (EMC) including Electromagnetic Pulse (EMP) and Lightning Protection;
VG 95374 series

[INFO-EED-59] RD8 Degrees of protection provided by enclosures (IP Code);
EN 60529

[INFO-EED-60] RD9 Dimensions of low-voltage switchgear and controlgear. Standardized mounting on rails for mechanical support of electrical devices in switchgear and controlgear installations;
EN 60715

[INFO-EED-61] RD10 E-ELT Power Sources General Description;
ESO-200562 Version 3
https://kronosrv.hq.eso.org/kronodoc/HQ/ESO-200562/3

3. Design Requirements

3.1 Principle design requirements

[R-EED-64] D/ / / Any device, equipment or system containing electrical and/or electronic parts shall be designed taking into account the requirements noted down in this chapter. The following list gives a generic overview of these requirements.

[R-EED-65] D/ /I/ Electrical and electronic equipment and/or systems shall:

- comply with relevant specifications and standards described in section 2 and the requirements given in the following sections of this chapter;
- have electrically safe and reliable signal interconnections to other electronic units;
- have reliable and easy to maintain cabling between electronic units;
- be mounted on standardized printed circuit boards in standardized boxes and cabinets;
- have connectors which are of high quality and standardized;
- be provided with local control and monitoring capabilities using to the maximum convenient extent standardized Local Control Units (LCUs);
- be suitable to be powered by the ESO Observatory electric power supply system;
- take into account environmental conditions applicable to the current project including seismic stresses and altitude;
- make use of SRECS satisfying the appropriate SIL for functional safety if needed (in case these aren't already properly implemented by non-electrical/electronic systems);
- be designed as much as convenient on a modular concept, making use of Line Replaceable Units (LRU) to minimize the repair time;
- have provisions to centrally access necessary functions and status signals of electronic units.

[INFO-EED-66] In general any control system compliant with the specific requirements listed in this document will fulfil the generic requirements listed above.

3.2 Safety

3.2.1 General

[R-EED-69] D/ /I/ Systems and subsystems (made up of components and equipment) shall, in addition to the requirements explicitly stated in this document, comply with the essential health and safety requirements (EHSR) contained in all applicable EU Directives.

[R-EED-70] D/ /I/ To ensure a safe design compliance with these EHSRs shall be verified using harmonised standards that are listed in the most recent Official Journal of the EU and that are applicable to the (sub)system (included but not limited to the most common ones listed in section 2).

[R-EED-71] D/ /I/ In case a system can be defined as 'machinery' one shall use EN 60204-1 (AD3) for its electrical equipment as a basis to presume compliance with the Machinery Directive and Low Voltage Directive plus any additional harmonised standards that may fall under the scope of the specific system.

[R-EED-72] D/A/I/ Components and equipment used on systems shall comply with their harmonised EN product or product-family standard or -in case this is not available- a generic standard. Commercially available equipment (COTS) shall bear the CE mark. In case suitable equipment with a CE mark is not available, the usage of non CE marked equipment shall receive explicit approval by ESO, and shall be in compliance with the EHSRs of all applicable EU directives.

[R-EED-73] D/ /I/ Custom made products shall be checked for compliance to the most appropriate harmonised standards under the scope of the applicable Directives (for example, custom made electrical equipment for laboratory type applications shall be verified according to EN 61010-1 (AD7)). Manufacturers shall provide to ESO the relevant CE declaration of conformity together with the Technical Construction File (see section 3.15.8).

[R-EED-74] D/ / / A Hazard Analysis and Risk assessment shall be part of the scope of work. The procedure noted down in AD1 shall be followed and complied with. Additionally the Hazard Analysis and Risk Assessment shall also cover risks to the equipment/system itself.

[R-EED-75] D/ / / ROHS compliance is mandatory for all COTS equipment.

[INFO-EED-76] The following diagram displays the sequence of ESO's compliance engineering tasks (not only limited to electrical design).

[INFO-EED-77]

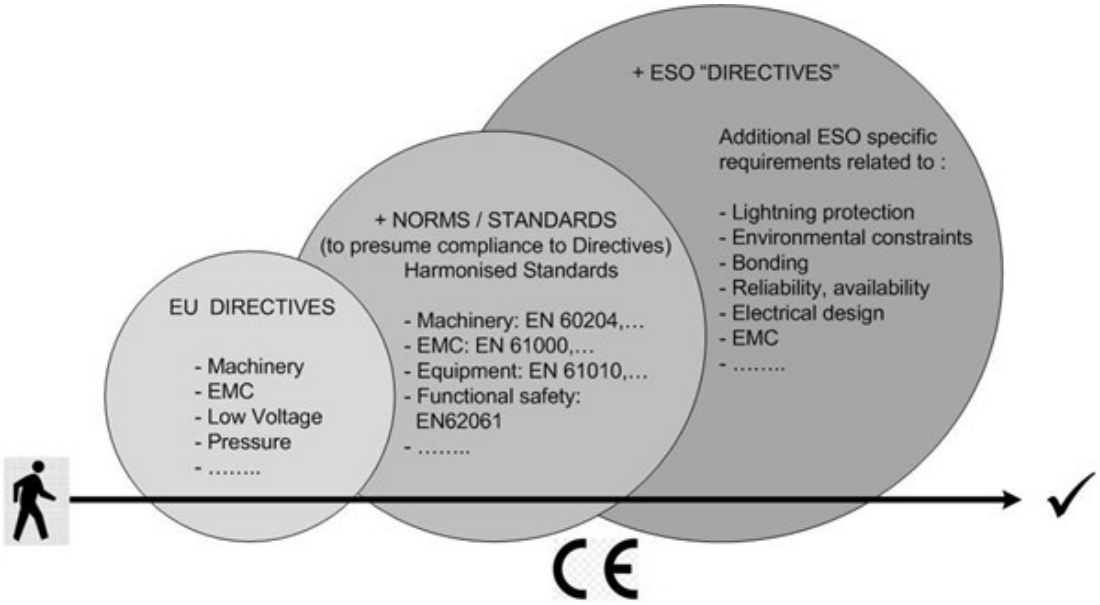

Figure 1: Path a project has to follow to reach compliance with ESO requirements.

[INFO-EED-78] A general overview of commonly applicable EU directives is presented in RD1.

3.2.2 Safety-related control systems on machines

3.2.2.1 Introduction

[INFO-EED-81] Rapid development in network technology used for industrial automation has made it possible to integrate the necessary levels of safety into process control systems that do not exclusively rely on hardwired components anymore. It enables the integration of safety features into automation systems and allows the existence of communication data and safety data on the same distributed network.

[R-EED-82] D/ / / In order to implement the operation of machine safety functions using electrical, electronic and/or programmable electronic control systems, the series of standards EN 62061 (AD8) shall be applicable.

3.2.2.2 EN 62061

[INFO-EED-84] EN 62061 (AD8) is a harmonised standard to the Machinery Directive. It is a product family standard written specifically for the machinery sector and is based on the generic EN 61508, 'Functional safety of electrical/electronic/programmable electronic safety-related systems' (RD5).

[INFO-EED-85] In terms of a design procedure, the following items are handled:

- identify the danger zones on the machine;
- define the risk parameters
- identify the required Safety Integrity Level (SIL)
- design and implement the necessary safety functions;
- determine the SILs
- compare the achieved SIL with the required SIL.

[INFO-EED-86] For the required calculations - such as for the failure rate – reliability data is to be collected from suppliers for specific components or, alternatively, generic data may be used.

3.2.2.3 Safety integrity levels

[INFO-EED-88] EN 62061-5 (AD5), Requirements for the specification of Safety Related Control Functions (SRCFs), explains how the functional requirements specification and safety integrity requirements for each SRCF should be compiled to create a safety requirements specification (SRS). Furthermore, the three safety integrity levels (SIL1/2/3) require that the probability of dangerous failures per hour (PFH/PFD) must fall between certain target values as follows:

[INFO-EED-89] Low Demand Mode

SIL 1: 10-2 ≤ PFD < 10-1 (or 1 failure in 10 years)

SIL 2: 10-3 ≤ PFD < 10-2 (or 1 failure in 100 years)

SIL 3: 10-4 ≤ PFD < 10-3 (or 1 failure in 1000 years)

[INFO-EED-90] High Demand Mode

SIL 1: $10^{-6} \leq PFH < 10^{-5}$ (or 1 failure in 100,000 h)

SIL 2: $10^{-7} \leq PFH < 10^{-6}$ (or 1 failure in 1,000,000 h)

SIL 3: $10^{-8} \leq PFH < 10^{-7}$ (or 1 failure in 10,000,000 h)

[INFO-EED-91] Based on that the safety related electrical control system is designed.

