



Programmable controllers

Part 4: User guidelines



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Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Standard through their representation on the Committee and through the public comment period.

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Australian Standard[®]

Programmable controllers

Part 4: User guidelines

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PREFACE

This Standard was prepared by the Standards Australia Committee IT-006, Industrial Process Measurement, Control and Automation, to supersede AS IEC 61131.4—2004.

The objective of this Standard is to introduce the end-users of Programmable Controllers (PLCs) to the AS IEC 61131 series, and to assist the end-users in their selection and specification of PLC equipment according to the AS IEC 61131 series. This user guideline has as its main audience PLC end-users.

This Standard should be read in conjunction with the other parts of the AS IEC 61131 series.

This Standard is identical with, and has been reproduced from, IEC/TR 61131-4, Ed. 2.0 (2004), *Programmable controllers—Part 4: User guidelines*.

This edition differs extensively from the previous (2004) edition. Whereas the previous edition was mainly tutorial in nature, this edition aims to provide an engineering overview of the AS IEC 61131 series for those end-users of PLCs who may not be expected to delve into the extensive details of the AS 61131 series, but wish to understand the benefit of using AS IEC 61131 compliant PLCs.

As this Standard is reproduced from an International Standard, the following applies:

- (a) In the source text ‘this part of IEC 61131’ should read ‘this Australian Standard’.
- (b) A full point substitutes for a comma when referring to a decimal marker.

References to International Standards should be replaced by references to Australian or Australian/New Zealand Standards, as follows:

<i>Reference to International Standard</i>	<i>Australian Standard</i>
IEC	AS IEC
61131 Programmable controllers	61131 Programmable controllers
61131-1 Part 1: General information	61131.1 Part 1: General information
61131-2 Part 2: Equipment requirements and tests	61131.2 Part 2: Equipment requirements and tests
61131-3 Part 3: Programming languages	61131.3 Part 3: Programming languages
61131-5 Part 5: Communications	61131.5 Part 5: Communications
61131-7 Part 7: Fuzzy control programming	61131.7 Part 7: Fuzzy control programming
61131-8 Part 8: Guidelines for the application and implementation of programming languages	61131.8 Part 8: Guidelines for the application and implementation of programming languages

The term ‘informative’ has been used in this Standard to define the application of the annex to which it applies. An ‘informative’ annex is only for information and guidance.

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INTRODUCTION

This part of IEC 61131 constitutes the fourth part of a series of standards on programmable controllers and the associated peripherals and should be read in conjunction with the other parts of the series.

Where a conflict exists between this and other IEC standards (except basic safety standards), the provisions of this standard should be considered to govern in the area of programmable controllers and their associated peripherals.

Terms of general use are defined in IEC 61131-1. More specific terms are defined in each part.

NOTES

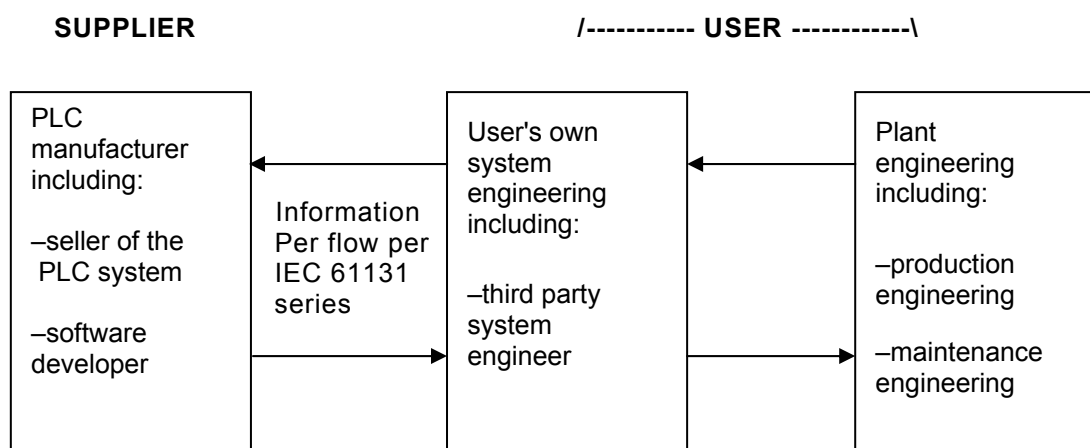
AUSTRALIAN STANDARD

Programmable controllers**Part 4:
User guidelines****1 General****1.1 Scope and object**

The object of this Technical report is to introduce the end-users of Programmable Controller (PLC) to the IEC 61131 series, and to assist the end-users in their selection and specification of their PLC equipment according to the IEC 61131 series. This user guideline has as its main audience PLC end-users.

PLCs, their application program and their associated peripherals are considered as components of a control system. Therefore, PLC users should take note that this standard does not deal with the automated system in which the PLC and PLC system is but one component. However, when applying this user guideline, an overall system architecture evaluation is recommended. Functional safety of the overall automated system is beyond the scope of this standard.

An objective of this user guideline is to facilitate communication between the PLC user and PLC supplier according to the specifications of the IEC 61131 series that applies to PLCs and their associated peripherals. This information exchange is illustrated in Figure 1.



IEC 1025/04

Figure 1 – Object of user guidelines

As depicted in Figure 1, the users consist of system integrators and end-users. The manufacturer of PLC is required by the IEC 61131 series to furnish appropriate product information to the user. Optionally, the user supplies operational requirements and specifications to the manufacturer in order to receive suitable products and services from the manufacturer. One objective of this Technical Report is therefore to assist in this communication, especially from the end-user's perspective. Accordingly, this Technical Report does not detail all the requirements of each and every part of the IEC 61131 series, such as conformance tests. The user should refer to the individual parts of the standard when needed.

1.2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61131-1: *Programmable controllers – Part 1: General information*

IEC 61131-2: *Programmable controllers – Part 2: Equipment requirements and tests*

IEC 61131-3: *Programmable controllers – Part 3: Programming languages*

IEC 61131-5: *Programmable controllers – Part 5: Communications*

IEC 61131-7: *Programmable controllers – Part 7: Fuzzy control programming*

IEC 61131-8: *Programmable controllers – Part 8: Guidelines for the application and implementation of programming languages*

1.3 Use of this report

A PLC application starts with the user's system analysis and specification. Inquiries and discussions (and suggestions/recommendations) with the manufacturer necessitate the use of a mutually agreed language for interactive information exchange as in Figure 1. The user can use this report as a basis and/or to supplement any in-house system design rules. The user can then specify the equipment and software requirements according to the relevant parts in the IEC 61131 series. In this user guideline, introductions and briefings of various parts of the IEC 61131 series are presented in Annex A according to the divisions in the IEC 61131 series. For example, Clause A.1 covers IEC 61131-1, Clause A.2 covers IEC 61131-2, etc.

This Technical Report presents only those specifications for which the user may have an immediate need for reference. It is not a complete summary of the whole IEC 61131 series.

2 Terms and definitions

For the purposes of this part of IEC 61131, the following terms and definitions, as well as those given in IEC 61131-1, apply.

2.1

application program (user program)

logical assembly of all the programming language elements and constructs necessary for the intended signal processing required for the control of a machine or process by a PLC system

2.2

automated system

control system beyond the scope of IEC 61131 in which PLC systems are incorporated by or for the user, but which also contains other components including their application programs

2.3

operator (human)

person commanding and monitoring a machine or process through an HMI connected to the PLC. The operator does not change the PLC hardware configuration, software or the application program. A PLC is not intended for use by untrained personnel. The operator is assumed to be aware of the general hazards in an industrial environment.

2.4

programmable controller

digitally operating electronic system, designed for use in an industrial environment, which uses a programmable memory for the internal storage of user-oriented instructions to implement specific functions (such as logic, sequencing, timing, counting and arithmetic) to control, through digital or analogue inputs and outputs, various types of machines or processes.

NOTE In the first edition of the IEC 61131 series, the acronym "PC" was used for Programmable Controller. However, usage of the earlier acronym PLC has been persisted with the majority of industries. After consultation, IEC Subcommittee 65B WG7 recommended that the more widely accepted acronym PLC be used, starting with all new editions of the IEC 61131 standard.

2.5

programmable controller system

user-assembled configuration, consisting of a programmable controller and associated peripherals that is necessary for the intended automated system. It consists of units interconnected by cables or plug-in connections for permanent installation and by cables or other means for portable and transportable peripherals.

2.6

service personnel

person changing or repairing the PLC hardware configuration or the application programme.

The service person may also install software updates provided by the manufacturer. They are assumed to be trained in the programming and operation of the PLC equipment and its use.

They are persons having the appropriate technical training and experience necessary to be aware of hazards – in particular, electrical hazards – to which they are exposed in performing a task and of measures to minimize danger to themselves or to other persons or to the equipment.

3 General recommendations for installation

The installation procedure should fulfil the requirements given by documents, which are prepared during the system selection/engineering/application phase. Not all site conditions can be recognized at the PLC selection phase. During installation, it is important to update all engineering and application documents according to how the PLC equipment is assembled or modified on site.

3.1 Environmental conditions

The user should ensure that care is taken concerning temperature, contaminants, shock, vibration and electromagnetic influence. Refer to IEC 61131-2 for specific environmental requirements. Table 1 describes environmental conditions to be evaluated during installation.

Table 1 – Environmental conditions

Criteria	Comments and considerations
Temperature	Check for possible influence of steady or temporary heat sources: - space heater - solar heat - hot goods passing by
Contaminants	Moisture, corrosive gases, liquids and conductive dust can affect the function of a PLC system. Therefore, check: - use of adequate enclosures in compliance with international/national codes - compliance with manufacturer's installation instructions - degradation of thermal efficiency caused by dust
Shock and vibration	Check for possible effects on site: - engines - compressors - transfer lines - presses, hammers - vehicles
Electromagnetic interference	Check electromagnetic interference from various sources on site: - motors - switch gears, thyristors - radio-controlled equipment - welding equipment - electrical arcs - switched power supplies - power converters/inverters

3.2 Field wiring

Proper field wiring practices are of prime importance to the application of PLCs. The installer needs to follow the manufacturer's wiring instructions and applicable local regulations.

