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IEC PUBLICATION 1131-4

PROGRAMMABLE CONTROLLERS— PART 4: USER GUIDELINES

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IEC Publication 1131-4

PROGRAMMABLE CONTROLLERS—
PART 4: USER GUIDELINES

ANSI approved, October 28, 1996

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FOREWORD

This Standards Publication is NEMA Authorized Engineering Information adopted from IEC 1131-4, "Programmable controllers—Part 4: User guidelines." IEC 1131-4 has been published by the International Electrotechnical Commission as a Type 3 Technical Report.

This NEMA Standards Publication was supported and reviewed by the Programmable Controller Technical Committee of the NEMA Automation Products and Systems Section. It was approved in accordance with the bylaws of NEMA and supersedes applicable portions of NEMA Standards Publications ICS 3-1988, Part 3-304.

This Standards Publication represents many years of direct NEMA member participation in IEC Subcommittee 65B/Working Group 7, and reflects the input provided to the IEC from the Programmable Controller Technical Committee.

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Proposed revisions to this Standards Publication should be submitted to:

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REFERENCED STANDARDS

This NEMA Standards Publication references standards published by the International Electrotechnical Commission (IEC), the International Organization for Standardization (ISO), and the National Fire Protection Association (NFPA). Copies of these standards are available from:

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AMENDMENTS

IEC 1131-4, "Programmable controllers – Part 4: User guidelines" is adopted in its entirety.

Authorized Engineering Information

When the phrase "national code" or the like is used in IEC 1131-4, reference to ANSI/NFPA 70, *National Electrical Code*, and other applicable codes is to be understood.

Authorized Engineering Information

Where a conflict exists between the provisions of IA 2.4 and other NEMA Standards Publications, the provisions of IA 2.4 should take precedence in the area of programmable controllers and their associated peripherals.

Authorized Engineering Information

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PROGRAMMABLE CONTROLLERS— Part 4: User Guidelines

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Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

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INTRODUCTION

This Technical Report provides guidelines that address the application of the programmable controllers (PC) and associated peripherals. It also deals with the integration of PCs into the automated system. Overall automated system safety, including installation and application, is beyond the scope of this part of the report.

The terms in upper case are defined either in IEC 1131-1 if of general use, or in 2.2 of this report. Annexes provide explanations or further information on subject items.

User guidelines are written to assist the USER in the specification and implementation of the PC system. The document is primarily intended for the USER responsible for all system level design, installation and final commissioning. The guideline covers the control system in general, and the programmable controller portion of the system in particular (see figures 1a and 1b).

The PC application process (the specification, design, development, and installation of a PC-based system for a particular application) may be a reiterative process to understand and address all system requirements. This reiteration can occur at any portion of the system life cycle, e.g., user system analysis, PC system selection and application engineering, safety and protection considerations, pre-installation system testing, installation, commissioning and maintenance.

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PROGRAMMABLE CONTROLLERS—
Part 4: User guidelines

1 General

1.1 *Scope*

The complete programmable controller standard applies to programmable controllers and their associated peripherals such as programming and debugging tools (PADTS), test equipment (TE) and man-machine interfaces (MMIS), etc.

This Technical Report refers to equipment for the control and command of machines and industrial processes used in overvoltage category II (IEC 664), in low-voltage installations, where the rated mains supply voltage does not exceed 1 000 V a.c. (50 Hz/60 Hz), or 1 500 V d.c.

Programmable controllers and associated peripherals (PC system) are considered components of a control system and may be provided as enclosed or open equipment. this report deals with the PC and interfaces to the other parts of the automated system and does not deal with the whole automated system itself (see figure 1a).

1.2 *Object*

The purpose of IEC 1131-4 is to provide information that assists the user in:

- utilizing the other parts of the programmable controller standard;
- specifying the requirements for PC applications;
- selecting and implementing PC systems. The following topics are covered in this Technical Report:
- references to pertinent information in other parts of the programmable controller standard. This information is useful in obtaining a better understanding of the environment and application of the PC;
- description of supplemental information, helpful in making use of other parts of this standard;
- system level functional analysis of the user's process;
- specification of a programmable controller system;
- programmable controller installation, commissioning and maintenance.

IEC 1131-4 does not provide a comprehensive analysis of a complete automated system. It is intended as a source of information about programmable controllers, their specifications, and selection. The reader may also refer to other parts of IEC 1131.

It is the responsibility of the user to obtain the required information to properly implement the programmable controller, such as user manuals and other technical references available from the manufacturer. The user will assume responsibility for final decisions in the selection and application of the programmable controller system.

This report is to address the interface between the vendor and system integrator, but the document also contains information which the end user will find of value (see figure 1b).

1.3 *Reference documents*

The following references apply within this part of IEC 1131.

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IEC 68: *Environmental testing*
IEC 204-1: 1992, *Electrical equipment of industrial machines Part 1: General requirements*
IEC 529: 1989, *Degrees of protection provided by enclosures (IP Code)*
IEC 664-1: 1992, *Insulation coordination for equipment within low-voltage systems Part 1: Principles, requirements and tests*
IEC 947-5-2: 1992, *Low-voltage switchgear and controlgear Part 5: Control circuit devices and switching elements Section 2: Proximity switches*

2 Terminology

2.1 *Definitions*

For the purpose of this Technical Report, the following definitions apply.