3.2.3 Protection against electric shock

3.2.3.1 General requirements

[R-EED-94] D/ /I/ Protection of persons against electric shock from direct and indirect contact shall be achieved by:

protective measures for direct contact (also called 'protection under normal conditions'):

- Protection by enclosure
- Protection by insulation of live parts
- Protection against residual voltages
- Protection by barriers (double/reinforced insulation)
- Protection by placing out of reach or use of obstacles

[R-EED-95] D/ /I/ protective measures for indirect contact (e.g. existing in case of a single fault condition):

- Prevention of the occurrence of a touch voltage
- Protection by automatic disconnection of supply

[R-EED-96] D/ / / use of protective or safety extra low voltage (PELV/SELV) where applicable

[R-EED-97] D/ /I/ The measures taken shall follow the requirements described in harmonised standards that are most applicable to the system or subsystem. For machinery (see definition in section 1.2) the standard EN 60204-1 (AD3) shall be conformed to.

[R-EED-98] D/ / / Requirements related to the protection against electric shock shall be complied with by following the applicable harmonized standard(s).

3.2.3.2 Protective bonding

[R-EED-100] D/ /I/ Protective bonding is a basic provision for fault protection to enable protection of persons against electric shock from indirect contact. In each situation where protection against electric shock relies on a safe connection to earth, a systems metallic enclosure shall be earthed via the protective earth of the power distribution. The protective bonding circuit (PBC) that is then formed provides the return current path upon which the power distribution circuitry can react in case of a short circuit.

[R-EED-101] D/ /I/ All requirements related to protective bonding shall be complied with, for this purpose EN 60364 (AD4) and EN 61000-5 (part 5 of AD6) are to be followed including possible additional requirements from applicable harmonized standard(s).

[R-EED-102] D/ / / Protective bonding for machinery shall be compliant as per AD3 in general. In particular it has to be compliant with 60364-4 and 60364-5 (parts 4 and 5 of AD4). Please consult the standards and RD3 for a complete picture.

3.3 Electromagnetic Compatibility (EMC)

3.3.1 Requirements

3.3.1.1 General

[INFO-EED-106] A basic set of general requirements for EMC is formulated in the following sections and is to be complied with for each (sub)system and its equipment.

[R-EED-107] / / /T Verification of the EMC requirements shall be done by conducting tests on complete subsystems and/or parts of such subsystem.

[INFO-EED-108] In exceptional cases, based on an evaluation of the EM environment and the peculiarities of the subsystem or parts of it, specific requirements may have to be added or may be relaxed. Also a relaxation on certain tests may be considered. In such cases a contractor shall consult ESO.

3.3.1.2 Commercial equipment

[R-EED-110] D/ /I/ Commercial equipment shall have a CE mark and information on EMC compliance contained in its conformance data sheet (DOC).

3.3.1.3 Intra- and inter-system EMC

[R-EED-112] D/ / /T The (sub)system shall exhibit complete electromagnetic compatibility (EMC) among its parts, components, devices and equipment (intra-system electromagnetic compatibility).

[R-EED-113] D/A/I/ Prevention of electromagnetic interference (EMI) between the (sub)system and systems in its environment (inter-system electromagnetic compatibility) shall be a major driver in the design and construction of the (sub)system.

[INFO-EED-114]

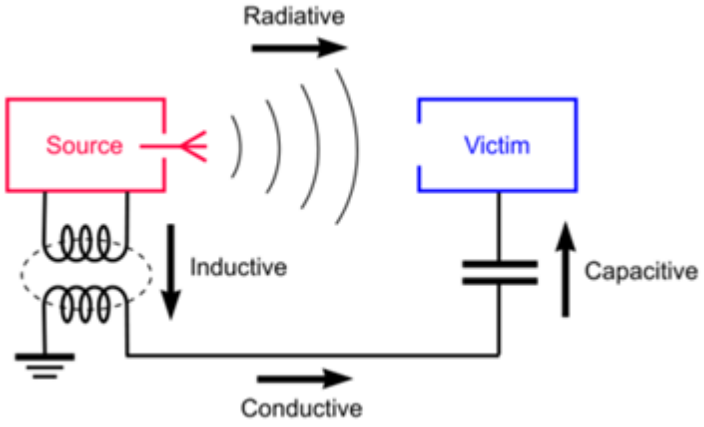

Figure 2: Electromagnetic Interference paths between two systems.

3.3.1.4 Immunity requirements

3.3.1.4.1 Performance criteria

[INFO-EED-117] As a general rule for all immunity tests, the test result is positive if the equipment shows its immunity, based on the applicable performance criterion given in the following table, for the entire period of application of the test. At the end of the tests the equipment under test (EUT) functions as it is supposed to work under normal conditions.

[INFO-EED-118] Performance criteria are:

PERFORMANCE CRITERION	DESCRIPTION
A	The apparatus shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended. The performance level may be replaced by a permissible loss of performance. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, either of these may be derived from the product description and documentation and what the user may reasonably expect from the apparatus if used as intended.
B	The apparatus shall continue to operate as intended after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended. The performance level may be replaced by a permissible loss of performance. During the test, degradation of performance is however allowed. No change of actual operating state or stored data is allowed. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, either of these may be derived from the product documentation and what the user may reasonably expect from the apparatus if used as intended.
C	Temporary loss of function is allowed, provided the function is self-recoverable or can be restored by the operation of the controls.

Table 1: Performance criteria for immunity tests (acc. to part 6-2 of AD6).

3.3.1.4.2 Conducted immunity - Voltage tolerance envelope (ITI (CBEMA) curve)

[R-EED-120] D/A/ /T As a minimum requirement of immunity, all electrical and electronic equipment to be connected to the electric power supply networks of ESO observatories shall be able to operate satisfactory as long as the "magnitude - duration" of the voltage swell is below the overvoltage condition (red curve). Respectively, the "magnitude - duration" of the voltage dip is above the undervoltage conditions (blue curve) of the so-called ITI (CBEMA) curve for equipment (for reference see RD1).

[INFO-EED-121]

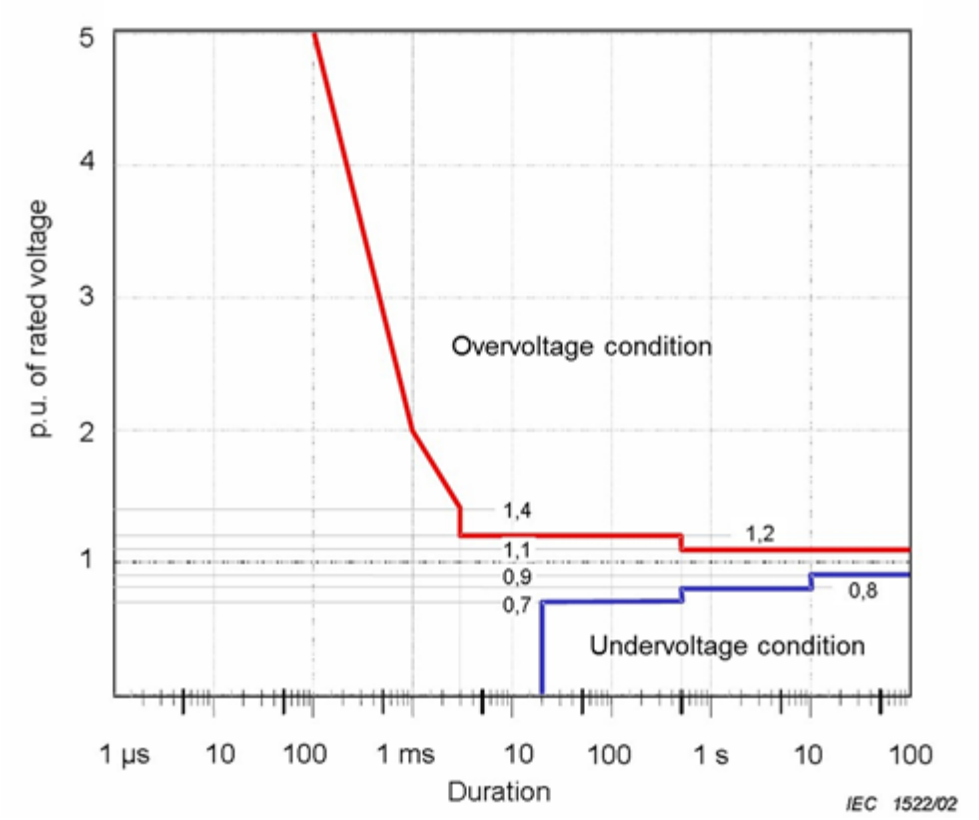

Figure 3: ITI (CBEMA) curve – Voltage tolerance envelope.

[INFO-EED-122] Performance criterion: A (see 3.3.1.4.1).

[INFO-EED-123] Verification to be done by test, alternatively the DOC of applicable parts or equipment may provide evidence of compliance.

[INFO-EED-124] For a general description of the E-ELT power sources and their main characteristics and limitations please refer to RD10.

3.3.1.4.3 Conducted immunity - Voltage dips

[R-EED-126] D/A/ /T The immunity limit for voltage dips on AC mains voltage lines to subsystems and equipment shall be:

- 0% residual voltage (ΔU1 = 100%) for 1 cycle (20 ms) – performance criterion B (see section 3.3.1.4.1 for the definition of performance criteria);
- 40% residual voltage (ΔU2 = 60%) for 10 cycles (200 ms) – performance criterion C;
- 70% residual voltage (ΔU3 = 30%) for 25 cycles (500 ms) – performance criterion C.