Two earthing/grounding requirements need to be fulfilled during installation: protective earth (safety grounding) and functional earth (signal ground reference).

Protective earthing requires the solid connection (e.g., low impedance connection, including star washers, welding, soldering, etc.) of inactive metal parts to an equipotential metallic grid (frames, chassis, cabinets). The grid needs to be connected to protective earth in accordance with local and national codes.

Functional earthing needs to be installed as the low impedance network of signal ground reference lines. It should be a network separate from protective earthing.

Protective and functional earth networks may be interconnected via wires or other low impedance paths. Such interconnections or lack thereof may be required by applicable local/national codes, or due to noise reduction requirements, depending on the type of controlled process/equipment. Table 2 describes installation rules of earthing measures.

Table 2 – Installation rules: earthing measures

Criteria	Reference	Comments and considerations
Protective earthing		- Provide sufficient conductor cross-section for connections to earth. - Doors should have electrical connections according to local and national codes. - Verify connections are tight and resistant to vibration and corrosion.
Functional earthing		- Usually functional ground reference is connected only at a single point to earth. When more than one connection to earth is made, care should be taken to avoid ground loop interference. Such multipoint earth connections must be made to an equipotential grid. - Protective earth conductors may be suitable for functional grounding. Such practice can be determined on site by measurement at 50 Hz/60 Hz and at frequencies above signal frequency. Such quality may be improved by specially installed electrodes or, possibly, earthed conductive building structures. - If a direct connection of the signal ground reference conductor of the PLC to earth is not possible, the connection may be made via a suitable capacitor. The capacitor should correspond to the rated insulation voltage of the PLC circuit, and should have good high-frequency properties. Static charging can be prevented by the use of a high ohm value resistor for discharge. - There should be no discontinuities on ground circuits, such as could be introduced by terminals and sockets.
Caution – protective earthing is intended to reduce the risk of electric shock hazard. Under no circumstances should the protective earth be disconnected from the PLC. Functional earth connections may be temporarily disconnected for servicing and/or maintenance as required.		

3.3 Electromagnetic compatibility

A number of common installation practices have been found to minimise EMC related problems. Some of these are listed in Table 3

Table 3 – Installation rules: EMC

Criteria	Reference	Comments and considerations
Mains		- Mains conductors should be separately installed from other PLC wiring, i.e., cable spacings of 10 cm or more from signal cables. - Unavoidable crossing should be at right angles. - Use of mains' filters on the cabinet feed-ins may be required. - Transient suppressor at mains' entrance may be required.
Input/output		- Separation of the field wiring from internal I/O cabling and from bus lines. - Care must be taken not to compromise isolation of circuits (e.g., by optical separation) between I/O field wiring and internal PLC system. - Filtering of susceptible I/O cables may be required. - Use of shielded cables with low inductance cable shields (low-level signals). - Earthing measurement in each individual case must be determined on site. - Shield may be connected to functional ground or protective earth. - Electrical contacts in series with inductive loads require special attention for voltage surge and stored energy.
Noise sources		Noise damping at emission sources with noise suppressers such as: - Separate cables for input, outputs, and power circuits. - Minimise the total length of wiring. - Use of manufacturer recommended cables and leads.
Analogue and other noise-sensitive circuits		- Use of shielded wires. - Use of twisted-pair wiring.
Routing		Interference voltage or current noise can enter PLCs where connections are made, as well as the power supply connections. The wiring which extends between the PLC and these control devices should be properly routed to minimize induced noise on these wires.

3.4 User system markings

User system markings of components (sensors, actuators, cables, distribution-boards, enclosures, modules, etc.) should be done in accordance with the installation drawings and applicable codes.

Special care needs to be taken on markings of wiring. Each and every field wire should be identified with a marking corresponding to drawing. Alteration from the drawing should be noted on the same drawing immediately.

Care needs to be taken to ensure the following:

- markings need to be indelible;
- adequate sizes of letters and signs;
- fuse location, type, rating need to be clearly marked;
- visibility of markings; and
- conformity with installation drawings according to revision of final documents.

4 PLC in functional safety applications

When PLCs are required to perform safety functions, it is necessary that special measures be taken to avoid and limit dangerous failures of the functional-safety-related system. Detailed requirements for Safety-Related System (SRS) are contained in IEC 61508 and in emerging sector implementation standards such as the IEC 61511 series. The purpose of this Clause is to provide an overview of some of the functional safety issues that will need to be addressed. It is not intended to provide definitive or detailed guidance for implementation.

4.1 Functional safety and safety-related-system concept

Functional safety, as defined in IEC 61508, refers to the ability of a SRS to carry out the functions necessary to achieve a safe state for the Equipment Under Control (EUC) or to maintain a safe state for the EUC. In this definition, the main subject is focused on the ability of a safety-related system to do what it is required to do.

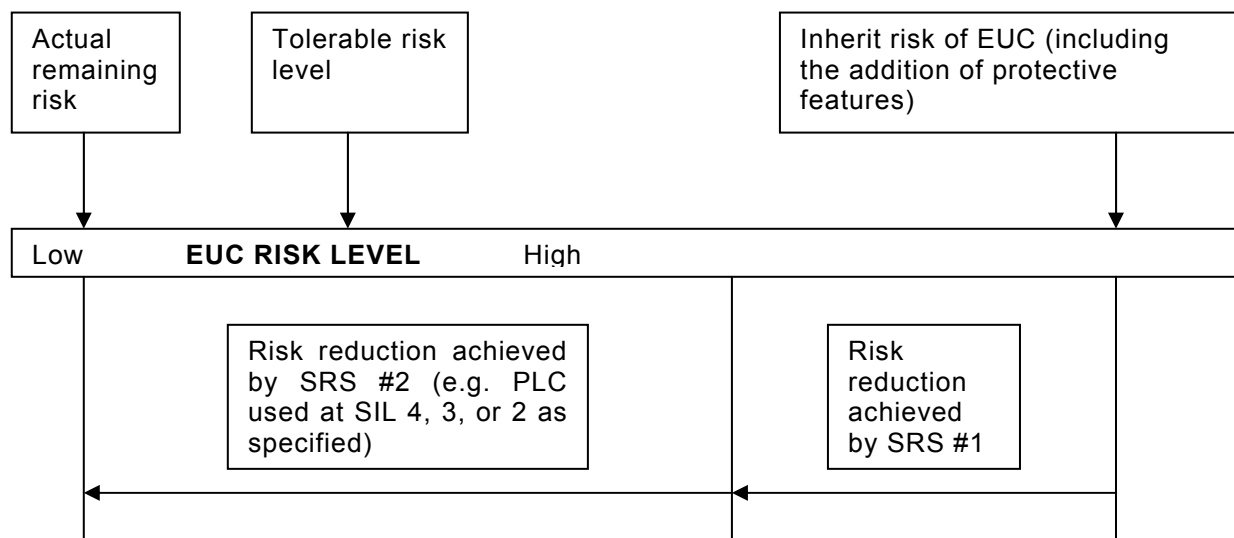
“Safety” refers to freedom from unacceptable risk. It follows that there are acceptable risks. The level of risks may be categorized as “broadly acceptable”, “tolerable” where further risk reduction is impracticable (the As Low As Reasonably Practical, ALARP, principle) and, the “intolerable” where risks cannot be justified, except in extraordinary circumstances. Risk level is assessed as a combination of “Consequence of hazardous event” and “Frequency of hazardous event”.

The task of a SRS is to reduce the risk to a tolerable level or lower as prescribed by the control system designer. This risk-reduction model is depicted in Figure 2.

NOTE 1 The IEC 61131 series does not deal with the functional safety or other safety aspects of the overall automated system. Safety considerations for the overall automated system are beyond the scope of this standard.

NOTE 2 The IEC 61131 series does not contain a part on functional safety. At the preparation of this part of IEC 61131, a sector standard for PLC and similar equipment is under consideration.

NOTE 3 Safety, as covered in IEC 61131-2, refers to prevention of electric shock and fire hazards.



IEC 1026/04

Figure 2 – SRS in risk reduction concept

Each SRS is assigned Safety Functions and is to fulfil the safety functions with a prescribed Safety Integrity Level (SIL) requirement. IEC 61508 categorises SIL in four levels as listed in Table 4 for Demand Mode and in Table 5 for Continuous Mode.

Table 4 – SIL of demand mode safety functions

SIL	Average probability of failure to perform the safety function on demand (PFD)
4	$\geq 10^{-5}$ to $< 10^{-4}$
3	$\geq 10^{-4}$ to $< 10^{-3}$
2	$\geq 10^{-3}$ to $< 10^{-2}$
1	$\geq 10^{-2}$ to $< 10^{-1}$

Table 5 – SIL of continuous mode safety functions

SIL	Probability of a dangerous failure of the safety function (per hour)
4	$\geq 10^{-9}$ to $< 10^{-8}$
3	$\geq 10^{-8}$ to $< 10^{-7}$
2	$\geq 10^{-7}$ to $< 10^{-6}$
1	$\geq 10^{-6}$ to $< 10^{-5}$

Note that Table 5 can also be used for Demand Mode safety functions when the demand rate is high compared with the proof test frequency of the safety function. Typically, when the demand rate is higher than twice the proof test frequency, then it is reasonable to specify the safety function in terms of probability of failure per hour using Table 5.