2.1.1 **autonomous:** Ability to operate as an independent system or subsystem.

2.1.2 **down loading:** Ability to load a program and/or data via a communication link.

2.1.3 **multitasking:** Capability of an operating system to service two or more separate programs.

2.1.4 **port:** A device or set of connections which provide access to a PC-CPU for transfer of data.

2.1.5 **topology:** The physical configuration of a system.

2.1.6 **hot standby:** Equipment energized and available for operation. Redundant equipment energized and available for operation.

2.17 **user:** Users are described in figure 1b.

Other definitions given in IEC 1131-1, IEC 1131-2, and IEC 1131-3 apply.

2.2 *Abbreviations and acronyms*

A/D Analog to digital
BCD Binary coded decimal
CMOS Complementary metal oxide semiconductor
CMRR Common mode rejection ratio
CMV Common mode voltage
CPU Central processing unit
D/A Digital to analog
dB Decibel
DC Direct current
DIP Dual integrated pin switch
EMF Electro-motive force
EMI Electromagnetic interference
EEPROM Electrically erasable programmable read only memory
EPROM Erasable programmable read only memory
ESD Electro-static discharge
FBD Function block diagram
Hz Hertz (cycles per second)
IEC International Electrotechnical Commission
IL Instruction list
I/O Input/output
ISO International Organization for Standardization

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LAN	Local area network
LED	Light emitting diode
LD	Ladder diagram
LSB	Least significant bit
MMI	Man-machine interface
MMS	Manufacturing message specifications
MOV	Metal oxide varistor
MPU	Main processing unit
MTBF	Mean time between failures
MTTR	Mean time to repair
PADT	Programming and debugging tool
PC	Programmable controller
PID	Proportional integral derivative
RF	Radio frequency
RIOS	Remote input/output station
RMS	Root mean square
RTD	Resistance temperature device
SFC	Sequential function chart
SRS	Safety related system
ST	Structured text
TE	Test equipment
V a.c.	Alternating voltage
V d.c.	Direct voltage
WAN	Wide area network

3 User system analysis and specification

For the purpose of PC application and selection, information to be presented is defined in this clause. The entire contents of the user guidelines should be considered in developing a functional system specification. Additional topics may need to be included to completely describe the system.

3.1 *Clause overview*

Programmable controller systems are utilized for a wide variety of industrial applications, ranging from control of a single machine to complete industrial plant control.

The functional analysis of the user's system is the basis for the production of a detailed system functional specification.

A detailed functional system specification should include engineering data and information relevant to the following:

- user objectives and application requirements;
- functions and tasks to be performed;
- detailed system description
- performance criteria;
- environmental constraints.

The design cycle for programmable controller systems is illustrated in figure 2. This clause describes possible contents and methods for presenting salient information relevant to the analysis and specification blocks in figure 2.

Topics to be considered for inclusion in the PC specification are listed in annex F.

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3.2 *Information presentation*

There are a variety of methods for the presentation of operational and engineering data relevant to the application of programmable controller systems. Each method embodies certain advantages. A combination of methods will usually be necessary to detail the total system requirements.

The presentation should take into account the programming language to be selected. There are definite advantages to correlating drawings with programming procedures. Furthermore, the information is likely to become the basis for equipment operation manuals.

Common presentation methods include: narrative specifications, flow charts, logic diagrams, and function and event diagrams. Information presentation may be included in the programming format being used for the application program, e.g., ladder logic.

3.2.1 *Narrative specifications*

Narrative specifications comprise literal descriptions of system operation and requirements. They are rarely adequate for system definition without additional diagrammatic clarifications.

3.2.2 *Flow charts*

A flow chart is a graphical presentation of the sequence of all events constituting the controlled system. Each event is connected to a prior event or combination of prior events which causes the current event. Decisions are required where there are alternative paths to the next connection(s). Feedback loops often occur in a flow chart in which an event causes the repetition of a portion of prior connected nodes.

The flow chart, therefore, represents the operational logic of a system and provides a sequential view of the system. An example of the principle of the flow chart is the programming language utilizing sequential function chart (SFC) elements in 2.6 of IEC 1131-3.

Flow charts are suitable for logic and engineering data presentation for all sizes and types of programmable controller systems.

3.2.3 *Logic diagrams*

A logic diagram represents a control system's logic equations (Boolean logic) which governs the operational events of the system. The logic diagram, therefore, highlights the relations between events and shows how an event does or does not occur. The logic diagram does not in itself indicate the time sequence of operations.

Logic diagrams are an acceptable method of engineering data presentation, providing that the basis for presentation and connectivity is consistent with a standard form of symbolization. However, additional narrative description to explain certain areas of operation may be necessary.