[INFO-EED-127] Verification to be done by test, alternatively the DOC of applicable parts or equipment may provide evidence of compliance.

3.3.1.4.4 Conducted immunity - Voltage interruptions

[R-EED-129] D/A/ /T The immunity to short voltage interruptions (0% residual voltage, ΔU_1 = 100%) for 250 cycles (5s) on AC mains voltage lines shall be according to performance criterion C. This requirement only applies to non-UPS supplied equipment. Verification to be done by test, alternatively the DOC of applicable parts or equipment may provide evidence of compliance.

3.3.1.4.5 Conducted immunity - Voltage (current) surges

[R-EED-131] D/ / / Subsystems and equipment shall be required to contain a level of immunity to high-energy disturbances on power and inter-connection lines caused by overvoltages from switching and lightning transients.

[INFO-EED-132] Switching transients can be separated into transients associated with:

- major power system switching disturbances, such as capacitor bank switching;
- minor switching activity near the instrumentation;
- load changes in the power distribution system;
- resonating circuits associated with switching devices, such as thyristors;
- system faults such as short circuits or arcing faults to the earthing system.

[INFO-EED-133] Major mechanisms by which lightning produces surge voltages are:

- a direct lightning stroke to an external circuit (outdoor) injecting high currents which produce high voltages by either flowing through earth resistance or flowing through the impedance of the external circuit;
- An indirect lightning stroke (e.g. between or within clouds) that induces voltages / currents on the conductors outside and/or inside a building;
- lightning earth current flow resulting from nearby direct-to-earth discharges coupling into the common earth paths at the earthing system of the installation.

[INFO-EED-134] The rapid change of voltage and flow of current, which may occur when a protector is excited, may couple into internal circuits.

[INFO-EED-135] The following classes of installation are defined according to annex B of EN 61000-4-5 (part 4-5 of AD6).

[INFO-EED-136]

CLASS	DESCRIPTION
0	Well-protected electrical environment, often within a special room.
1	Partly protected electrical environment.
2	Electrical environment where cables are well separated, even at short runs.
3	Electrical environment where cables run in parallel.
4	Electrical environment where the interconnections are running as outdoor cables along with power cables, and cables are used for both electronic and electric circuits.
5	Electrical environment for electronic equipment connected to telecommunication cables and overhead power lines in a non-densely populated area.

Table 2: Installation classes for electrical environments.

[INFO-EED-137] Compliance levels following the above mentioned different installation classes are given in the following table:

[INFO-EED-138]

INSTALLATION	TEST VOLTAGE LEVELS

	Power supply coupling mode		Unbalanced operated circuits/lines, LDB coupling mode		Balanced operated circuits/lines coupling mode		SDB, DB[1)] coupling mode	
	Line to line(kV)	Line to earth(kV)	Line to line(kV)	Line to earth(kV)	Line to line(kV)	Line to earth(kV)	Line to line(kV)	Line to earth(kV)
0	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	0.5	0.5	0.5	NA	0.5	NA	NA
2	0.5	1.0	1.0	1.0	NA	1.0	NA	0.5
3	1.0	2.0	2.0	2.0[3)]	NA	2.0[3)]	NA	NA
4	2.0	4.0[3)]	2.0	4.0[3)]	NA	2.0[3)]	NA	NA
5	[2)]	[2)]	2.0	4.0[3)]	NA	4.0[3)]	NA	NA
Acronyms : DB = copper data bus/line,SDB = short-distance bus, LDB = long distance bus								
[1)] Limited distance, special configuration and layout, 10-30 m max. : no test up to 10 m, class 2 [2)] Depends on the class of the local power supply system [3)] Normally tested with primary protection								

Table 3: Compliance levels for surge immunity test.

[R-EED-139] D/ / /T As a general rule subsystems and equipment shall withstand class 3 severity levels as given in Table 3 taking into account performance criterion B as defined in Table 1.

Exceptions to this rule may be handled according to #108 and may involve the choice for a different installation class according to Table 2.

It is typically necessary to install surge protective devices to meet this requirement.

[R-EED-140] / / /T A test (see requirement #107) to verify immunity to surges according to the above said classes shall typically involve the injection of surges with a rise time T_r is1,2 microseconds and hold time T_h is 50 microseconds (8/20 microseconds for current injection) see part 4-5 of AD6 for further details.

3.3.1.4.6 Conducted immunity - Electrical Fast Transient (EFT) / Burst

[R-EED-142] D/ / /T Subsystems and equipment shall be required to contain a level of immunity when subjected to types of transient disturbances such as those originating from switching transients (interruption of inductive loads, relay contact bounce, etc.). Designers shall follow proper design practice to avoid such disturbances being emitted from their equipment.

This repetitive fast transient test is a test with bursts consisting of a number of fast transients, coupled into the power supply, control and signal ports of electrical and electronic equipment.

The recommended selection of required levels noted down in the following table shall be done according to the characteristics of the electromagnetic environment the system is in (e.g. well-protected environments like computer control rooms versus industrial environments where higher levels are applicable). For I/O, control, signal and data ports it is required to choose half the test voltage value applied on power supply ports.

[INFO-EED-143]

Environment[1)]	Voltage level (kV)
1 (well–protected environment)	0.5
2 (protected environment)	1.0
3 (typical industrial environment)	2.0

4 (severe industrial environment)	4.0
[1)] See EN 61000-4-4 (part 4-4 of AD6) for a detailed description on levels 1-4.	

Table 4: EFT environments and required levels.

[R-EED-144] D/ / /T As a general rule subsystems and equipment shall withstand class 2 severity levels as displayed in Table 4 taking into account performance criterion B as defined in Table 1.

[INFO-EED-145] Exceptions to this rule may be handled according to #108 and may involve the choice for a different installation class according to Table 2.

[INFO-EED-146] Verification of this requirement (see #107) involves tests as described in EN 61000-4-4 (part 4-4 of AD6). Typical parameters for the injected surge are: rise time T_r = 5 ns, hold time T_h = 50 ns and repetition rate = 5 kHz.

3.3.1.4.7 Immunity to conducted disturbances induced by RF fields

[R-EED-148] D/ / /T Subsystems and equipment shall be required to contain a level of immunity to EM fields, coming from intended RF transmitters (e.g. hand-held radios), that may act on the whole length of cables connected to installed equipment (cables then may act as passive receiving antenna networks of several wavelengths). Verification of this requirement involves tests as described in EN 61000-4-6 (part 4-6 of AD6) where the frequency range shall typically be from 150 kHz – 80 MHz and levels shall be similar to section 3.3.1.4.9 according to the appropriate class.

[INFO-EED-149] The test method to verify immunity to such conducted disturbances typically involves the use of a ferrite clamp to inject RF signals into cables while inspecting system behaviour.

3.3.1.4.8 Electrostatic Discharge (ESD) requirements

[R-EED-151] D/ / /T Subsystems and equipment shall be required to contain a level of immunity to electrostatic discharge (ESD) according to part 4-2 of AD6.

[INFO-EED-152] Compliance levels according to EN 61000-4-2 (part 4-2 of AD6) are:

Level	Contact discharge test voltage (kV)	Air discharge test voltage (kV)
1) Relative humidity as low as 35%, anti-static material	2	2
2) Relative humidity as low as 10%, anti-static material	4	4
3) Relative humidity as low as 50%, synthetic material	6	8
4) Relative humidity as low as 10%, synthetic material	8	15

Table 5: ESD levels.

[R-EED-153] D/ / /T As a general rule subsystems and equipment installed shall withstand the levels of ESD presented in Table 6 when injected to any accessible points outside of a closed cabinet (e.g. door handles or removable panels) and other parts representing an ESD risk (for a complete description of applicable points see part 4-2 of AD6).

[INFO-EED-154]

Method	Level	Criteria
Air-Discharge	3) 2 to 8 kV in 2kV increments.	Criteria B up to 8kV
Contact	4) 2 to 6 kV in 2kV increments.	Criteria B up to 6kV

Table 6: ESD requirements

[INFO-EED-155] Exceptions to these levels may be handled according to #108 and may involve another choice of level according to Table 5.

3.3.1.4.9 Radiated immunity - EM fields.

[R-EED-157] D/ / /T Systems and subsystems shall be required to comply with the limits on radiated EM field immunity according to the limits set forth in the generic EMC standard for immunity in industrial environments EN 61000-6-2 (part 6-2 of AD6).

[INFO-EED-158] Different types of environments classes are defined by this standard:

CLASS	DESCRIPTION
1	Low-level EM radiation environment. Levels typical of local radio/television stations located at more than 1 km, and transmitters/receivers of low power.
2	Moderate EM radiation environment. Low power portable transceivers (typically less than 1 W rating) are in use, but with restrictions on use in close proximity to the equipment. A typical commercial environment.
3	Severe EM radiation environment. Portable transceivers (2 W rating or more) are in use relatively close to the equipment but not less than 1 m. High power broadcast transmitters are in close proximity to the equipment and ISM equipment may be located close by. A typical industrial environment.