The international standard for safety instrumented system for the process industry is the IEC 61511 series. In the IEC 61511 series, the safety instrumented system (SIS) includes all components and subsystems necessary to carry out the safety instrumented function, from sensor(s) to actuator(s).

For the machine sector, IEC 62061 is in preparation. This standard is being harmonized with international standard ISO 13849-1 (EN 954-1). The Safety-Related Part (SRP) which carries out safety functions is viewed as a component of the total control system. The ability of SRP to fulfil a safety function is described as Performance Levels (PL). Performance Levels PL-a, PL-b, PL-c, PL-d, and PL-e correspond to the “average probability of a dangerous failure per hour” ranging from 10^{-4} to 10^{-8} . The required PL (for a SRP) is determined on risk parameters of “Severity of injury”, “Frequency and/or exposure time to the hazard” and “Probability of avoiding the hazard”. Each of these parameters is categorized as high or low. PL-a describes risks lower than SIL1. PL-b and c approximately correspond to SIL1. PL-d corresponds to SIL2 and PL-e corresponds to SIL3. A SRP is then specified as one of five categories: Basic, 1, 2, 3, and 4.

4.2 Using a PLC in a safety-related application

When applying a PLC in a safety-related application (that is, an application where a failure of the SRS to carry out its intended safety function could lead to injury, loss of life or damage to health), then it will be necessary to take into account the likelihood of dangerous failure due to random hardware faults. It will also be necessary to address the possibility of systematic faults in hardware and software.

Notice that safety-related applications should not be confused with basic control applications where there are other measures, such as safety interlocks, which provide protection in the event of such failure.

In safety-related applications, a PLC will usually form only one part of a programmable electronic safety-related system. The other parts, or subsystems, of the SRS include switches and/or sensors as input devices and contactors and/or valves as output actuators.

4.2.1 Safety functions

In order to determine the particular requirements for a PLC used in a safety-related application, it is first necessary to specify the entire safety requirements of the safety-related system.

The safety requirements of a programmable electronic SRS are assigned safety functions. Each safety function required to be carried out by the SRS is specified in terms of Safety Function and Safety Integrity Level (SIL). The safety functional specification is a description of the required function in terms of the action of the safety-related system under a specific set of circumstances.

It is very important that the safety functional specification also needs to include a description of any states of the system which should be avoided in order to prevent hazardous situations. For example, in the case of a system used for an emergency stop safety function on a machine tool, it is necessary to ensure that the machine does not restart when the emergency stop actuator is reset. The machine restarts only when all faults are cleared and a start command is given.

4.2.2 Safety Integrity Level (SIL)

The Safety Integrity Level (SIL) part of the safety functions specification is a measure of the target acceptable probability of failure of the safety function. To determine the SIL level for a safety function, it is necessary to take into account the hazards and risks associated with the application together with the tolerable risk target, and any contribution to risk reduction provided by other safety measures. Generic methods for SIL determination are given in IEC 61508-5. Sector functional safety standards provide guidance relevant to particular applications (see, for example, IEC 61511-3 for the process sector or IEC 62061 for the machinery sector).

Experts in the industry have found that in order to achieve the required reduction of dangerous failure rates required for higher levels of safety integrity (e.g. SIL3 and above), it may be necessary to employ redundant architectures (e.g. 2 out of 3 voting), even taking into account the high levels of diagnostic coverage (e.g. >99 %) typically seen in such PLCs.

4.3 Requirements on PLCs in a safety-related system

In order for a safety-related system to meet the requirements of IEC 61508 or associated sector standards, it is necessary that the following characteristics of a PLC used in the safety-related system be taken account of when designing a safety-related system to carry out a safety function with a specified SIL:

- hardware reliability;
- diagnostic test coverage and test interval;
- periodic testing/maintenance requirements;
- hardware fault tolerance; and
- SIL capability.

This information should be obtained from the PLC manufacturer.

Notice that the 'SIL capability' is the highest SIL which can be claimed for a safety function which uses the PLC, taking into account the measures and techniques used for the avoidance and control of systematic faults in the PLC hardware and software (including system software and firmware) according to IEC 61508. Note also that in order to determine the actual SIL that can be claimed for a safety function in a particular application, it is necessary to consider all of the above characteristics for all of the subsystems which contribute to the safety function.

4.4 Integration of PLC into a safety-related system

The process for deployment of protective features may be illustrated in the event analysis diagram in Figure 3.

The activities undertaken to integrate a PLC into a safety-related system include the development of application software safety requirements. Application programming or configuration and testing should be carried out and verified according to the requirements of IEC 61508 or associated sector standards. It will be necessary to determine how frequently it is required to undertake proof tests in order to detect any dangerous faults which are not revealed by the automatic diagnostic tests. Proof tests are particularly important when PLCs are applied in redundant configurations, or when there are components (such as batteries) whose failure may not be apparent during normal operation.

If previously developed application software library functions are to be used, their suitability in satisfying the software safety requirements specifications need to be verified. Suitability may be based on evidence of satisfactory operation in a similar application which has been demonstrated to have similar functionality or having been subject to the same verification and validation procedures as would be expected for newly developed software. Any constraints from the previous software environment (for example operating system and compiler dependencies, order of execution of library functions, etc.) need to be evaluated.

Application programs should be well documented, including at the least the following information:

- legal entity (e.g.: company, author(s), etc.);
- description;
- tractability to application functional requirements;
- logic conventions used;
- standard library functions used (and associated justifications, see above);

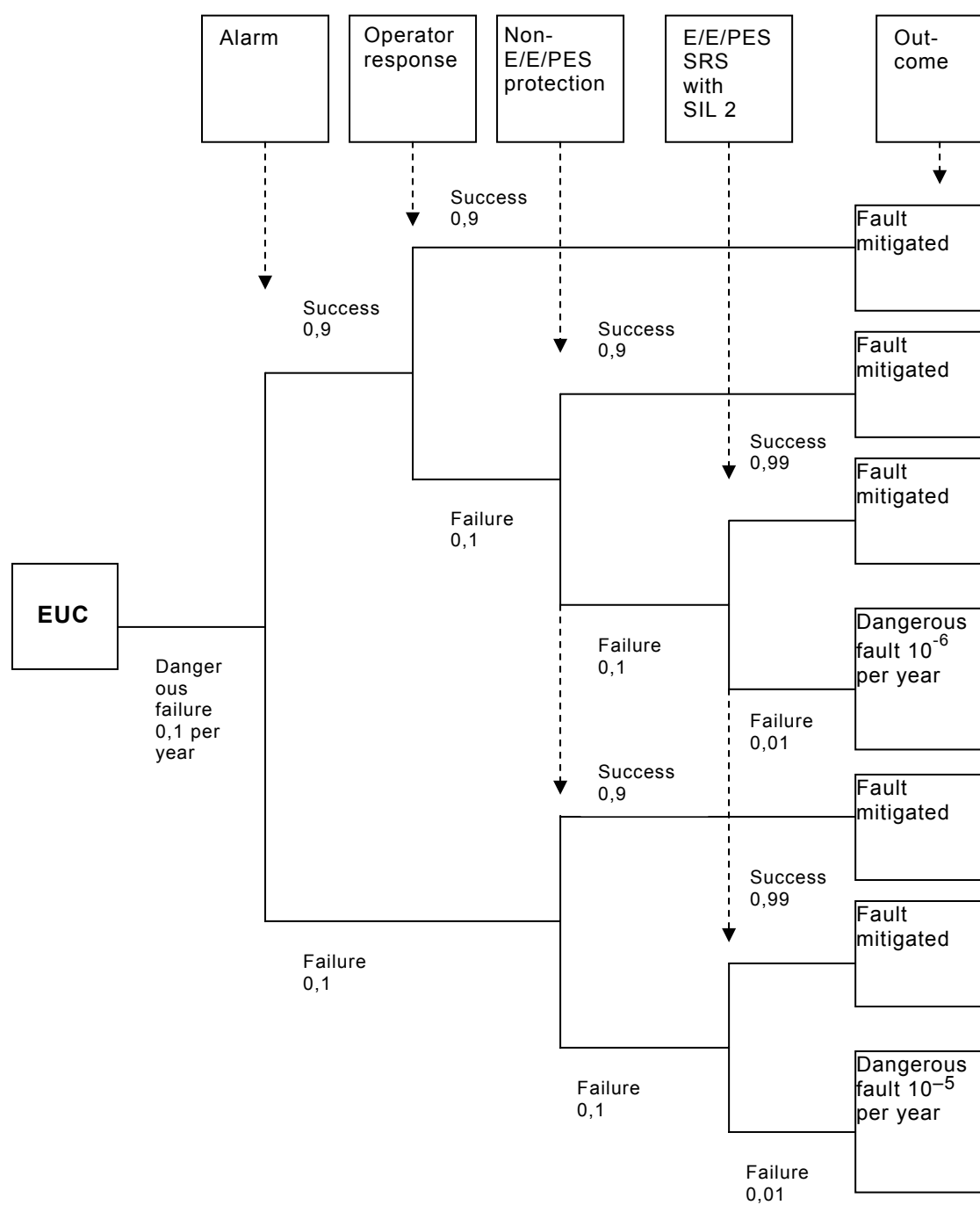
- inputs and outputs; and
- configuration management including a history of changes.

All integration (including hardware, software, mechanical assembly and wiring, use of tools and programming languages, interfacing of inputs and outputs) need to be in accordance with instructions of the PLC manufacturer.

Note that extreme caution should be exercised when combining PLCs in redundant architectures in order to meet hardware reliability requirements. Such architectures could introduce the possibility of systematic failure modes associated with timing synchronization and voting which may outweigh the benefits to be gained from redundancy.

Integration should take into account the possibility of reasonably foreseeable fault conditions, such as open circuits on inputs or power supply failure, so as to ensure that such fault conditions do not lead to hazardous situations.