3.2.4 *Function and event lists*

A function and event list indicates the functions and the events included in the operation of a system. The list can be descriptive and is usually sequential. It is useful, in qualifying and extending detailed areas of engineering data, for the presentation methods cited above.

3.3 *User's control objectives and application requirements*

The user objective and application requirements should include a general description of the process/equipment to be controlled in order to provide essential design information. This information will enable the user and the manufacturer of programmable controllers to establish general equipment requirements and considerations.

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Major topics to be considered include:

- process to be controlled;
- user control objectives;
- general control and operation requirements;
- plant and personnel protection considerations (see clause 5);
- general installation and environmental considerations;
- expansion and integration requirements;
- hardware configuration and regulations;
- system availability requirements;
- equipment breakdown implications;
- spare parts requirements;
- redundancy;
- applicable local/national/international standards and regulations;
- performance requirements;
- interface to other systems;
- maintenance;
- cable wiring, routing and termination;
- company regulations;
- documentation: content, format;
- regulatory/certification/approval requirements;
- delivery and equipment installation schedule;
- engineering responsibility: hardware, software, documentation, protective measures, testing, commissioning;
- other considerations as required.

3.4 *User system description*

This subclause refers to information to be presented to the vendor by the user as shown by the dashed lines in figure 1b.

The description of the user's system should consolidate the user's objective and provide the programmable controller vendor with relevant information concerning the user's process/equipment operation, control, monitoring, and configuration of hardware and software. The description should be supported with appropriate explanatory diagrams, drawings, and signal (I/O) sequence and timing requirements.

3.4.1 *User system characteristics*

User system characteristics include:

- continuous or batch processing;
- loop (PID) control;
- distributed control;
- changing of process (recipe supporting);
- down loading;
- autonomy of local stations;
- system availability requirements;
- total system response time;

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- redundancy;
- multitasking;
- alarm handling;
- trending;
- operator interface;
- operator prompt;
- remote supervision;
- manual over-ride;
- protection/safety considerations;
- interlocks;
- dynamic characteristics;
- non-linearities;
- authorization;
- normal shutdown;
- automatic restart;
- data communication;
- peripherals;
- networks (LAN, WAN).

3.4.2 *Control system parameters*

Plant/equipment operation parameters with reference to maximum and minimum process variables/values, elapsed time limits for actions and reactions should be detailed where process control is required.

Other topics to be considered include:

- I/O listing;
- sensors: types, signal level, power requirements;
- signal conditioning;
- control outputs: types, power requirements;
- data transfer/access;
- local/remote display;
- logging and archiving;
- electrical interference rejection criteria;
- system availability;
- I/O redundancy: single or voting (e.g. two out of three).

3.4.3 *Alarms*

The user's system description should include alarm requirements. The organization concept, priority, alarm operation and display should be defined.
Other major topics to be considered include:

- alarm sensing methods;
- first fault identification;
- fault discrimination;
- dedicated alarm display;

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- alarm at man-machine interface;
- alarm acknowledgement;
- alarm logging.

3.4.4 *Man-machine interface*

Man-machine interface (MMI) requirements include considerations for operator intervention, access control and security arrangements.

Other major topics include:

- multistation display;
- dedicated display areas;
- dynamic graphics;
- access control, authorization and passwords;
- key locks;
- software locks;
- keyboard, track ball, mouse, touch screen, etc.;
- ergonomics.

3.4.5 *Interlocks*

The use of interlocks, including their effects, should be described.
Major topics to be considered include:

- physical requirements of interlock;
- types of systems to be interlocked;
- system/system communication (see IEC 1131-5);
- requirements for data network.

3.4.6 *System outage*

Topics relating to system outage include the following:

- power supply configuration;
- system back-up;
- diagnostics;
- failure mode;
- failure display levels: system, module, or card;
- restart: cold, hot, or warm;
- protection of personnel and equipment.

3.4.7 *Peripherals*

Major topics to be considered include:

- types of peripherals;
- MMI facilities (see 3.4.4);
- displays;

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- keyboard layout: standard or customized;
- printers;
- chart recorders.

3.4.8 *System software*

Major topics to be considered include:

- programming structure/programming language;
- PADT;
- access to control programs: access methods, authorization;
- documentation;
- computer aided engineering tools;
- on-line/off-line configuration.

3.5 *Environmental constraints and requirements*

The PC system should be used within the manufacturer's environmental specification.

3.5.1 *Geographic location*

The following items should be considered in view of indigenous (local) factors:

- maintenance and service support;
- transportation regulations;
- local culture and customs;
- import/export regulations.

3.5.2 *Installation site*

The following items should be considered:

- building layout;
- equipment separation;
- equipment and peripheral layout;
- installation space;
- maintenance access.

3.5.3 *Environmental factors*

Environmental factors of the user's system which can have an effect on the operation of programmable controllers include:

- temperature (maximum/minimum);
- humidity (maximum/minimum);
- dust and airborne contamination;
- hazardous gases (appropriate certification approval may be needed);
- corrosive atmosphere;
- vibration;
- electrostatic discharge;
- RF interference (both susceptibility and emissions);

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- climate control;
- tropicalization requirements;
- water hazards, including hosing down either automatically or manually;
- pre-installation storage;
- fungi;
- insects;
- small animals;
- equipment storage;
- galvanic corrosion;
- metallurgical migration (as related to integrated circuits);
- dendritic growth;
- fretting corrosion;
- lightning.