Table 7: Classes of EM radiation environments.

[R-EED-159] D/ / /T For the frequency range from 80-1000 MHz, the related field strength the system shall be immune to (according to the appropriate class) is given in the following table:

Level	Test Field Strength (V/m)	Test Parameters
1	1	80% AM (amplitude modulated) with 1 kHz sinewave, acc. to EN 61000-4-3
2	3	
3	10	

Table 8: Radiated EM field immunity test levels from 80-1000, 800-960 and 1400-2000 MHz.

[R-EED-160] D/ / /T For the frequency range from 800-960 MHz and 1.4 – 2 GHz (the measurement range 1.4 GHz to 2.0 GHz may be reduced to cover just the specific frequency bands allocated to digital mobile telephones in the country of use) , bands that are related to the protection against RF emissions from digital radio telephones, the applicable related field strength the system shall be immune to (according to the appropriate class) is similar to what is given in Table 8.

[R-EED-161] / / /T In general, systems in ESO projects shall be considered to be placed in a class 3 environment (immunity to a field strength of 10 V/m) and shall obey performance criterion B. Verification of this requirement involves tests and test parameters (frequency, modulation, etc.) as described in EN 61000-4-3 (part 4-3 of AD6).

[INFO-EED-162] Exceptions to these levels may be handled according to #108.

3.3.1.5 Emission requirements

[R-EED-164] D/ / /T The radiated and conducted electromagnetic disturbances emitted shall not exceed the limits set in the sections below. Margins for emission shall be provided based on system operational performance requirements, tolerances in system hardware, and uncertainties involved in verification of system-level design requirements.

3.3.1.5.1 Conducted emission - Harmonic currents

[R-EED-166] D/ / /T For rated currents ≤ 16A per phase the harmonic current emission limits shall satisfy the values given in EN 61000-3-2 (part 3-2 of AD6) according to the applicable class.

[R-EED-167] D/ / /T For rated currents > 16A the harmonic currents injected into the power distribution system shall not exceed the percent ratios given in IEC 61000-3-4 and noted down in the following Table 9 where I_1 = rated fundamental current and I_n = harmonic current.*

* Note: Higher emission values may be allowed, provided the short-circuit ratio Rsce is > 33.

[INFO-EED-168]

Harmonic number n	Admissible harmonic current I_n/I_1 (%)	Harmonic number n	Admissible harmonic current I_n/I_1 (%)
3	21.6	21	≤ 0.6
5	10.7	23	0.9
7	7.2	25	0.8
9	3.8	27	≤ 0.6
11	3.1	29	0.7
13	2	31	0.7
15	0.7	≥33	≤ 0.6
17	1.2		
19	1.1	Even	≤ 8/n or ≤ 0.6

Table 9: Harmonic current emission limits (simplified connection, rated current > 16A).

3.3.1.5.2 Conducted emission - RF disturbance voltage

[R-EED-170] D/ / /T Conducted radio-frequency terminal disturbance voltages on low voltage AC mains power ports shall not be emitted in excess of the values given below taken from the generic EMC standard EN 61000-6-3 (part 6-3 of AD6) for emission in residential commercial and light industrial environments and noted down in the following Table 10. DC power ports (if applicable) shall conform to the limits noted down in the same standard.

[INFO-EED-171]

LOW VOLTAGE AC MAINS TERMINAL DISTURBANCE VOLTAGE LIMITS dB(μV)		
Frequency band (MHz)	Quasi-peak	Average
0.009 – 0.15	See EN 61000-6-3	See EN 61000-6-3
0.15 – 0.50	66 Decreasing linearly with logarithm of frequency to 56	56 Decreasing linearly with logarithm of frequency to 46
0.50 – 5	56	46

5 – 30	60	50

Table 10: Mains terminal RF disturbance voltage limits (acc. to class B ITE - CISPR22).

[INFO-EED-172] The test method to verify emission of such conducted disturbances can be found in EN 61000-4-6 (part 4-6 of AD6).

3.3.1.5.3 Conducted emission - Voltage fluctuations and flicker

[R-EED-174] /A/ /T Voltage fluctuations and flicker injected into a power distribution system shall not exceed the limits in current industrial practice to avoid misoperation of monitors and the like. Verification may be done by test or analysis.

3.3.1.5.4 Radiated emission - Radiated field emission limits

[R-EED-176] D/ / /T Systems and subsystems shall be required to comply with the limits on radiated field emission according to the generic EMC standard EN 61000-6-3 (part 6-3 of AD6) for emission in residential commercial and light industrial (or domestic) environments and noted down in Table 11.

[INFO-EED-177]

RADIATED FIELD EMISSION LIMITS dB(μV/m)		
Frequency band (MHz)	Quasi-peak at 10m	Quasi-peak at 3m
30-230	30	40
230-1000	37	47
	Average at 3m	Peak at 3 m
1000-3000	50	70
3000-6000	54	74

Table 11: Radiated field emission limits (according to class B ITE as per CISPR22).

[INFO-EED-178] The following conditions apply to the applicability of the frequency range in Table 11 (the highest internal source of an EUT is defined as the highest frequency generated or used within the EUT or on which the EUT operates or tunes):

[INFO-EED-179]

Highest frequency f of the internal sources of the EUT	Measurement range
f < 108 MHz	up to 1 GHz
108 MHz ≤ f < 500 MHz	up to 2 GHz
500 MHz ≤ f ≤ 1000 MHz	up to 5 GHz
f > 1000 MHz	up to 6 GHz

Table 12: Applicability of radiated field emission measurement ranges.

3.3.1.6 EMC Control Plan

[R-EED-181] D/ / / The manufacturer of a system or equipment shall submit an EMC Control Plan that describes the design measures implemented to conform to the requirements set in the project on EMC, grounding, protection against lightning and LEMP. The EMC Control Plan shall be prepared according to the procedures and purposes set in RD7 or a similar reference standard.

3.4 Digital (logic) Signals

3.4.1 Signal levels

[R-EED-184] D/ / / The voltage level of logic signals shall be 24 VDC. Other lower voltage levels may be chosen if strictly necessary, however are not preferred.

3.4.2 Interconnection methods with 24V supply

[R-EED-186] D/ /I/ The 24V system for non-safety related applications is intended for interconnection with relays or optocouplers and shall therefore be galvanically isolated according to the applicable norms. The interconnection cable shall be shielded. Recommended ways of interconnection can be found in RD1.

3.4.3 Interconnection methods with voltage levels lower than 24V

[R-EED-188] D/ /I/ An interconnection method with galvanic isolation is required in case of a connection between a UPS powered control system and machinery that is not supplied by UPS.

[R-EED-189] D/ /I/ An interconnection method with differential signals is required in the case that all conditions that follow are valid:

- Cable length above 3 meters.
- Galvanic isolation is not implemented.

[R-EED-190] D/ /I/ The interconnection method with single ended driver and single ended receiver is generally not recommended and shall only be used in case all following conditions are valid:

- A cable length of not more than 3 meters.
- Galvanic isolation is not required.
- The receiver has a Schmitt trigger input.

3.5 Analogue Signals

3.5.1 Signal levels

[R-EED-193] D/ / / Analogue signals shall either be of voltage or current type. Voltage-type analogue signals shall be restricted to local interconnect to fieldbus I/O modules or inside electrical cabinets. Cables used for these connections shall provide the proper shielding properties to fully ensure electromagnetic

compatibility (EMC) of the carried signal. Current-type analogue signals shall be used for long cable interconnects and be restricted to 4-20mA level.

3.5.2 Interconnection methods

[R-EED-195] D/ /I/ The interconnection cable shall be shielded and twisting is recommended.

[INFO-EED-196] Recommended ways of interconnection can be found in RD1.

3.6 Earthing, Bonding and Protection against Lightning and LEMP

[INFO-EED-198] Section 3.3.1.4.5 formulates requirements on lightning overvoltage/over-current surges for electrical equipment. For further information please refer to RD3.

[R-EED-416] D/ /I/ For the sake of grounding and equipotential bonding, metallic structures, cabinets, ducts and similar components shall apply the methods described in RD3.

3.7 Cabling

3.7.1 General

[INFO-EED-201] Apart from the general design requirements noted down in 3.1 that are valid for cabling, this subsection contains additional requirements. Cabling guidelines on EMC can be found in RD1.

[R-EED-202] D/ /I/ Any type of electrical cable (power, control, telecommunication, data, signal, etc.) shall be shielded. If the use of unshielded cables is needed in exceptional cases this shall be communicated to ESO for approval.

3.7.2 Fire properties

[R-EED-204] D/ / / Any cable installed for any purpose and application (power, control, telecommunication, data, signal, etc.) whether electrical or optical shall not propagate fire. To this purpose it shall conform and have been successfully type tested to the series of EN 60332-1 (part 1 of RD4).