Care should be taken to ensure that it is not possible, during use of the PLC, for a previous version of an application program (e.g. stored in NVRAM) to over-write an application program which may have been changed to remove faults. Such over-writing could lead to software faults being re-introduced.



IEC 1027/04

Figure 3 – Event tree analysis for deployment of SRS

Annex A (informative) **Overview of normative parts of IEC 61131**

This Annex presents overviews of all normative parts of the IEC 61131 series. Not presented are IEC 61131-4, which is this Technical Report, IEC 61131-8 which is itself a guideline Technical Report and IEC 61131-6 which is reserved for future use.

This Annex is divided into Clauses: Clause A.1 to Clause A.7. Each Clause's number and title (but not Subclause numbers) correspond directly with the part number of the IEC 61131 series, viz:

- Clause A.1: Overview of IEC 61131-1;
- Clause A.2: Overview of IEC 61131-2;
- Clause A.3: Overview of IEC 61131-3;
- Clause A.4: (blank);
- Clause A.5: Overview of IEC 61131-5;
- Clause A.6: (blank);
- Clause A.7: Overview of IEC 61131-7;
- Clause A.8; (blank).

The purpose of this Annex is to provide the user with a window and a bridge to the IEC 61131 series. It is not intended as a definitive specifications on PLCs, nor does it intend to substitute for any part of the IEC 61131 series. This Annex is prepared to provide information and selective guidance on IEC 61131 in its entirety, more related to the user point of view.

Some key specifications in IEC 61131-1, IEC 61131-2 and IEC 61131-3 that are especially germane to the user's specification and selection of PLCs are reflected directly from those parts.

A.1 Overview of IEC 61131-1

A.1.1 General

The scope of IEC 61131-1 is to deal with the framework for the overall IEC 61131 series. It applies to PLCs and their associated peripherals which have as their intended use the control and command of machines and industrial processes. IEC 61131-1 defines the terms and principal functional characteristics of programmable controller system.

PLCs and their associated peripherals are intended to be used in an industrial environment. If a PLC or its associated peripherals are used in other environments, then the specific requirements, standards and installation practices for those other environments must be additionally applied to the PLC and its associated peripherals.

The IEC 61131 series does not deal with the functional safety or other aspects of the overall automated system. Safety considerations for the overall automated system is beyond the scope of this standard.

PLC safety as related to electric shock and fire hazards, electrical interference immunity and error detecting of the PLC system operation are addressed in the IEC 61131 series. For installation IEC 60364 and applicable national/local regulations should be referred to. IEC 61131-1 was prepared with normative referencing to IEC 61131-2 and IEC 61131-3.

A.1.2 Terms and definitions

Some of the terms and definitions used in IEC 61131-1 are as follows:

a) Field devices

catalogued part to provide input and/or output interface or to provide data pre-conditioning.

NOTE The abbreviation "PLC" is used in this standard to stand for "programmable controllers", as is the common practice in the automation industry. The use of "PC" as abbreviation to "programmable controllers" leads to confusion with personal computers.

b) Programmable Controller system (PLC system)

user-built configuration, consisting of a programmable controller and associated peripherals, that is necessary for the intended automated system. It consists of units interconnected by cables or plug-in connections for permanent installation and by cables or other means for portable and transportable peripherals.

c) Programming And Debugging Tool (PADT)

catalogued peripheral to assist in programming, testing, commissioning and trouble-shooting the PLC system application, program storage and documentation. PADTs may be used as Human-Machine-Interface (HMI). PADTs are said to be pluggable when they may be plugged or unplugged into their associated interface at any time without any risk to the operator and the application. In all other cases, PADTs are said to be fixed.

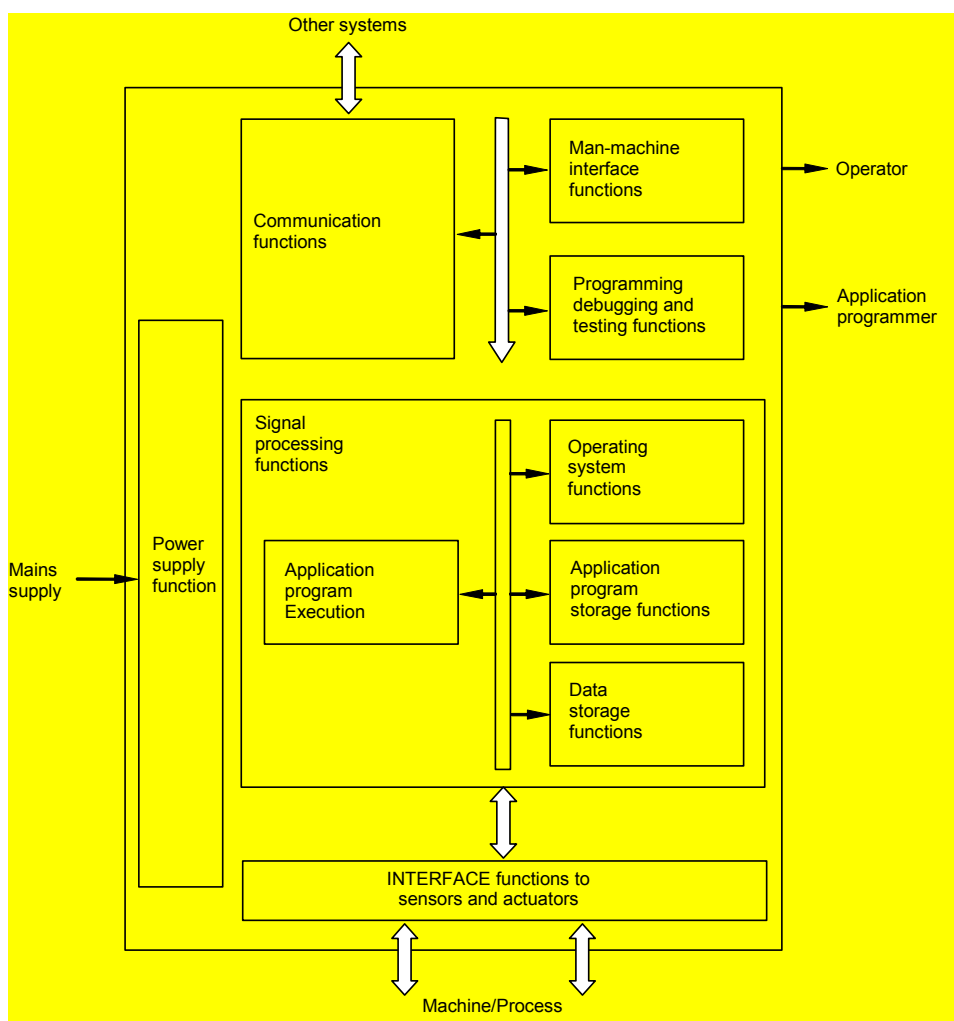
d) Remote Input/Output Station (RIOS)

manufacturer's catalogued part of a PLC system, including input and/or output interfaces allowed to operate only under the hierarchy of the main processing unit (CPU) for I/O multiplexing/de-multiplexing and dated pre-processing/post-processing. The RIOS is the only peripheral permitted to have limited autonomous operation, for example, under emergency conditions such as breakdown of the communication link to the CPU, or when maintenance and trouble-shooting operations are to be performed.

A.1.3 Functional characteristics

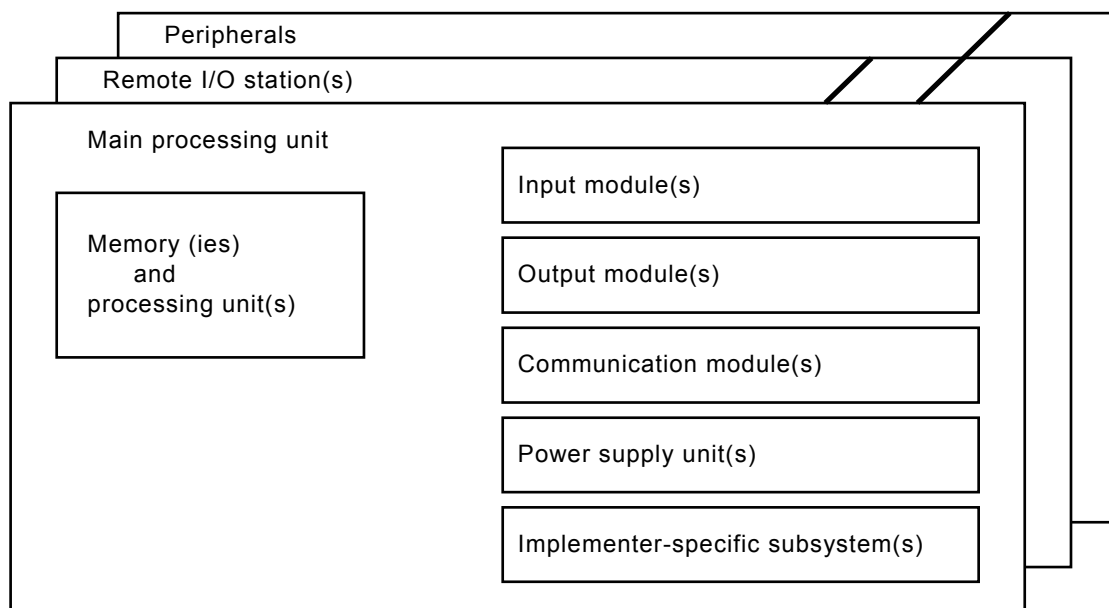
A.1.3.1 Basic functional structure of a PLC system

The structure of a PLC system and communication interfaces are illustrated in Figure A.1, Figure A.2 and Figure A.3. These models are the basis of IEC 61131-2 on hardware, IEC 61131-3 on programming, IEC 61131-5 on communication and IEC 61131-7 on fuzzy programming.