4 Programmable controller system selection and application engineering

4.1 *Clause overview*

PC system selection involves assessment of functional system requirements, configuration, performance, ease of operation, availability, protection and best value with respect to the user requirements. These requirements can usually be related to:

- general requirements;
- hardware;
- software;
- documentation.

To aid in PC system selection, the user should list selection criteria with respect to the application requirements and allocate priority to the criteria. This information will aid in making technical and economic trade-offs.

4.2 *General requirements*

General requirements are related to overall objectives and operation of the PC system. Table 1 lists references and considerations to be taken into account during the selection process.

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Table 1 – PC system selection General considerations

Criteria	Reference		Comments and considerations
Geographic Location	IEC 113104 3.5.1	Work force	– Knowledge and skill level
		Suppliers' facilities	– Ability to support servicing and spare parts supply requirements
		Standards/local codes	– Suitability of equipment with respect to standards
Environment	IEC 1131-2 2.1, 3.9.1	Local conditions	– Suitability for environmental conditions
	IEC 1131-4 3.5.3		– Compliance with IEC 1131-2 – Equipment operating limits with respect to environmental conditions
Radiated EMF	IEC 1131-4 Annex A		– Equipment modifications needed to meet conditions (if any)
	IEC 1131-2 3.9.1		
ESD	IEC 1131-4 Annex B		
Conducted noise	IEC 1131-2 3.9.1		
System architecture	IEC 1131-4 Table 6	Power supply	– Controlled start-up and shutdown of connected system power supplies
	IEC 1131-5	Communication	– Single-station failure effect
	IEC 1131-1 4.3.1, 4.3.2	Remote I/O	– Requirements – Operating
	IEC 1131-2 3.7		– Update rate
	IEC 1131-4 Table 10		
	IEC 1131-1 2.6.8, 4.3	Total system response time I/O mix	– Scan – Update rate of I/O, RIOS – Amount/ratio of digital/analog inputs supported
	IEC 1131-4 Table 7	MPU PC system restart	– Scan time – Methods to determine type of restart (warm, hot) if applicable
Product supports	IEC 1131-4 Annex F	Experience	– System level experience should be considered
	IEC 1131-2 4.5 to 4.12 IEC 1131-4 4.12	Model/type Software	– Purchasing records – Availability of replacements – Version and date of operating system – Applications program language – Software support

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Table 1 (Continued)

Criteria	Reference		Comments and considerations
Expansion	IEC 1131-5	System	– Needs for expansion – Communication facilities and protocol – Response time changes
	IEC 1131-1 4.4	Communication ports	– Number and usage of ports – Availability of port extenders and limitations of use
	IEC 1131-1 4.2.2.2, 4.2.2.3 IEC 1131-2 3.6.3	Memory	– Memory included with respect to maximal expandability – Memory available for application program
		Displays	– Expansion capability of graphics – Response time
	IEC 1131-4 Table 11	Remote I/O	– Number of RIOS allowed, total number of inputs/ outputs
	IEC 1131-4 Table 6	I/O Power supply	– Examine I/O mix limitations number of inputs/outputs – Voltage rating and capacity
Exceptions to specifications			– Exceptions/omissions and clarify with manufacturer
Manufacturer information	IEC 1131-2 Clause 5		– Relevant data listed and compliance requirements
Availability	IEC 1131-1 2.4 IEC 1131-4 Table 2		– System availability data
Maintainability	IEC 1131-4 Table 18, 19		Concept of preventive maintenance
Reliability	IEC 1131-1 2.34 IEC 1131-2 5.5		– MTBF (mean time between failures) – MTTR (mean time to repair)
Access control	IEC 1131-4 3.4.4 Table 12		– Temper resistance – Restricting the access – Access control and logging
Internal diagnostics	IEC 1131-2 3.11		– Basic requirements – Self-diagnostics – Watch-dog timer – Memory test – Power supply – Status monitor – Alarm signalling – Type of tests and diagnostics functions performed (system response time may be impacted by diagnostics)
External diagnostics			May also be provided
Effects of peripherals	IEC 1131-1 2.44, 2.45 IEC 1131-2 3.8		– Effects of plugging and unplugging, connecting/ disconnecting non-permanently installed peripherals on the various system performance times – Security aspects
Isolation	IEC 1131-2 3.10 IEC 1131-4 Clause 7		– Safety/protection between field circuits and the PC system – As required for noise immunity – Analog measurements where isolation is necessary

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4.3 *Redundancy*

There are various levels of redundancy and fault tolerance that can be implemented in the control system. These requirements are primarily based on the needs of the controlled system, including safety/protection, which is discussed in clause 5. Table 2 lists some of these considerations, but should not be construed to be an all-inclusive list.