[R-EED-205] D/ / / The same non fire propagating property shall be exhibited by any cable routing means made of non-metallic materials.

[R-EED-206] D/ /I/ When cables are laid in bunches additional fire propagation protection measures shall be taken (as e.g. use of cables conforming to the series of EN 60332-3 (part 3 of RD4), use fire blocking and partitioning materials, separate the cables of the bunch, use of automatic fire alarm - detection and extinguishing system, etc) in order eliminate the risk of fire propagation through the cable bunch.

[R-EED-207] D/ /I/ In locations where fire hazards exists, in all installations where people might be concentrated or where equipment having high property value exists, in addition to the above mentioned fire properties requirements any cable and cable routing means used shall be of the low-smoke zero-halogen (LSZH) type.

[R-EED-208] D/ /I/ To this purpose they shall conform and have been successfully type tested to the following standards:

- IEC 60754-1, “Test on gases evolved during combustion of materials from cables – Part 1: Determination of the halogen acid gas content”;
- IEC 60754-2, “Part 2: Determination of acidity (by pH measurement) and conductivity”;
- EN 61034-2, “Measurement of smoke density of cables burning under defined conditions - Part 2: Test procedure and requirements”.

3.7.3 Cable dimensions

[R-EED-210] D/ /I/ The minimum cross sectional area of copper conductors shall be according to AD3. Conductors with smaller cross-sectional areas or other constructions than shown in AD3 may be used in equipment provided adequate mechanical strength is achieved by other means and proper functioning is not impaired.

[R-EED-211] D/ /I/ The current carrying capacity of cables and conductors shall be according to EN 60364-5-52 (part 5-52 of AD4) for a given method of installation. Since current-carrying capacity depends on factors like insulation material, number of conductors in a cable, design (sheath), methods of installation, grouping and ambient temperature, correction factors shall apply. In cases where cables are laid close to the optical path in a Telescope it is to be reminded that over-dimensioning may be needed to avoid hot spots.

3.7.4 Cable routing

[R-EED-213] D/ /I/ Cable routing shall be reliable and maintenance friendly and shall be done according to the following basic principles:

[R-EED-214] D/ /I/ Cables and cable bunches outside cabinets, racks or enclosures shall be put in metallic conduit or metal ducts. Other methods, if intended to be used, need to get prior ESO approval.

[R-EED-215] D/ /I/ Wiring inside enclosures shall be placed in conduits or ducts. If this may not be possible or impractical, conductors and cables that do not run in ducts shall still be adequately supported.

[R-EED-216] D/ /I/ Cables shall be protected against damage from abrasion, contact with sharp edges or protrusions and environments.

[R-EED-217] D/ /I/ Accessibility of cables shall be provided to the maximum extent possible.

[R-EED-218] D/ /I/ Cable arrangement and connector bracket design shall allow rapid operational disconnection.

[R-EED-219] D/ /I/ The cabling supporting devices shall provide the possibility for removal and replacement of cables for maintenance.

[R-EED-220] D/ /I/ The cabling routing shall ensure connector replacement capability.

[R-EED-221] D/ /I/ The bending radius shall not be smaller than the minimal value as specified by the cable manufacturer. Flexible cable shall be used for functions requiring movements. Frequently moved cables like the ones laid in cable wraps shall be specifically designed for this purpose.

[R-EED-222] D/ /I/ In conduit and ducts a recommended amount of 40% spare space shall be reserved for future use.

[R-EED-223] D/ /I/ The most direct routing of cables and ducts compatible with structural provisions shall be applied. However, EMC requirements prevail over practical considerations, convenience of mounting and aesthetic aspects.

[R-EED-224] D/ /I/ Power and signal cables shall be routed as far away as possible from each other.

[R-EED-225] D/ /I/ All cables/ducts shall be positioned as close as possible to structural components.

[R-EED-226] D/ /I/ Earthed conductors shall be routed parallel to live conductors to keep earth loop areas small.

[R-EED-227] D/ / / Cable routing shall be planned and designed to comply with the installation and mitigation guidelines contained in EN 61000-5 (part 5 of AD6), in particular, but not exclusively, with those specified in EN 61000-5-2, “Earthing and cabling” (part 5-2 of AD6).

[R-EED-228] D/ / / If not already mentioned in the above list, possible additional requirements set forth by a harmonised standard that is applicable to the (sub)system (see section 3.2.1) shall also be complied with.

3.7.5 Cable/conductor identification

[R-EED-230] D/ /I/ Conductors of any cable terminated at terminal blocks shall be individually identifiable by means of alphanumeric codes attached to the conductor. As an alternative, identification through colour coding alone may be used. This method however can only be accepted in case the cable number or the terminal block number is unambiguously identifiable and visible. Other methods shall always allow unique conductor identification and require prior approval by ESO.

[INFO-EED-231]

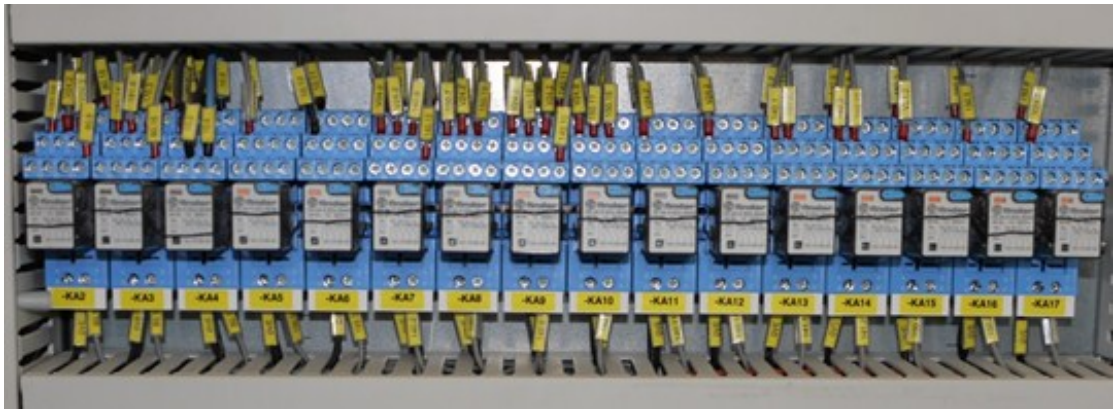

Figure 4: Identification of conductors by means of alphanumeric codes

[R-EED-232] D/ /I/ Identification tags shall be legible, permanent and appropriate for the environment, resistive to wear from abrasion, from presence of water, oils, etc. No paper or any type of hand written labels or stickers is allowed.

[R-EED-233] D/ /I/ The cable labelling scheme, whenever feasible, shall allow identifying as to which subsystem, equipment or part the cable belongs to. It shall be consistent with the technical documentation.

[R-EED-234] D/ /I/ Where UPS power is present the relevant items shall be identified (e.g. by labels).

3.7.5.1 Power cables

[R-EED-236] D/ /I/ Low voltage AC power distribution systems are implemented as a TN-S system. AC power cables shall therefore contain:

L1, L2, L3, N (neutral) and PE (protective earth) for three phase power cables.

L (line conductor), N (neutral) and PE (protective earth) for single phase power cables.

[R-EED-237] D/ /I/ All power cables (AC or DC) and relevant connection terminals shall bear identification in full compliance with the requirements of EN 60445 (AD5).

3.7.5.1.1 Colours of power cables

[R-EED-239] D/ /I/ Colours of power cables shall be according to harmonised standard EN 60445 (AD5) as indicated by the following scheme:

	Single phase			Three phase				
Conductor:	PE	N	L	PE	N	L1	L2	L3
Colour:	Green/ yellow	Light blue	Brown	Green/ yellow	Light blue	Brown, Black **or** Grey		
								

Table 13: Colours of power cables according to AD5.

[R-EED-240] D/ /I/ Where identification is by colour alone, the protective earth (PE) conductor shall be coloured green-and-yellow throughout its whole length. This colour identification is strictly reserved for the PE conductor and the colours green as well as yellow shall be avoided for other wiring in case this may cause confusion.

[R-EED-241] D/ /I/ Where a circuit includes a neutral conductor identified by colour, the colour shall be light-blue. This colour shall be avoided on other conductors in case confusion may arise.

[R-EED-242] D/ /I/ Where a circuit includes a cable supplied from an external power source the cable shall be identified by orange colour.

3.7.5.2 Signal cables

3.7.5.2.1 Colour coding of signal conductors

[R-EED-245] D/ / / In case colour coding is chosen identification shall be done by an internationally accepted standard.