IEC 1028/04

Figure A.1 – Basic functional structure of a PLC system



IEC 1029/04

Figure A.2 – PLC hardware model

The CPU function consists of the application program storage, the data storage, the operating system, the execution of the application program function and processes signals obtained from sensors as well as internal data storage and generates signals to actuators as well as internal data storage in accordance with the application program. These include:

- Interface function to sensors and actuators converts I/O signals including pre-processed signal from special modules such as PID, fuzzy control module, high speed counter module, and motion module.
- Communication function provides the data exchange with other systems (third party devices) such as other PLC systems, robot controllers, computers, etc.
- Human-Machine Interface (HMI) function provides for interaction between the operator, the signal processing function and the machine/process.
- Programming, debugging, testing and documentation functions provide for application program generation and loading, monitoring, testing and debugging as well as for application program documentation and archiving.
- Power supply functions.



A.1.3.2.1 Programmable functions

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Table A.1 – Summary of programmable functions

Function group	Examples
Logic control – Logic – Timers – Counters	Programming language elements AND, OR, NOT, XOR, bi-stable elements On-delay, off-delay Up and/or down counting (of pulses)
Signal/data processing – Mathematical functions – Data handling – Analogue data processing	Basic arithmetic: ADD, SUB, MUL, DIV Extended arithmetic: SQRT, trigonometric functions Comparisons: greater, smaller, equal Selecting, formatting, moving PID, integration, filtering (not as standard elements) Fuzzy control
Interfacing functions – Input/output – Other systems – HMI – Printers – Mass memory	Analogue, digital I/O modules BCD conversion, Communication protocols Display, commands Messages, reports Logging
Execution control periodic	Periodic, event-driven execution
System configuration	Status checking

A.1.3.2.2 Operating system and re-start of PLC

The operating system is responsible for the management of internal PLC system functions. According to the controlled system application, the user needs to ascertain how the PLC system is to re-start after interruption of operation. Re-start is classified into Cold restart, Hot restart, and Warm restart.

1) Cold restart

Restart of the PLC system and its application program after all dynamic data (variables such as I/O image, internal registers, timers, counters, etc., and program contexts) are reset to a predetermined state. A cold restart may be automatic (e.g. after a power failure, a loss of information in the dynamic portion(s) of the memory(ies), etc.) or manual (e.g. push-button reset, etc.).

2) Hot restart

Restart after power failure, within the maximum interruption time allowed, for the PLC system to recover as if there had been no power failure. All I/O information and other dynamic data as well as the application program context are restored or unchanged.

Hot restart capability requires a separately powered real time clock or timer to determine elapsed time since the power failure was detected and a user accessible means to program the process dependent maximum interruption time allowed.

3) Warm restart

Restart after a power failure with a user programmed predetermined set of dynamic data and a system predetermined application program context. A warm restart is identified by a status flag or equivalent means made available to the application program indicating that the power failure shut down of the PLC system was detected in the run mode. At warm restart, usually only the MPU is supplied with Un-interruptible Power Supply (UPS) power source.

A.1.4 Languages and documentation of program

For programming of the PLC application, four types of languages are defined in IEC 61131-3. These languages are: Instruction List (IL), Structured Text (ST), Function Block Diagram (FBD) and Ladder Diagram (LD). Although one type of language may be more widely used in a particular region, the collection encompasses the whole spectrum of software technology and complement each other in many instances. The user may note that IEC 61131-3 specifies PLC language elements and does not describe any particular language in practical use. Such practical language would necessarily include proprietary information or copyright issues that are outside the scope of this standard.

Application program(s) should be documented in a package that may consist of description(s) of the hardware configuration(s) with project-dependent notations. Program documentation should include the following:

- program listing with mnemonics for signal and data;
- cross-reference tables for all data processed;
- comments;
- description of modifications;
- maintenance manual.

Application program archiving in non-volatile media enables rapid repair and minimizes down-time.

A.1.5 Availability and reliability

Every automated system requires a certain level of availability and reliability of its control system. It is the user's responsibility to ensure that the architecture of the overall automated system, the characteristics of the PLC system and its application program will jointly satisfy the intended application requirements. Factors governing availability and reliability include:

a) Architecture of the automated system

Techniques such as redundancy, fault tolerance and automatic error checking, as well as machine/process diagnostic functions can provide enhancements in the area of availability of the automated system.

b) Architecture of the programmable controller system

A modular construction in conjunction with suitable internal self-tests allowing rapid fault identification may provide enhancements in the area of maintainability of the PLC system and therefore of the availability of the automated system. Techniques such as redundancy and fault tolerance may also be considered for special applications. Evaluation of availability and reliability of a PLC system with a particular architecture may be carried out with the help of related IEC standards such as IEC 61508-6 for the process industry.

c) Design, testing and maintenance of the application program

Most programmable controllers provide enough computing power to permit implementation of diagnostic functions in addition to the minimum control function. Machine/process behaviour modelling and subsequent identification of faulty conditions should be considered.

Adequate testing of the application program is mandatory. The extent of testing, such as point-to-point, loop back or full simulation of process, should be specified. Every modification requires proper design and testing such that the overall availability and reliability are not impaired. The program documentation needs to be maintained and annotated accordingly.

d) Installation and service conditions

PLC systems are typically of rugged design and construction intended for general purpose service. The more stressful the service conditions are, the more degradation is possible for availability and reliability. Conversely, improvements in availability and reliability may be expected when actual service conditions are less stressful than the normal service conditions specified in IEC 61131-2.

Some applications may require consideration of special enclosure, cooling, electrical noise protection, etc., for reliable operation.

A.2 Overview of IEC 61131-2

A.2.1 General

A.2.1.1 Scope and objectives

IEC 61131-2 establishes the functional, electrical safety, electromagnetic compatibility (EMC) and electrical, mechanical, environmental and construction requirements for the PLC and specifies testing methods accordingly. This standard covers PLCs and any products performing the function of PLCs and their associated peripherals. Only equipment intended for use in an industrial environment for control and command of machines and industrial processes are covered.

This standard also applies to any products performing the function of PLCs and/or their peripherals.

Equipment covered in IEC 61131-2 are intended for use in Overvoltage Category II as per IEC 60664-1 in low-voltage installations where the rated mains supply does not exceed 1 000 V r.m.s. or 1 500 V DC.

The object of IEC 61131-2 is to establish the definitions and identify the principle characteristics relevant to the selection and application of PLCs and their associated peripherals. It specifies the minimum requirements for functional, electrical, mechanical, environmental and construction characteristics, service conditions, safety, EMC, user programming and tests applicable to PLCs and the associated peripherals.

A.2.1.2 Compliance with this standard

When compliance with IEC 61131-2 is indicated without qualification, compliance with all clauses, including all tests and verifications required in IEC 61131-2, must be verified. Moreover, the manufacturer's obligations expressed in IEC 61131-2 are not waived if no type test is required, or if the test conditions are restricted for practical reasons.

When compliance with some portion of IEC 61131-2 is indicated, it is only necessary to verify compliance with those clauses against which the compliance claim is made. The manufacturer's obligations as indicated above are still applicable. The smallest unit of IEC 61131-2 for compliance purposes is a Clause, such as Functional Requirements, Immunity Requirements, Safety Requirements, etc.

All requirements not tested according to Tests and Verifications Clauses need to be verifiable under a procedure to be agreed upon by the manufacturer and the user. The manufacturer needs to provide, on request, compliance verification information for all requirements referenced in the claims of compliance with all or a portion of this standard.

A.2.1.3 Normative references

IEC 61131-2 lists some 28 normative references, including:

IEC 60068-2-1, *Environmental testing - Part 2: Tests. Tests A: Cold*

IEC 60364-4-443, *Electrical installations of buildings – Part 4: Protection for safety – Chapter 44: Protection against overvoltages – Section 443: Protection against overvoltages of atmospheric origin or due to switching*

IEC 60417-DB:2002¹, *Graphical symbols for use on equipment*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60664-1:1992, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60664-3:1992, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coatings to achieve insulation coordination of printed board assemblies*

IEC 60695-2-1, *Fire hazard testing – Part 2: Test methods – Section 1: Glow-wire test and methods*

IEC 60707, *Flammability of solid non-metallic materials when exposed to flame sources – List of test methods*

IEC 60947, *Low-voltage switchgear and controlgear*

IEC 60950, *Safety of information technology equipment, including electrical business equipment*

IEC 60947-5-1:1997, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

IEC 60947-7-1:2002, *Low-voltage switchgear and controlgear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors*

IEC 60950-1:2001, *Information technology equipment–Safety – Part 1: General requirements*

IEC 61000-4-2:1995, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3:2002, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated radio-frequency electromagnetic field immunity test*

IEC 61000-4-4:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test*

IEC 61000-4-5:1995, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6:1996, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances induced by radio-frequency fields*

¹ "DB" refers to the IEC on-line database.

IEC 61000-4-8:1993, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-12:1995, *Electromagnetic compatibility (EMC) – Part 4-12: Testing and measurement techniques – Oscillatory waves immunity test*

IEC 61010-1:2001, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*

CISPR 11:1999, *Industrial, scientific and medical (ISM) radio-frequency equipment – electromagnetic disturbance characteristics – limits and methods of measurement*

CISPR 16-1:1999, *Specification for radio disturbance and immunity measuring apparatus and methods. – Part 1: Radio disturbance and immunity measuring apparatus*

CISPR 16-2:1999, *Specification for radio disturbance and immunity measuring apparatus and methods. – Part 2: Methods of measurement of disturbances and immunity*

A.2.2 Terms and definitions

Some basic PLC equipment related definitions are listed in this Clause.

a) clearance

Shortest distance in air between two conductive parts.

b) creepage distance

shortest distance along the surface of the insulating material between two conductive parts.

c) digital input types

- Type 1 Digital Input
senses signal from mechanical contacts such as pushbuttons.
- Type 2 Digital Input
senses signals from solid state switching devices such as 2-wire proximity switches.
This class could also be used for type 1 or type 3 applications.
- Type 3 Digital Input
senses signals from solid state switching devices only.

d) earth, functional earth, protective earth

- Earth refers to part of the earth globe considered as conductive, the electrical potential of which is conventionally taken as zero.
- Functional Earth is a conductor that is in electrical contact with earth for purposes of interference immunity improvement.
- Protective Earth is a conductor in electrical contact with earth for purposes of safety.

e) Electro-Magnetic 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.