Table 2 – Redundancy – Selection criteria

Criteria	Reference	Comments and consideration
System availability	IEC 1131-1 2.34	– MTBF – Mean time between failures – MTTR – Mean time to repair – System performance following a fault – System level effect of single points of failure – Continuance of system operation after faults have occurred
Restart	IEC 1131-1 2.56	Cold restart resets all system conditions to those of initial start-up conditions Warm restart will restart the system at a point which occurred somewhat before the shutdown Hot restart remains all system information and restart exactly where the system stopped
Bumpless transfers		The ability to switch over to a back-up system without significant process variations, or "bumps"
Redundant units		More than one power supply, CPU, I/O to perform the same function
Voting		One out of two Two out of two – dual I/O devices and I/O channels Two out of three – three devices and three channels

NOTES—Some of the criteria in table 2, such as hot, warm, cold restart, and bumpless transfers, are often defined and implemented differently by various manufacturers.

4.4 *Digital inputs/outputs*

4.3.2 of IEC 1131-1 and 3.3 of IEC 1131-2 list relevant details and the following table 3 contains selection considerations.

Table 3 – Digital inputs/outputs – Selection criteria

Criteria	Reference	Comments and considerations
Circuit type Inputs Outputs	IEC 1131-2 3.3	For hard contacts (type 1) or two-wire proximity switch (type 2) Proximity switch – IEC 947-5-2 Solid state, electromechanical
Current sourcing/sinking	IEC 1131-2 3.3 Note 1, Figure 2	Current sourcing outputs and current sinking inputs are recommended
Standard ratings	IEC 1131-2 3.3.1 to 3.3.3	Section 3.3.2 and 3.3.3 are for outputs Figure 3 of 3.3.1.1 and table 9 of 3.3.1.2 can be used to ensure inputs comply with standard
Status indicators	IEC 1131-2 3.3.1.3, 3.3.2.2	To indicate status condition of I/O points and aid in system maintenance

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Table 3 (Continued)

Criteria	Reference	Comments and considerations
Protection provided	IEC 1131-2 3.3.2.2 3.3.2.3 4.10	– Over voltage – Over current – Protection for single or group of I/O – Resettable or replacable – Protective devices coordination
Configuration	IEC 1131-2 3.3.1	Channels per card, channel groupings
Derating	IEC 1131-2 3.3.2.3 Note 10	Circuit loading limitations depend on the number of I/O energized and temperature
Isolation	IEC 1131-2 4.2	Voltage levels from system and between channels
Intrinsic safety		Compliance with national/local standards, which may also restrict certain I/O configurations
Override		– Forcing with hardware or software – Maintenance – Authorization and security measures
Address select		On card, backplane – replacement implications
Power supply		Field side, PC-resident (may be uninterruptible)
Diagnostics	IEC 1131-2 3.11	Detecting open circuit/short circuit; open fuse
I/O response time	IEC 1131-1 2.68	Delay time of I/O (Critical in some applications)
Field wiring	IEC 1131-2 4.6.2 IEC 1131-4 7.2	Wire size, torque, terminations

4.5 *Analog inputs/outputs*

Refer to 4.3.2 of IEC 1131-1 and 3.4 of IEC 1131-2 for relevant details, and table 4 for a listing of selection considerations.

Table 4 – Analog inputs/outputs – Selection criteria

Criteria	Reference	Comments and considerations
I/O type	IEC 1131-2 3.4.1	Differential, single-ended, isolated, etc.
Range	IEC 1131-2 3.4.1.1 3.4.1.2.1	Voltage and/or current, thermocouple, RTD, etc.
Impedance	IEC 1131-2 3.4.1.2 3.4.2.1	Input: for in operating range and out of operating range signals Output: load impedance driven and related accuracy
Accuracy resolution	IEC 1131-2 3.4.1.2.1 3.4.2.2.1	– Maximum error at 25°C – Temperature range – Calibration interval
Digital resolution	IEC 1131-2 3.4.1.2.1 Item 4 3.4.2.2.1	8 bits (1 in 256), 12 bits (1 in 4,096), etc.
Data format	IEC 1131-2 3.4.1.2.1 3.4.2.2.1	– Binary – BCD – Floating point

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Table 4 (Continued)