[INFO-EED-246] As an example DIN 47100 may be used for paired cables (although withdrawn still widely used) as indicated in the table below:

[INFO-EED-247]

Pair #	Colour of a-conductor	Colour of b-conductor	Pair #	Colour of a-conductor	Colour of b-conductor
1	white	Brown	13	white/black	brown/black
2	green	yellow	14	grey/green	yellow/grey
3	grey	pink	15	pink/green	yellow/pink
4	blue	red	16	green/blue	yellow/blue

5	black	violet	17	green/red	yellow/red
6	grey/pink	red/blue	18	green/black	yellow/black
7	white/green	brown/green	19	grey/blue	pink/blue
8	white/yellow	yellow/brown	20	grey/red	pink/red
9	white/grey	grey/brown	21	grey/black	pink/black
10	white/pink	pink/brown	22	blue/black	red/black
11	white/blue	brown/blue	23-44	see 1-22	see 1-22
12	white/red	brown/red	45-66	see 1-22	see 1-22

Table 14: Colour identification for paired cables (acc. to DIN 47100)

[INFO-EED-248] Colour identification for single conductors from the same standard may be as displayed in the next table.

[INFO-EED-249]

Conductor number	Colour	Conductor number	Colour	Conductor number	Colour
1	white	12	red/blue	23	white/red
2	brown	13	white/green	24	brown/red
3	green	14	brown/green	25	white/black
4	yellow	15	white/yellow	26	brown/black
5	grey	16	yellow/brown	27	grey/green
6	pink	17	white/grey	28	yellow/grey
7	blue	18	grey/brown	29	pink/green
8	red	19	white/pink	30	yellow/pink
9	black	20	pink/brown	31	green/blue
10	violet	21	white/blue	32	yellow/blue
11	grey/pink	22	brown/blue	33-61	see DIN 47100

Table 15: Identification for single signal conductors (without colour repetition)

[INFO-EED-250] Local Area Network (LAN) cabling

Preferred colour for a straight cable of TIA/EIA 568A type using RJ45 connectors (also for 'Power over Ethernet' if applicable):

[INFO-EED-251]

Pin #	Colour
1	White with green stripe
2	Green
3	White with orange stripe
4	Blue
5	White with blue stripe
6	Orange
7	White with brown stripe
8	Brown

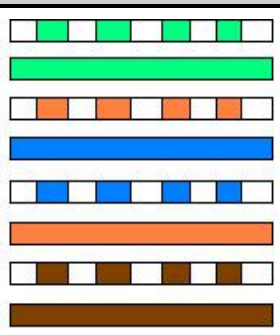

Table 16: Colour identification for LAN cabling

3.7.6 Fibre optic cables

[R-EED-253] D/ /I/ Fibre optic cables shall be able to withstand movement and bending where applicable and shall be compliant with their harmonised product standard.

[R-EED-254] D/ /I/ Optical fibre type shall be single-mode (OS2 transmission standard). All fibres shall be certified for 10Gbit/s operation according to ANSI/TIA-568-C.3. In some specific applications, after ESO approval, 1Gbit/s certification may be considered.

3.8 Connections

3.8.1 General

[R-EED-257] D/ /I/ Electrical connections to terminal blocks shall be made with screw terminals using ferrules with insulating collar for fine stranded wires. As an alternative, subject to prior approval by ESO, cage-clamp (spring) terminals without the use of ferrules may be used.

3.8.2 Marking

[R-EED-259] D/ /I/ All connectors shall be marked in order to uniquely identify them. All mating sockets shall also be correspondingly marked.

[R-EED-260] D/ /I/ Cable connectors have to be labelled on the cable, just behind the connector, or directly on the connector if possible. The panel sockets have to be labelled on the panels where they are mounted.

[R-EED-261] D/ /I/ A cable identification label shall be permanently marked at each end of the cable. If the total length of the cable is less than 30 cm and the cable is visible in its full size without removal of any other parts, then only one cable identification label is acceptable.

[INFO-EED-262]

Figure 5: Example of proper identification of cables and sockets/connectors.

3.8.3 Electric power connectors

[R-EED-264] D/ /I/ Electric power shall be supplied utilising the following standard connectors subject to current and voltage ratings.

[INFO-EED-265] Three phase 400 VAC connectors according to EN 60309

EN 60309-2 type. 3L+N+PE, 240/415V (red type), earthing contact at 6h. Rated current according to application.

[INFO-EED-266]

Figure 6: EN 60309-2, 3L+N+PE 6h.

[INFO-EED-267] Single phase 230 VAC connectors

According to CEE 7/4 (SCHUKO type F). Rated current 16A.

[INFO-EED-268]

Figure 7: SCHUKO plug/socket

[INFO-EED-269] L+N+PE, 220/250V blue type (acc. to EN 60309), earthing contact may be used in cases where the CEE-el 7/VII (SCHUKO) type connector can't be used.

[INFO-EED-270]

Figure 8: L+N+PE 6h, single phase

[INFO-EED-271] Single phase 230 VAC connectors for non-COTS equipment

According to EN 60320. Preferred type: C13, L+N+PE.

The use of a cable clamp is recommended.

[INFO-EED-272]

Figure 9: EN 60320 C13/14 connectors

[R-EED-273] / /I/ When, e.g. during a commissioning phase, it is unavoidable to make use of other types of plugs, the use of them shall always involve adapters to the SCHUKO system and shall be of a temporary nature.

3.8.4 Signal connectors

[R-EED-275] D/ /I/ Signal connectors shall make use of crimped pins/terminals, no soldered connections.

[R-EED-276] D/ /I/ The connectors shall be selected based on their intended use and environment. A list of possible connectors is given in RD1.

3.8.5 Optical fibre connectors

[R-EED-278] D/ /I/ Optical fibre shall be exclusively equipped with LC-type connectors.

3.8.6 Break-out box

[R-EED-280] D/ /I/ If a break-out box is needed, this shall be of metal and it shall have a similar schematic as shown in Figure 10. The example shows a sub-D connector and the following characteristics:

- The break-out box can be inserted into the system without changing its electronic characteristics.
- Each connection can be opened individually with banana contacts.
- The shielding shall be fed through.
- Box material shall be electrically conducting.

[INFO-EED-281]

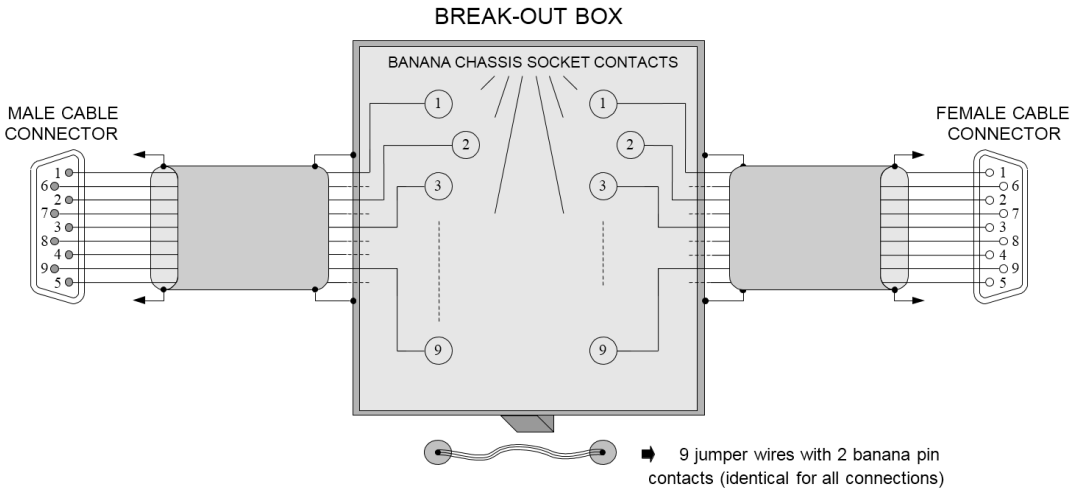

Figure 10: Break-out box principle

3.9 Printed circuit boards (PCBs)

[R-EED-283] D/ /I/ Printed circuit boards (PCB) shall be developed with dimensions and connectors according to EN 60297-3 (AD10), except in cases of space limitations. Recommended dimensions of printed circuit boards (PCB) are:

- height 100 mm, depth 160 mm.
- height 100 mm, depth 220 mm.
- height 233 mm, depth 160 mm.

[R-EED-284] D/ /I/ Insulation shall be designed according to relevant safety standards (see section 3.2.1) so as to provide proper creepage and clearance distance (taking into account the environmental conditions) as well as appropriate distance through insulation.

[INFO-EED-285] EMC recommendations on PCB design can be found in RD1.

3.10 Cabinets and devices

[R-EED-287] D/ /I/ Cabinets for mounting of electronic equipment shall be according to EN 60297-3 (AD10). The type of cabinet shall be standardised and shall be of metal. The use of another type or custom designed cabinet is allowed after explicit approval by ESO.

[R-EED-288] D/ / / IP protection of a cabinet shall be appropriate for its expected environment as per RD8.

[R-EED-289] D/ /I/T All cabinets in an environment where light pollution is forbidden (especially inside astronomical telescopes and/or instruments) shall have opaque metallic doors and panels in order to eliminate such pollution. If LEDs or other light indicators are mounted on the exterior of such cabinets there must be a switch to disable them.

[INFO-EED-290] EMC requirements may imply the use of HF screened-, custom made cabinets.