NOTE 1 According to IEC 161-01-07.

f) equipment class

Equipment classes, or Protection classes, designate the means by which electric shock protection is maintained in normal use and single fault conditions:

- Class I Equipment
are those with protection against electric shock which does not only rely on basic insulation, but also include means by which accessible conductive parts cannot become live in the event of a failure of the basic insulation.
- Class II Equipment
are those with protection against electric shock which does not rely on basic insulation only but also include additional safety precautions such as double insulation or reinforced insulation.
- Class III Equipment
are which protection against electric shock is provided by circuits supplied by Safety Extra-Low Voltage (SELV, 30 V r.m.s., 42,4 V peak or 60 V DC) and where voltages generated do not exceed the limits for SELV.

g) functional earthing conductor

A conductor that is in electrical contact with earth or earth equal-potential, for example those used for purposes of interference immunity improvement.

h) hazardous live

Capable of rendering an electric shock or electric burn in normal conditions or single fault conditions.

i) hazardous voltage

Hazardous voltage is which under normal conditions exceeds either 30 V r.m.s., or 42,4 V peak.

j) immunity (to a disturbance)

The ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

NOTE 2 Definition according to IEC 161-01-20.

NOTE 3 Immunity may also refer to no degradation of performance in the presence of vibration, humidity, etc.

k) insulation

NOTE 4 Insulation can be a solid, a liquid, a gas (e.g. air), or any combination. According to IEC 151-03-30.

— Basic Insulation

Insulation of hazardous live parts, which provides basic protection against electric shock under fault free conditions.

NOTE 5 According to IEC 195-06-06 and IEC 195-06-01. This concept does not apply to insulation used exclusively for functional purposes. Such insulation is referred to as functional insulation.

— Double Insulation

Insulation comprising both basic insulation and supplementary insulation.

Note 6 According to IEC 195-06-08.

— Reinforced Insulation

Insulation of hazardous live parts which provides a degree of protection against electric shock equivalent to double insulation.

NOTE 7 According to IEC 195-06-09. Reinforced insulation may comprise several layers which cannot be tested singly as basic or supplementary insulation.

— Supplementary Insulation

Independent insulation applied in addition to basic insulation, for fault protection.

NOTE 8 According to IEC 195-06-07.

l) live part

A conductor or conductive part intended to be energized in normal use, including a neutral conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor.

NOTE 9 According to IEC 195-02-19. This concept does not necessarily imply a risk of electric shock. (IEC 195-02-19).

- PEN conductor
A conductor combining the functions of both a protective earthing conductor and a neutral conductor. (IEV 195-02-12).
- PEM conductor
A conductor combining the functions of a protective earthing conductor and a mid-point conductor. (IEV 195-02-13).
- PEL conductor
A conductor combining the functions of both a protective earthing conductor and a line conductor. (IEV 195-02-14).

m) normal condition

Condition in which all means for protection against hazards are intact, that is, a fault-free condition.

n) normal use

Operation, including stand-by, according to the instructions for use or for the obvious intended purpose.

NOTE 10 Normal service conditions are stated in IEC 61131-2.

o) operator

Person commanding and monitoring a machine or process through an HMI connected to the PLC. The operator does not change the PLC hardware configuration, software or the application program. A PLC is not intended for use by untrained personnel. The operator is assumed to be aware of the general hazards in an industrial environment.

p) overvoltage category (of a circuit or within an electrical system)

A classification based on limiting (or controlling) the values of prospective transient overvoltages occurring in a circuit (or within an electrical system having different nominal voltages) and depending upon the means employed to influence the overvoltages.

NOTE 11 Equipment covered in IEC 61134-2 is intended for use in overvoltage category II.

q) pollution degree (in the micro-environment)

For the purpose of evaluating clearances and creepage distances, three degrees of pollution in the micro-environment are established.

NOTE 12 The conductivity of a polluted insulation is due to the deposition of foreign matter and moisture. The minimum clearances given for pollution degrees 2 and 3 are based on experience rather than on fundamental data.

- Pollution Degree 1
No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.
- Pollution Degree 2
Normally, only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation must be expected.
- Pollution Degree 3
Conductive pollution occurs, or dry, non-conductive pollution occurs which becomes conductive due to condensation, which is expected.

r) protective conductor

A conductor provided for purposes of safety, for example protection against electric shock.

NOTE 13 According to IEC 195-02-09.

s) Protective Extra-Low Voltage (PELV) circuit

An electrical circuit in which the voltage cannot exceed AC 30 V r.m.s., 42,4 V peak or DC 60 V under normal condition and under single fault conditions, excepting earth faults in other circuits.

A PELV circuit is similar to an SELV circuit that is connected to protective earth.

t) Safety Extra-Low Voltage Circuit (SELV circuit)

An electrical circuit in which the voltage cannot exceed AC 30 V r.m.s., 42,4 V peak or DC 60 V under normal and under single fault conditions, including earth faults in other circuits.

An SELV circuit is not connected to protective earth.

u) service personnel

The person changing or repairing the PLC hardware configuration or the application program.

The service personnel may also install software updates provided by the manufacturer. They are assumed to be trained in the programming and operation of the PLC equipment and its use.

They are persons with the appropriate technical training and experience necessary to be aware of hazards – in particular, electrical hazards – to which they are exposed in performing a task and of measures to minimize danger to themselves or to other persons or to the equipment.

v) type of test

The following ways of testing may be used by PLC manufacturers to evaluate and confirm specified quality. IEC 61131-2 extensively specifies test methods and requirements. That information is not presented in this Technical Report since the user is normally not expected to delve into the details of the PLC manufacturing process.

- Routine Test
is applied to each individual catalogued device during or after its manufacturing process to ascertain compliance with certain criteria.
- Type Test
is applied to one or several basic PLC systems or samples of catalogue devices subjected to in order to ascertain compliance with required criteria.
- Withstand Type Test (Withstand Test)
Verifies that the application of more severe influencing quantities to the basic PLC system does not impair its ability to assume its intended mission. During this test, the basic PLC system is not energised.

A.2.3 Type tests to verify conformity

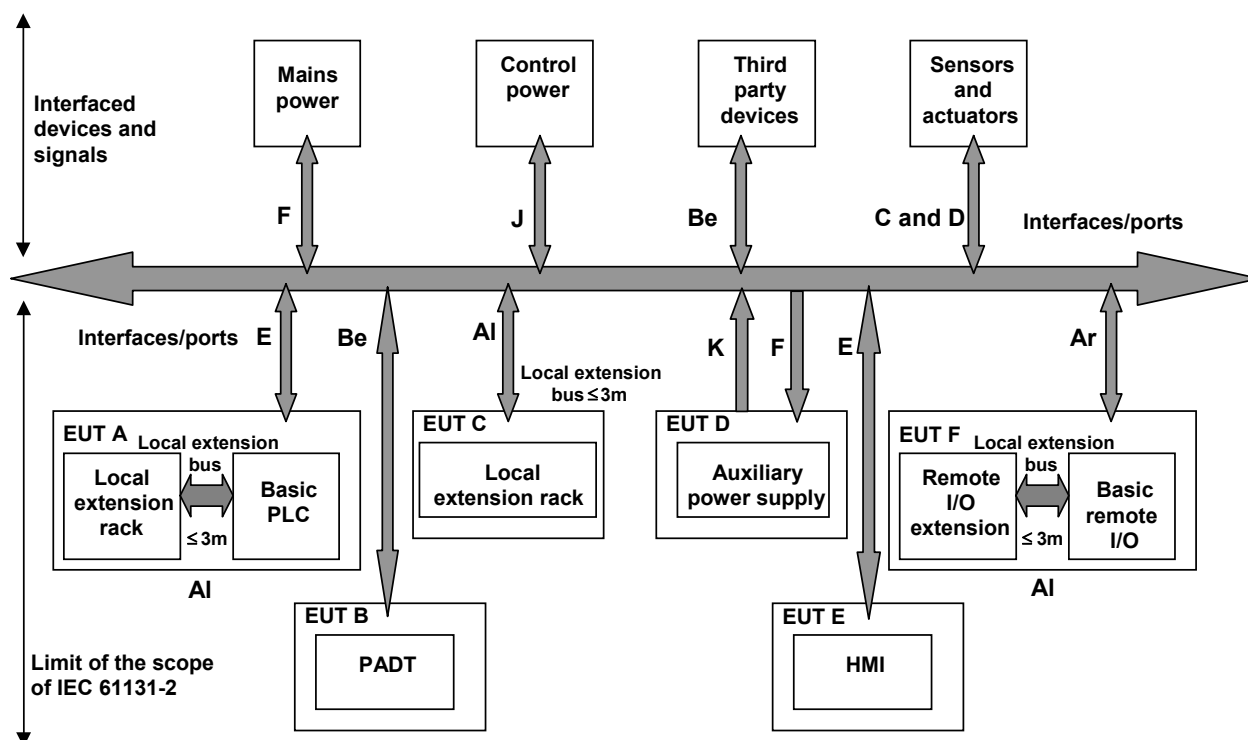
A Type Test is a conformity test on one or more items representative of the production.