Criteria	Reference	Comments and considerations
LSB value	IEC 1131-2 3.4.1.2.1 3.4.2.2.1	Value of least significant bit (LBS) in engineering units
Field wiring	IEC 1131-2 4.6.2 IEC 1131-4 7.2	Wire size, torque, terminations
Maximum overload	IEC 1131-2 3.4.1.2.1 3.4.2.2.3	Input: maximum input for no damage Output: maximum overload applied to output with no damage
Input over range	IEC 1131-2 3.4.1.2.1	Input reading under/over range input conditions
Isolation provided	IEC 1131-2 3.4.2.2.3 3.4.1.2.3	Isolation voltage range, channel to channel, channel to system
CMV	IEC 1131-2 3.4.2.2.1	Input common mode voltage range
CMMR	IEC 1131-2 3.4.1.2.1	Input common mode rejection radio (dB)
Special inputs	IEC 1131-2 3.4.2.2.1	– Interface to special sensor types – Linearization method
Thermocouple	IEC 1131-2 3.4.1	– Cold junction compensation method
I/O timing	IEC 1131-1 2.68	Input – Total input system transfer time – Sample duration time – Sample repetition time – Input filter order and transition frequency Output – Total output system transfer time
Maximum temporary deviation	IEC 1131-2 3.4.1.2.2 3.4.2.2.2	The amount the analog signal will change (as a percentage of full scale) during the noise testing (see 3.9 of IEC 1131-2)
A/D method	IEC 1131-2 3.4.1.2.3	– Successive approximation – Dual slope – Flash – Others
D/A method	IEC 1131-2 3.4.1.2.3	– D/A per channel – Common D/A with sample/hold
Operating modes	IEC 1131-2 3.4.1.2.3	– Self-scan – Triggered – Others
Protection type	IEC 1131-2 3.4.1.2.3 3.4.2.2.3	– Resistor – Capacitor – Opto-isolator – MOV – etc.
Power supply	IEC 1131-2 3.4.1.2.3 3.4.2.2.3	External power supply specification, if required
Cable specification	IEC 1131-2 3.4.1.2.3 3.4.2.2.3 IEC 1131-4 7.2	– Type and length – Installation rules for noise

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Table 4 (Continued)

Criteria	Reference	Comments and considerations
Calibration	IEC 1131-2 3.4.1.2.3 3.4.2.2.3	Method and interval (time between calibrations)
Monotonicity	IEC 1131-2 3.4.1.2.4 3.4.2.2.4	With or without missing codes
Crosstalk	IEC 1131-2 3.4.1.2.4 3.4.2.2.4	Measured between channels
Non-linearity	IEC 1131-2 3.4.1.2.4 3.4.2.2.4	As a percentage of full scale
Repeatability	IEC 1131-2 3.4.1.2.4 3.4.2.2.4	At fixed temperature after stabilization time
Setting time	IEC 1131-2 3.4.2.2.2	Time to settle for a full-range change, in ms
Overshoot	IEC 1131-2 3.4.2.2.2	Maximum percentage beyond specified value Percentage of full range
Current outputs	IEC 1131-2 3.4.2.2.3	Maximum and minimum voltage range Maximum allowable inductive load
Voltage output	IEC 1131-2 3.4.2.2.3	Maximum and minimum output current Maximum capacitive load
Load types		Floating, grounded
Ripple	IEC 1131-2 3.4.2.2.4	Maximum r.m.s. output ripple, as percentage of full range

4.6 *Application-specific modules*

In some applications, there may be a need for an I/O module which has a processor of its own to perform some functions that are not possible or less efficient to perform with the CPU. This module is a part of the PC system and reports to the PC system on a supervisory basis.
The following table describes some of the most used modules.

Table 5 – Application – Specific modules

Criteria	Reference	Comments and considerations
PID control		When it is necessary to control a part of the application, the user should define the required performance to verify that the module has adequate characteristics
High-speed digital signal		Used when high-speed signals have to be acquired; e.g., a pulse counter
Servo-control		Used in applications where it is necessary to control movements. This module requires positions (generally digital inputs from sensor) and control movement (generally ON/OFF digital outputs)
Interrupt control		In some parts of the application, it may be necessary to have a fast response to important events. This module can react to some combinations of signals and controls a predefined position, of an actuator, for example.

4.7 *Power supplies*

There are many and varied power supplies required for a programmable controller system. The power supplies which power the MPU, memories and communication modules are normally supplied by the manufacturer and have all the required features for system start-up, configuration and other power system

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features incorporated. These power supplies also normally furnish the required system interface power for both local and remote I/O and are powered from the mains power supply. These manufacturer-supplied power supplies are dedicated and highly recommended.

NOTE—When the above subclause applies to machinery, see also IEC 204-1.

The following table describes the incoming power supply.

Table 6 – Incoming power supplies – Selection criteria

Criteria	Reference	Comments and considerations
Rated voltages	IEC 1131-2 3.2.1.1	24 V d.c. and 48 V d.c.; 24 V a.c., 48 V a.c., 120 V a.c., 230 V a.c., 400 V a.c.
Frequency	IEC 1131-2 3.2.1.1 Note 3	50 Hz or 60 Hz, ± 5%
Voltage tolerance	IEC 1131-2 3.2.1.1 Note 3	(RMSA values at point of equipment entry) +20%/-15% on d.c. voltage; +10%/-15% on a.c. voltage
Ripple	IEC 1131-2 3.2.1.1 Note 3	On d.c. voltages, only, 5% maximum additional error
Harmonics	IEC 1131-2 3.2.1.1 Note 1 Note 3	– Up to 10% harmonic distortion from second through tenth harmonic – 2% allowed for other frequencies and harmonics above tenth incoming power source to PC may require conditioning – Other power sources to PC system shall meet the requirements of this standard
Voltage dip	IEC 1131-2 3.2.1.2 6.3.7.3	Short disturbances of power supply
Interruption	IEC 1131-2 3.2.1.2	Disruptions of longer duration than voltage dip
Other input voltages	IEC 1131-2 3.2.1.1 Note 5	Such as 100 V a.c., 110 V a.c., 200 V a.c., 240 V a.c., 380 V a.c. or 110 V d.c., 125 V d.c., the same tolerances may apply as above
Non-periodic over voltage	IEC 1131-2 2.1.2.4	Non-periodic over-voltage peaks may appear on MAINS POWER SUPPLY lines due to power interruptions to high-energy equipment. There may be high-current pulses causing voltage peaks up to two times peak. The user needs to protect the PC equipment from this type of overload (e.g. by the use of an interposing transformer).
Protection	IEC 1131-2 3.3.2.3	Protection methods and failure modes