3.10.1 Accessibility

[R-EED-292] D/ /I/ In order to facilitate maintenance, service and repair of equipment, cabinets shall generally not have a height above 2 meters. Deviation of this requirement may only be granted after prior approval of ESO.

[R-EED-293] D/ /I/ All elements inside electrical or electronic cabinets (including terminal blocks) must have good access in order to allow maintenance, trouble-shooting and easy replacement.

[R-EED-294] D/ /I/ When the cabinet is installed in its final location, doors shall allow to be opened by at least 90 degrees. For safety reasons open cabinet doors shall not block the escape path from inside the cabinet.

[R-EED-295] D/ /I/ At the back of a cabinet access shall be provided in order to allow access for possible maintenance and repair.

[R-EED-296] D/ /I/ Indicators, displays, control actuators and the like shall be mounted on the front panel. Preferred location is 120-140 cm above floor for control elements and 160 cm for screens, meters, etc. All other elements and devices (including screw terminals) shall be mounted on the back panel of the cabinet; mounting on the side walls should be avoided. Other methods shall be agreed with ESO.

[R-EED-297] D/ /I/ The mounting method of devices shall allow easy replacement (e.g. DIN-rails). Devices mounted on DIN-rail (and similar) should be prevented from slipping sideways by means of mechanical hold-downs at both ends of the device(s). For reference see EN 60715 (RD9).

3.10.2 Connection of field devices

[R-EED-299] D/ /I/ All field devices connections shall be terminated on screw type terminal strips or cage-clamp (spring) terminals. An alternative way to interface specific LCU level signals to the field (e.g. motor control functions) could be by using intermediate mating connectors mounted directly on the rear panel of the LCU chassis or on a mounting plate/DIN-rail.

3.10.3 Space

[R-EED-301] D/ /I/ If it can be reasonably expected that future additions or changes may be added, cable ducts and cabinets shall have enough capacity to allow for additional installation.

3.10.4 Labelling

[R-EED-303] / /I/ All devices and components like terminal blocks, switches, relays, circuit breakers, etc. shall have a unique label consistent with the technical documentation.

[R-EED-304] / /I/ Labels shall be of permanent type. They shall be either engraved or silk-screen printed. No hand written labels are allowed.

[R-EED-305] / /I/ In the case of removable equipment, labels shall not be attached to the device itself, unless a second label is placed internally to ensure correct replacement.

[R-EED-306] D/ /I/ Identifiers for electrical schematics shall be according to EN 81346 (see next table) and shall be used in the label number as much as possible.

[INFO-EED-307]

Identifier	Description
A	PLC modules, devices with no single purpose.
B	All sensor types: temperature, proximity switch, pressure measure device, photo resistor.
C	Capacitor, coil buffer battery, CD ROM, EPROM.
E	Laser, heaters, lamp, chiller.
F	Fuse, RCD, CB, and overvoltage protector.
G	Tacho generator, fan (generator of air), oscillator, battery.
K	Relay, opto-coupler, analogue digital converter.
M	Motor, electromagnetic valve, mechanical unit controlled by electrical signal.
P	Acoustic indicator/alarm, alarm flash light (attached to instrument cabinet), display, pulse generator, pulse counter, multi-meter.
Q	Power switch, contactor to switch power, on/off valve.
R	UPS, diode, resistor, inductor, proportional valves.
S	Command unit (button, switch).
T	Power supply, transformer, media converter (Ethernet/Fibre), signal converter (current to voltage), amplifier, frequency converter, antennas.
U	Cabinets, rooms, ducts cable wrap, casing.
V	Filter, semiconductor.
W	Cable, fibre, busbar, antenna.
X	Terminal, connector, socket, multi-sockets.
Y	Electrically controlled flow valves (as used for temperature control in cabinets).

Table 17: Identifiers for electrical schematics acc. to EN 81346

[R-EED-308] D/ /I/ A cabinet, instrument and system itself shall have a label containing the following information (according to AD3):

- name or trade mark of supplier;
- certification mark, when required;
- serial number, where applicable;
- rated voltage, number of phases and frequency (if AC), and full-load current for each supply;
- short-circuit rating of the equipment;
- the electrical diagram number(s) or the number of the index to the electrical drawings.

3.11 Power distribution

3.11.1 Electric power distribution system

[INFO-EED-311] Preamble: Requirements related to the electric power supply in ESO projects may also be found in RD2.

[R-EED-312] D/ / / Inrush current or current transients at start up shall be limited. Motors greater than 3 kVA shall apply modern soft starting means (e.g. no star-delta starters) in their connection to the power distribution system.

[R-EED-313] D/ /I/ Overvoltage protective means and RF mains filters shall be installed. As a general rule overvoltage protection in cabinets for instrumentation shall contain SPDs of class II.

[R-EED-314] D/ / / Protection of low-voltage installations against temporary overvoltages and faults between high and medium voltage systems and earth shall be accomplished according to EN 60364 (AD4), in particular according to EN 60364-4, which is a part of AD4.

[R-EED-315] D/ /I/ Cabinets shall be equipped with temperature monitoring. In addition they shall have an adjustable thermal switch and smoke sensor that may act as an interlock to the electrical supply upon the event of an over-temperature or detection of smoke. Interlock signals and alarms shall be interfaced with the associated Local Control System.

Naturally cooled cabinets, upon ESO approval, may be exempted from this requirement.

[INFO-EED-316] An example of a general single phase power distribution scheme for cabinets can be found in RD1.

3.11.2 AC mains supply

[R-EED-318] D/ / / Electronic units shall be powered by the ESO Observatory electric power supply system according to the TN-S power distribution principle.

[INFO-EED-319] The following electrical supplies are available:

- 400 VAC three-phase, 50 Hz including neutral (N) and protective earth (PE) conductor;
- 230 VAC single phase, 50 Hz including N and PE conductor.

[INFO-EED-320] For a general description of the E-ELT power sources and their main characteristics and limitations please refer to RD10.

3.12 Common functions related to the safety of a system

3.12.1 Requirements

[INFO-EED-323] The following sections provide detailed requirements on the implementation of certain safety functions.

[R-EED-324] D/ / / Possible additional requirements set forth by a harmonised standard that is applicable to the (sub)system (usually AD3) shall also be complied with.

3.12.2 Interlock

[R-EED-326] D/ /I/T Where an operating limit (for example speed, pressure, position) can be exceeded leading to a hazardous situation, means shall be provided to detect when a predetermined limit(s) is exceeded and initiate an appropriate automatic control action.

[R-EED-327] D/ /I/T The reclosing or resetting of an interlocking safeguard shall not initiate hazardous machine operation.

[R-EED-328] D/ / / The 'hazardous situation' in the definition shall be analysed and documented beforehand in a hazard analysis according to AD1.

[R-EED-329] D/ / /T All contactors, relays, and other control devices that control elements of the machine and that can cause a hazardous situation when actuated at the same time (for example those which initiate contrary motion), shall be interlocked against incorrect operation.

[INFO-EED-330] 'Interlock' is intended to detect these situations in an early stage and to prevent damage in such a situation e.g. by stopping of a moving part.

[INFO-EED-331] AD3 defines three categories of stop functions as follows:

- stop category 0: stopping by immediate removal of power to the machine actuators;
- stop category 1: a controlled stop with power available to the machine actuators to achieve the stop and then removal of power when the stop is achieved;
- stop category 2: a controlled stop with power left available to the machine actuators.

[R-EED-332] D/ / /T In case of moving machinery an interlock shall lead to either a category 0,1 or 2 stop in the definition of EN 60204-1 (AD3) as indicated by the risk assessment and the functional requirements of the machine.

[R-EED-333] D/ / /T Stop functions shall override related start functions.

[R-EED-334] D/ / / The implementation of the interlock function shall meet the required Safety Integrity Level (SIL) determined as outlined in section 3.2.2.2; safety logic shall be implemented in software running on safety-certified Programmable Logical Controller (PLC).

[R-EED-335] D/ / /T The status of all individual interlock conditions shall be fed to the LCU of the subsystem that controls the unit, so that it can be monitored centrally.

3.12.2.1 Implementation requirements

3.12.2.1.1 Simple interlock schemes: basic hardware components

[R-EED-338] D/ / /T The implementation of the interlock function shall meet the required SIL (Safety Integrity Level) determined as outlined in section 3.2.2.2.

[R-EED-339] D/ / / In the case PLC control systems are used, safety logic shall be implemented using safety certified software running only on safety-certified Programmable Logical Controllers (PLC's).

3.12.2.1.2 Standard interlock scheme solution: safety related electrical control system

[R-EED-341] D/ / / Depending on the required SIL, related variables and all other applicable safety related concerns the SRCF (Safety Related Control Function) shall be suitably designed.

[INFO-EED-342] Special care has to be taken to properly select sensors in order to achieve the appropriate SIL.

[INFO-EED-343] For reference only, examples of programmable electronic control systems can be found in RD1.