Type tests are used to verify compliance of the PLC and the associated peripherals with the requirements given in IEC 61131-2. This compliance verification also includes visual inspection or/and measurement. In addition, routine tests are specified in IEC 61131-2. A routine test is a conformity test made on each individual item during or after manufacture.

The tests specified in IEC 61131-2 are qualification tests, and not tests related to the ways PLCs are employed. According to the scope of IEC 61131-2, the compliance verification may not cover the verification of the ability of the PLC system to satisfy the intended automated system requirements. Where special tests (not covered by IEC 61131-2) are required, those tests need to be agreed to between the manufacturer and the user.

Examples of Equipment Under Test (EUT) for noise immunity and EMC tests are shown in Figure A.4 in which each subpart of the PLC system as shown may constitute an EUT represented in Figure A.3 as EUT A, B, C, D, E and/or F. To exercise the different ports of each EUT, the manufacturer may define subsystems and the different EUTs are tested in turn.

Interfaces/Ports shown are meant to represent major/example links, not all links. Most EUTs will have multiple interface/ports active during testing.



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Figure A.4 – Type test EUT configuration

A.2.3.1 Withstand test conditions

A Withstand Test is a Type Test which verifies that the application of more severe influencing quantities to the basic PLC system does not impair its ability to assume its intended mission. In general, the manufacturer's catalogued module needs to be tested alone during the Withstand Test.

A.2.3.2 General conditions for tests

Tests are carried out under the general test conditions given in IEC 61131-2, unless otherwise specified. No sequence is imposed for type tests, unless otherwise specified.

Table A.2 – General conditions for tests

	Test conditions
Mains power supply	Rated voltage and frequency
Temperature	15 °C to 35 °C
Relative humidity	≤75 %
Barometric pressure	86 kPa to 106 kPa (650 mm Hg to 800 mm Hg)
Output loads	Outputs loaded to rated load
Pollution	Pollution degree 2

A.2.4 Normal service conditions and requirements

It is the user's responsibility to ensure that the equipment service conditions are not exceeded. The PLC and PLC system is intended to be used in an industrial environment.

The user must ensure the installation conditions match the environmental conditions given in IEC 61131-2.

A.2.4.1 Climatic conditions and requirements

A.2.4.1.1 Operating ambient air temperature

The equipment needs to be suitable for the operating temperature ranges given by Table A.3.

Table A.3 – Operating ambient air temperature of PLC systems

		Enclosed equipment (ventilated/non-ventilated)		Open equipment
Temperature range	Type of limit	Permanent installation	Non-permanent installation	Permanent installation
	Max.	40 °C	40 °C	55 °C
	Min.	5 °C	5 °C	5 °C
Average temperature over 24 h	Max.	35 °C	35 °C	50 °C
Notes		1 m away for non-ventilated. Temperature of incoming air for ventilated.		Temperature of incoming air immediately below the equipment.

No forced external cooling is assumed. Open peripherals, which are intended to be permanently installed as part of the PLC system, need to meet the operating temperature range of the PLC.

A.2.4.1.2 Relative Humidity

The equipment needs to be suitable for a relative humidity level from 10 % to 95 %, non-condensing.

A.2.4.1.3 Altitude

The equipment needs to be suitable for operation up to 2 000 m. No test required.

A.2.4.1.4 Pollution degree

Where not otherwise specified by the manufacturer, the equipment is designed for use in Pollution Degree 2.

A.2.4.2 Mechanical service conditions and requirements

Vibration, shock and free fall conditions vary widely depending on the installation and environment and are very difficult to specify.

The service conditions listed in IEC 61131-2 are indirectly defined by the following requirements which apply to fixed equipment as well as to unpackaged portable and hand-held equipment. Experience shows that equipment meeting these requirements is suitable for industrial use on stationary installations.

Conditions are also prescribed for transportation and storage, including temperature, altitude, free fall in manufacturer's original packaging and other conditions.

A.2.4.3 Electrical service conditions and requirements

Electrical service conditions prescribed in IEC 61131-2 include: AC and DC mains power supply, overvoltage category, control of transient overvoltages, transient overvoltages at the point of connection to the mains power supply, non-periodic overvoltages.

The user needs to take the necessary steps to prevent damage to the PLC system (e.g. by interposing a transformer) under overvoltage conditions, in particular the very damaging nature of non-periodical overvoltage (spike) at the mains resulting from power interruption of high-energy circuit/equipment.

When the service conditions are more severe than those given in IEC 61131-2, or other adverse environmental conditions exist, (e.g. air pollution by dust, smoke, corrosive or radioactive particles, vapours or salts, attack by fungi, insects or small animals), the manufacturer should be consulted to determine suitability of the equipment or the steps to be taken.

A.2.5 Functional requirements

A.2.5.1 Functional power supply and memory power back-up requirements

a) Rated value and operating range

Incoming power supplies to the PLC system and to the externally powered I/O modules are specified as:

- Rated DC voltages are: 24 V, 48 V and 125 V with tolerance (min./max.) of $-15\%/+20\%$.
- Rated AC r.m.s. voltages are: 24 V, 48 V, 100 V, 110 V, 120 V, 200 V, 230 V, 240 V, and 400 V with voltage tolerance of $-15\%/+10\%$. The specified frequencies are 50 Hz or 60 Hz. with tolerance (min./max.) of $-6\%/+4\%$.
- AC voltage is in terms of the total r.m.s. voltage values measured at the point of entry to the equipment.
- Total r.m.s. content of true harmonics (integral multiple of nominal frequency) less than 10 times nominal frequency may reach 10 % of the total voltage. Harmonic and other frequency content for higher frequencies may reach 2 % of the total voltage. However, to provide constant comparative results, the equipment needs to be tested at the third harmonic only (10 % at 0° and at 180° phase angle).

b) Memory power back-up

Power back-up for volatile memories needs to be capable of maintaining stored information for at least 300 h under normal use, and 1 000 h at a temperature not greater than 25°C when the energy source is at rated capacity. (For power back-up needing replacement, the rated capacity is the value used to designate the procedure and time interval for replacement.)

The manufacturer is to specify storage time information relative to volatile memory if different from stated durations.

It should be possible to change or refresh power back-up without loss of data in the backed-up portions of memory. If a memory back-up battery is provided, a warning of "Low Battery Voltage" needs to be provided.

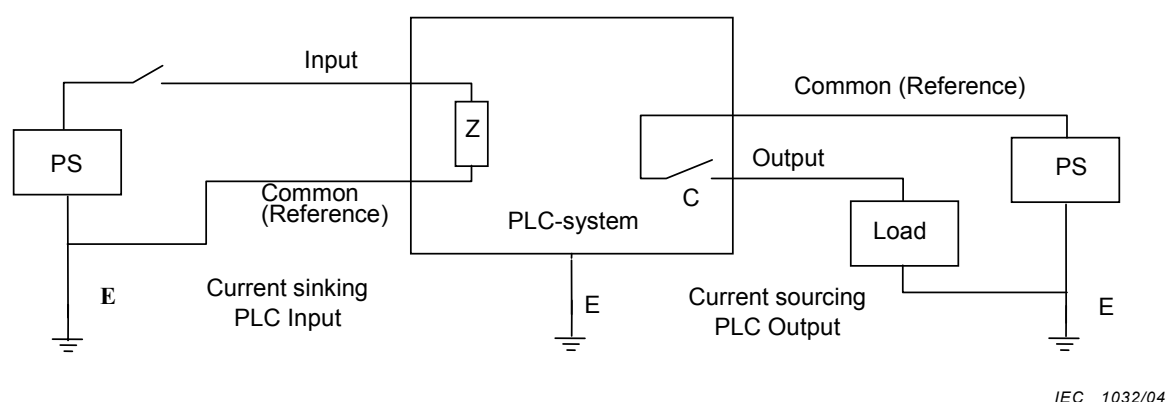
A.2.5.2 Digital inputs/outputs

Some digital I/O parameters are illustrated in Figure A.5.

Other types of outputs include: protected outputs, short-circuit-proof outputs, and non-protected output fitted with an external protective device recommended by the manufacturer. With protected outputs, the PLC system is specified to return to normal operation after re-setting or replacement of the protective device alone.

Electromechanical relay outputs are to be capable of performing at least 0,3 million operations at specified load.

Current sourcing digital output for direct current has rated value of 0,1 A to 2 A with maximum range for state 1 of 0,12 A to 2,4 A.



Key:

C: Output.

Mechanical or static contact (e.g. dry relay contact, triac, transistor or equivalent).

E: Earthings.

The earths shown are optional.

Earthing is dependent on national regulations and/or application needs.

Z: Input.

Input impedance.

PS: External power supplies.

NOTE Some applications may use only one PS common to inputs, outputs and PLC system.

Figure A.5 – Digital I/O parameters

A.2.5.3 Analogue I/Os

Analogue input voltage signals are rated ± 10 V, (0 to 10) V and (1 to 5) V with input impedance limit of ≥ 1 k Ω , ≥ 1 k Ω and ≥ 500 Ω respectively. The rated current signals are (4 to 20) mA and (0 to 20) mA both with input impedance of ≤ 300 Ω .

Analogue output voltage outputs are rated ± 10 V, (0 to 10) V and (1 to 5) V with input impedance limit of ≥ 10 k Ω , ≥ 10 k Ω and ≥ 5 k Ω respectively. The rated current outputs are (4 to 20) mA and (0 to 20) mA both with input impedance of ≤ 600 Ω .

A.2.5.4 Remote Input/Output Stations (RIOSs) requirements

RIOSs are part of the permanent PLC installation and are therefore to be tested accordingly. In the case of loss of communication with the MPU application program, RIOSs are able to fix the states of their outputs to specified values, within specified delays and without passing through unspecified states and are capable of providing a fault indication signal. The MPU system needs to provide the user's application program with relevant information on current status of RIOSs.