4.8 *Main processing unit*

Refer to IEC 1131-1 and 3.1 (figure 1) and 3.6 of IEC 1131-2 for relevant details as well as table 7 for a listing of selection considerations.

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Table 7 – Main processing unit – Selection criteria

Criteria	Reference	Comments and considerations
User program memory	IEC 1131-2 3.6.3	The organization and size of user application program memory
Data memory	IEC 1131-2 3.6.3	Organization, size and bits per word
Memory types	IEC 1131-2 3.6.3	For example, CMOS-EPROMM, EEPROM
Memory back-up	IEC 1131-2 3.2.2	Power back-up for volatile memory
System hardware configuration	IEC 1131-4 Table 1	– Racks – Cables – Bus expanders – Power supplies – Number of I/O modules per type – Memory allocation per I/O type – etc.
Programming languages supported	IEC 1131-4 Table 1	– Languages supported by the MPU and PADT – Conformance to the P.C. language standard IEC 1131-3 – Any difference in objects, instructions, semantic and syntactic rules should be noted
Scan time	IEC 1131-1 2.68 Item 4	The calculation of scan time which includes: – Scan – Memory utilization – Transfer – Program execution – User program diagnostics
I/O memory processing	IEC 1131-2 3.6.3	i.e., use of I/O image registers periodically refreshed, "get/put" type instructions, interrupt and event-driven programs, etc. and their effects on system response times, including restart (cold, warm, hot restart)

4.9 *Peripherals*

General requirements for peripherals are listed in 4.5 of IEC 1131-2 and 3.8 of IEC 1131-2.

4.9.1 *Man-machine interface*

The man-machine interface (MMI) should be carefully specified and selected because it will be the operator's window to the plant control system. It may also be the access facility for programming and fault diagnosis for the PC system.

Selection criteria for MMI are listed in table 8.

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Table 8 – Man-machine interface – Selection criteria

Criteria	Reference	Comments and considerations
Types	IEC 1131-2 3.8	1) Integrated in PC – uses PC-MPU and memory, may restrict display features and PC operating features 2) Intelligent – permits extensive displays and operating features which may include operator support
Display	IEC 1131-1 4.9.3	– Brightness – Contrast – Screen size – Definition – Resolution – Colour purity – Number of characters – Labels – Touch screen – Mouse – Rollerball – Display refresh time – Formats – Windows – Menus – Native language support
Keyboard	IEC 1131-1 4.9.4	– Tactile feel – Ergonomics – Mouse, rollerball
Access control	IEC 1131-4 Table 1	– Operator and/or programmer – Keylock or software protected levels
Alarms	IEC 1131-4 3.4.3	– Separate display – Screen windows – Active data points – Alarm management
Graphics	IEC 1131-4 Table 1	– Number of screens available – Expandability of screens – Build time – Refresh times – Characters and symbols – Visual quality

4.9.2 *Test equipment (TE)*

Test equipment may be special-purpose and only applicable to the particular PC system being considered. Refer to 2.67 of IEC 1131-1 and table 9 for selection characteristics.

4.9.3 *Programming and debugging tool (PADT)*

The PADT may also be the access facility for programming and fault diagnosis.
Selection criteria for PADT are listed in the following table 9.

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Table 9 – Test equipment and PADT Selection criteria

Criteria	Reference	Comments and considerations
PADT	IEC 1131-1 252	Used for PC programming, debugging, monitoring and documentation
Display unit	IEC 1131-1 4.9.3 IEC 1131-4 Table 8	1) Integrated in PC – share PC-MPU and memory, may restrict display and operating features 2) Stand alone – permits extensive displays and operating features
Type of TE	IEC 1131-1 or IEC 1131-3	General purpose – uses industry standard hardware to perform the required test or function Manufacturer provided/recommended – may use unique hardware and software/firmware to perform intended function, e.g. communication tester
Keyboard	IEC 1131-4 Table 8 IEC 1131=1 4.9.4	
Access levels	IEC 1131-4 Table 8	
Alarms	IEC 1131-4 Table 8	
Graphics	IEC 1131-1 Table 8	

4.10 *Communications*

Communication criteria apply where a PC system is part of a distributed system and must communicate with peer equipment or in controlling a subordinate configuration with another PC system or computer. Communication facilities should also be assessed if the user has expansion plans for the future.