[R-EED-344] D/ / / Interlock-signals between failsafe PLCs shall be interchanged by failsafe bus-communication, as well as the data transfer to / from the remote I/O's.

3.12.2.2 Override/suspension of safeguards

[INFO-EED-346] In the case of crossing over operational limits, an override/suspension of safeguards is necessary to move the unit out of the limit.

[R-EED-347] D/ / / When it is necessary to suspend safety functions/protective measures, protection shall be ensured by:

- disabling all other operating modes;
- one or more of the following:
  - initiation of operation by hold-to-run device (or similar);
  - portable control station with emergency stop and enabling device where motion can only be controlled from that station;
  - cableless control station with stop device/enable/exclusive control;
  - limitation of speed or power of motion or the range of motion.

[R-EED-348] D/ / / This override function shall be such that the moving unit can be seen from the point where the override function is implemented.

3.12.2.3 Brake

[R-EED-350] D/ / / The brake shall be of a safety break type of the appropriate SIL level.

[R-EED-351] D/ / /T In conditions of no power, brakes shall be engaged.

[R-EED-352] D/ /I/ The brake shall have status signals (engaged/disengaged, etc.) so that its state can be monitored. The type of state signal shall be according to the selected SIL level.

3.12.3 Emergency stop

3.12.3.1 Requirements

[R-EED-355] D/ / / The amount of emergency stops and their location is an outcome of the analysis made according to AD1. As a basic requirement the distribution and number of emergency stops shall allow action by the affected persons as well as witnesses at a distance.

[R-EED-356] D/ /I/ The emergency stop device shall be a push-button operated switch, shall be of the self-latching type and shall have positive (or direct) opening operation. For reference see EN 60947-5-1.

[R-EED-357] D/ /I/ The actuator shall be coloured red while the background immediately around the device actuator shall be coloured yellow. The actuator shall be of the palm or mushroom head type.

[R-EED-358] D/ / /T Where several emergency stop devices are provided in a circuit, it shall not be possible to restore that circuit until all emergency stop devices that have been operated have been reset.

[R-EED-359] D/ / / Emergency stopping shall always be achieved through a Category 0 or a Category 1 stop with a preference for category 1 if the risk assessment allows this. See AD3 for reference.

[R-EED-360] D/ / / Regardless of the outcome of the risk assessment the following requirements apply to the emergency stop system:

- it shall be implemented with a safety integrity level (SIL) of 2 or higher;
- it shall be implemented with a two line evaluation scheme (for reference see section 3.12.2.1, for examples refer to RD1).
- it shall follow the principle implementation requirements as stated in AD9.

3.12.4 Lockout/Tagout

3.12.4.1 Description

[INFO-EED-363] Lockout/Tagout is a means to avoid potentially hazardous energy (including motion, electrical, thermal, chemical, pneumatic, hydraulic, mechanical and gravitational energy) to be present in a (sub)system during installation, repair or maintenance.

[R-EED-364] D/ / / During installation, repair or maintenance a (sub)system must have the ability to lock out, block or release all forms of potentially hazardous energy. The system or equipment involved shall be designed to enable these features (e.g. by means of a mains switch that is lockable in the 'off' position for the electrical supply, visible isolation).

[R-EED-365] D/ / / A review shall be part of the risk analysis to determine which switches, valves, or other energy isolating devices apply to the equipment being locked out. More than one energy source (electrical, mechanical, hydraulic, pneumatic, chemical, thermal and gravitational) may be involved.

3.13 Safety functions

[INFO-EED-367] Note: This section is usually not applicable to small moving systems.

[R-EED-368] D/ / / In all cases where drive applications may pose a hazard to people, environment or property, safety functions shall be implemented by means of adjustable speed electrical power drive systems (PDS) that are suitable for use in safety-related applications PDS(SR) following the procedures as explained in RD6. Examples of such safety functions can be found in RD1.

[INFO-EED-369] EN 61800-5-2 (RD6) gives a methodology to identify the contribution made to identified safety functions by an adjustable speed electrical power drive systems (PDS) that are suitable for use in safety-related applications PDS(SR).

[R-EED-370] D/ / / The technical measures required to implement the safety functions shall depend on the SIL capability and the required probability of dangerous hardware failure.

3.14 Network/Fieldbus systems

3.14.1 Control

[R-EED-373] D/ / / In general the connection between control units and field devices shall be established exclusively with an Ethernet-based fieldbus following the standards presented in AD2.

3.14.2 Power over Ethernet (PoE)

[R-EED-375] D/ / / If Power over Ethernet (PoE) is used, the configuration (levels, connection, cables, etc.) shall be in compliance with IEEE 802.3at – 2009.

3.14.3 Safety

[R-EED-377] D/ / / Connection between safety units and field devices shall be established only with Profisafe. See AD2 for reference.

3.15 Technical Documentation

3.15.1 General

[INFO-EED-380] The information provided may vary with the complexity of the electrical equipment. For very simple equipment, the relevant information may be contained in one document, provided that the document shows all the devices of the electrical equipment and enables the connections to the supply network to be made. Otherwise, documentation shall contain what is mentioned in the following sections.

[R-EED-381] / /I/ Data sheets and manuals of all COTS equipment shall be provided.

[R-EED-382] / /I/ Complete technical documentation in English language shall be part of the delivery, in both printed (2 copies) and electronic format (editable native + PDF). Technical documentation as described below is within the scope of work and acceptance can't be granted if it is partially missing.

3.15.2 Information to be provided with the electrical equipment

[R-EED-384] / /I/ The information provided with the electrical equipment shall include the information requested in the section 3.15.2 of RD1.

3.15.3 Requirements applicable to all documentation

[R-EED-386] / /I/

- in accordance with relevant parts of EN 61082-1.
- reference designations: according to relevant parts of EN 81346.
- instructions/manuals in accordance with EN 82079.
- parts lists in accordance with EN 62027, class B providing info necessary for ordering spare or replacement parts required for preventive or corrective maintenance incl. those in stock by user.
- proper referencing.

3.15.4 Installation documents

[R-EED-388] / /I/ The information contained in the installation documents shall be made in accordance to the guidelines given in RD1.

3.15.5 Circuit diagrams

[R-EED-390] / /I/ All circuit diagrams shall be made in accordance to the guidelines provided in RD1.

3.15.6 Operating manual

[R-EED-392] / /I/ The information contained in the operating manual shall be made in accordance to the guidelines given in RD1.

3.15.7 Maintenance manual

[R-EED-394] / /I/ The information contained in the maintenance manual shall be made in accordance to the guidelines given in RD1.

3.15.8 Technical Construction File

[INFO-EED-396] The Technical Construction File (TCF) is the complete documented supporting evidence of compliance of a system applying the steps explained in section 3.2.1. and AD1.

[R-EED-397] / /I/ All relevant information to presume compliance with the EHSRs of the Applicable Directives using harmonized standards and with the ESO requirements shall be delivered in the form of a TCF including the Declaration of Conformity (DOC) sheet.

[INFO-EED-398] To give an example, among others, the TCF includes documented safety relevant information like check lists, hazard analysis and risk assessment, test reports, etc. See RD1 for reference.

4. Tests/verification

4.1 General

[INFO-EED-401]

[R-EED-402] / /I/T Systems, subsystems and equipment shall be checked for compliance according to the requirements described in the harmonised standards that are most applicable to them. For machinery (see definition in section 1.2) the standard EN 60204-1 (AD3) provides the harmonised requirements in the electrical/electronic area. For non-COTS equipment usually EN 61010-1 (AD7) will be considered applicable.

[R-EED-403] / /I/T Low voltage electrical installations shall be checked for compliance according to AD4.

[R-EED-404] / / /T According to what has been said in section 3.2.1 a system or subsystem shall be exposed to safety verification tests that are required as per the most applicable standard. The following sections detail some of the most frequently required tests to be complied with.

4.2 Safety relevant tests

4.2.1 Continuity of protective bonding

[R-EED-407] / / /T All protective earth (PE) and bonding conductors shall be tested to ensure that they are electrically safe and correctly connected. Provided that the supply is not yet connected, it is permissible to disconnect the protective and equipotential conductors from the main earthing terminal to carry out testing. Where the mains supply is connected, as will be the case for periodic testing, the protective and equipotential conductors must not be disconnected.

4.2.2 Insulation resistance test.

[R-EED-409] / / /T The Insulation Resistance Test consists in measuring the Insulation resistance of a device under test, while phase and neutral are short circuited together. The measured resistance shall be higher than the limit indicated by the international standards.

[INFO-EED-410] An insulation resistance tester is used to measure the impedance value of an insulator supplied from a voltage source. To measure a high value resistance, techniques for measuring a low value

current are used. A constant voltage source is applied to the resistance to be measured and the resulting current is read on a highly sensitive ammeter circuit that can display the resistance value.

4.2.3 Possible destructive tests for non-COTS equipment

[R-EED-412] /A/ / In general destructive tests required by harmonised standardisation shall be avoided if analysis shows that such tests are unreasonable.

4.3 EMC tests

[INFO-EED-414] See section 3.3.

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