A.2.5.5 Peripherals (PADTs, TEs, HMIs) requirements

Peripherals which are not a permanent part of the PLC system should not cause malfunction of the system when making or breaking communication with an operating system.

Connectors for the peripherals need to be polarized to prevent improper connection, or the PLC system needs to be so designed that no malfunction occurs if a connection is improper.

The system consisting of the peripheral and the PLC system needs to be designed to ensure that the edited program executing in the PLC system is functionally identical to the edited program displayed on the peripheral.

If on-line modification of the application program and/or the modes of operation of the PLC system by a peripheral is possible (i.e. when the PLC system is in active control of a machine or industrial process), then:

- The peripheral needs to automatically give clear warnings equivalent to "during on-line modification, program display may differ from application program, control of the machine/process may be interrupted during ... ms, etc.", as applicable.
- The peripheral needs to ask the operator "do you really want to carry out this action?" or some similar words and execute the command only after a positive reply has been given by the operator.

It has to be possible to upload the new application program to the manufacturer's supplied data media and verify, on-line, that the record is functionally equivalent to it, and means need to be provided to prevent unauthorized use of these functions (hardware or software).

A.2.5.6 PLC system self-tests and diagnostics requirements

The manufacturer needs to provide means of self-tests and diagnostics of the PLC system operation. Such means are built-in services of the PLC system, and/or recommended ways to implement the intended application.

The following need to be provided;

- a means for monitoring the user's application program (i.e. watchdog timer, etc.),
- a hardware or software means to check the memory integrity,
- a means to check the validity of the data exchanged between memory(ies), processing unit(s) and I/O modules (such as an application loop-back test),
- a means to check that the power supply unit(s) does not exceed the current and voltage limits allowed by the hardware design,
- a means to monitor the status of MPU.

The permanently installed PLC system needs to be capable of operating an alarm signal on an alarm output. When the system is monitored as "functioning correctly", this alarm output shall be in a predetermined state; in the other case it shall go to the opposite state. The manufacturer needs to specify the conditions of the "correct functioning state" and the self-tests which are executed to drive this alarm output.

RIOSs need to be capable of operating an alarm signal on an alarm output (for example, through a digital output module) in the event of loss of power or loss of normal communication with the MPU and go to a predetermined state.

A.2.5.7 Other requirements

Other requirements prescribed in IEC 61131-2 include: functional earthing, mounting requirements, and general marking requirements.

For marking, functional earth terminals (i.e. used for non-safety purposes such as interference immunity improvement) are marked with the following symbol:



A.2.6 Normal service and function type tests and verification

IEC 61131-2 prescribes the following tests and verifications:

- climatic tests, mechanical tests;
- shut-down test, start-up test;
 - gradual shut-down/start-up test;
- verification of special functional requirements for power ports and memory back-up;
 - special Immunity limits for power ports;
 - verification of functional mains power port (AC or DC);
 - voltage range, ripple and frequency;
 - external energy supply variation tests (immunity tests);
 - supply voltage variation test;
 - Improper power supply connection tests;
 - reverse of DC power supply polarity test (withstand test);
 - improper voltage level and/or frequency test;
- verification of memory back-up requirements;
- verification of input/output requirements;
- verification of digital inputs;
- operating range test;
- reversal of signal polarity test (withstand test);
- verification of digital outputs, including:
 - operating range test,
 - test of protected not-protected,
 - short-circuit proof outputs, and
 - reversal of signal polarity;
- verification of analogue I/Os, including:
 - operating range test,
 - analogue input overload withstand test,
 - short-circuit test (voltage output), and
 - open-circuit test (current output);

NOTE No physical damage or abnormal phenomenon should be detected. Functional verification is performed after the tests, voltage supply variation test and reversal of signal polarity test (withstand test).

- verification of remote I/O station, including:
 - response time test;
 - loss of communication test;
- verification of peripherals (PADTs, TEs, HMIs) requirements;
- verification of PLC system self-tests and diagnostics;
- verification of markings and manufacturer's documentation.

A.2.7 Equipment information to be provided by the manufacturer

A.2.7.1 Information on type and content of documentation

A.2.7.1.1 Information on catalogues and datasheets

These documents need to contain the description and the specifications of the PLC system and its associated peripherals. Additionally, they need to contain any other relevant information to aid in understanding the application and use of these products including functional characteristics, equipment configuration rules, normal service conditions, physical dimensions and weights, and list compliance with standards and certifications.

A.2.7.1.2 Information on user's manuals

These documents include the necessary information for the proper installation, wiring, troubleshooting, user programming and commissioning of the PLC system by the user. They are to include as a minimum:

- installation and commissioning instructions;
- programming and troubleshooting instructions;
- maintenance and service requirements, and
- accessory and spare parts lists (e.g. fuses).

A.2.7.1.3 Information on technical documentation

The manufacturer may optionally provide a set of documents which contain more information than those given in the users manual such as: schematic diagrams, internal or external data protocols, bus assignments, physical dimension characteristics, energy available, firmware, internal test programs or repair procedures, etc.

A.2.7.2 Information on compliance with this standard

The manufacturer needs to provide information on compliance with IEC 61131-2, which can be claimed on two levels:

- a) full compliance with all of the requirements contained in all clauses of the standard, such as indicated by reference to IEC 61131-2 without qualification;
- b) compliance with a portion of the standard where documentation identifies the specific clauses of the standard with which the product has been determined to comply.

A.2.7.3 Information on reliability

If the manufacturer provides values of the Mean Time Between Failures (MTBF) of any subassembly or module, and of the type-test configuration (s) (PLC system (s)) under normal service conditions the manufacturer also needs to explain the method used to determine it.

A.2.7.4 Information on other conditions

The user is to reach agreement with the manufacturer for any mechanical conditions that are not specified in IEC 61131-2.

A.2.7.5 Information on shipping and storage

The manufacturer provides shipping and storing instructions.

A.2.7.6 Information on AC and DC power supply

The manufacturer is to provide the following information:

- data to allow selection of a suitable power distribution network to provide specified voltage at each power utilization point. This information includes peak inrush (at cold start and warm restart), repetitive peak and steady-state r.m.s. input currents under full load conditions;
- external terminal identification for power supply interfaces;
- typical example(s) for power supply system(s);
- special supply installation requirements, if any, for PLC systems energized through multiple power supplies or supply voltages and frequencies not included in IEC 61131-2;
- the effect of the following incorrect connections of power to the supply(ies): reverse polarity, improper voltage level and/or frequency and improper lead connection;
- complete information on PLC system behaviour for typical power up/down sequences;
- data to allow evaluation of the maximum values of interruption time which do not affect the normal operation of any PLC system configuration; PS class (PS-1 or PS-2) of DC supplied devices;
- memory back-up time with respect to temperature and maintenance requirements;
- recommended time interval between replacement of energy sources, if applicable, and recommended procedure and subsequent effects on the PLC system;
- peak inrush current (at cold start and warm restart) or recommended fuse size and blowing characteristics.

A.2.7.7 Information on digital inputs (current sinking)

The manufacturer is to provide the following information:

- volt-ampere curve over the full-operating range, with tolerances or equivalent;
- digital input delay time for 0 to 1 and 1 to 0 transitions;
- existence of common points between channels;
- effect of incorrect input terminal connection;
- isolation potentials between channel and other circuits (including ground) and between channels under normal operation;
- type of input (Type 1, Type 2 or Type 3);
- monitoring point and binary state of visual indicator;
- effects when withdrawing/inserting input module under power;
- additional external load when interconnecting inputs and outputs, if needed;
- explanation of signal evaluation (for example static/dynamic evaluation, interrupt release, etc.);
- recommended cable and cord lengths depending on cable type and electromagnetic compatibility;
- terminal arrangements;
- typical example(s) of external connections.

A.2.7.8 Information on digital outputs for alternating currents (current sourcing)

The manufacturer is to provide the following information with respect to digital outputs for AC operation:

- type of protection (i.e. protected, short-circuit proof, not-protected output) and:
 - for protected outputs: operating characteristics beyond 1,1 rated current including the current(s) level(s) at which the protecting device energizes, the current behaviour beyond, and the time(s) involved;
 - for short-circuit proof outputs: information for replacement or resetting the protective device as required;
 - for not-protected outputs: specification for protective device to be provided by the user, as required;
- output delay time for state 0 to state 1 and state 1 to state 0 transitions;
- commutation characteristics and turn-on voltage with respect to zero voltage crossing;
- existence of common points between channels;
- terminal arrangements;
- typical example(s) of external connections;
- number and type of outputs (e.g. NO/NC contacts, solid state, individually isolated channels, etc.);
- for electromechanical relays, the rated current and voltage complying with IEC 61131-2;
- output ratings for the other loads such as incandescent lamps;
- total output current for multi-channel modules;
- characteristics of suppresser networks incorporated into the output circuit against voltage peaks due to inductive kickback;
- type of external protective networks, if required;
- effects of incorrect output terminal connection;
- isolation potentials between channel and other circuits (including ground) and between channels under normal operation;
- monitoring points of visual indicators in the channel (e.g. MPU side/load side);
- recommended procedures for changing output modules;
- output behaviour during interruptions of MPU control, voltage drops and interruptions and power up/down sequences;
- type of operation (i.e. latching/non-latching type);
- effects of multiple overloads on isolated multi-channel modules.

A.2.7.9 Information on digital outputs for direct current (current sourcing)

The information to be provided by the manufacturer for digital outputs for DC is the same as for digital outputs for AC. However, the specification of commutation for zero voltage crossing does not apply, and with regard to electromechanical relay outputs.