Communications are used for many portions of the PC system. Serial communications networks are covered in IEC 1131-5. Communications selection criteria are found in table 10. Requirements are found in 3.5 of IEC 1131-2.

Table 10 – Communications – Selection criteria

Criteria	Reference	Comments and considerations
Topology		Multi-drop, star, expansion potential for future (network disruption could occur during expansion and reconfiguration)
Redundancy	IEC 1131-2 3.5 IEC 1131-1 3.19	Of media, nodes, communication interface. Redundancy is related to application criticality and degree of PC system autonomy.
Number nodes		Expansion capability
Media length		Extension, application, configuration, repeaters (determined by signal loss and noise, unit length)
Media loading		Capability, response time variations with loading
Protocol		Compliance with IEC 1131-5
Data checks		Compliance with IEC 1131-2, 3.11
Failure alarm		Indication of communication failures/malfunctions

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Table 10 (Continued)

Criteria	Reference	Comments and considerations
Operating features and capabilities	IEC 1131-2 3.5, 3.7, 3.8 6.3.10, 6.3.11	Should be capable of testing, controlling and monitoring the communication system directly or through a dedicated communications processor unit/communications director for carrier losses, time-outs, detected errors, illegal characters or sequences, failure or other nodes, media breaks
Media type	IEC 1131-2 3.5, 3.7	Twisted pair, coax, optical fiber, etc., cost of media, installation, termination
Routing		Message routing
Gateways, bridges, repeaters		Networks interconnected
Applications layer	IEC 1131-5	Adequate user services
Performance		– Effective data rate – Baud rate – Bits/s – As agreed between user and supplier

4.11 Remote I/O stations (RIOS)

Remote I/O station information is found in table 11.

Table 11 – RIOS – selection criteria

Criteria	Reference	Comments and considerations
Type of remote adapter	IEC 1131-2 3.7	– Availability of various I/O functions – Maximum number of RIOS points of various types requirements – Power requirements – Mounting requirements (enclosure type, spacing between devices or racks), etc.
RIOS communication link	IEC 1131-2 3.7	– Type of link control – Speed of updates – Number of drops – Cable drops – Distance and impedance match – Isolation
Access control	IEC 1131-4 Table 1	Operator and/or programmer, keylock or software protected levels
Alarms		– Module/faults – Rack faults – Communications loss
Redundancy	IEC 1131-4 Table 4	Media duplication should be related to application criticality
Remote power supply drop0outs and interruption	IEC 1131-2 3.7.1 IEC 1131-4 Table 4	– State of RIOS communication link – Initialisation of start-up – Reporting of interruptions, predetermined output states under fault – Fault indications
Status	IEC 1131-2 3.7.1	Report RIOS status to application program

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Table 11 (Continued)

Criteria	Reference	Comments and considerations
Network type	IEC 1131-2 3.7.2	Point-to-point, star, multidrop, ring, etc.
Response time	IEC 1131-2 2.68 IEC 1131-2 3.7.2 IEC 1131-4 Table 1	– Transfer time – Error coding/detection – Data rates – Retries – I/O change delay time

4.12 *Software*

Software for PC systems includes operating system and application program software (see 4.2.1, 4.2.3, 4.6.1 and 4.6.2.5 of IEC 1131-1). The PC operating system may be of a proprietary nature and the user should not expect access to this information.

4.12.1 *Manufacturer's software*

The selection of software and hardware are complementary procedures and should be concurrently evaluated during system selection procedures.

Two of the programming languages of the IEC 1131 are textual:

instruction list (IL)	– 1131-3, 3.2
structured text (ST)	– 1131-3, 3.3

The other three programming languages are graphical languages:

ladder diagram (LD)	– 1131-3, 4.2
function block diagram (FBD)	– 1131-3, 4.3.1
sequential function charts (SFC)	– 1131-3, 2.6

Major topics covered in IEC 1131-3 are:

- programming language;
- functions required;
- utilizing available programming aids;
- program structure;
- special requirements;
- training constraints;
- monitoring and alarming;
- process interaction;
- code in modular form;
- criteria for access control;
- safety/protection considerations;
- software documentation;
- archiving software versions;
- project life cycle;
- software back-ups.

Selection criteria are listed in table 12.

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Table 12 – Manufacturer's software – Selection criteria

Criteria	Reference	Comments and considerations
Software development	IEC 1131-1 4.2	– Time in production – Version and release date of manufacturer software – Manufacturer's update recording documentation – Supplier's ability to respond to software issues
Functions available	IEC 1131-1 4.2.1 4.6.1	– Timing – Sequence – Controls – Monitoring – Alarms – Display – Special functions mathematics, PID, etc. – Ensure software meets requirements of functions – Recipe support
Documentation	IEC 1131-2 5.3.2	– Completeness and clarity of the programming manual and syntax information – Availability of application programming examples
Diagnostics	IEC 1131-2	– User program oriented – Operator oriented – Maintenance oriented
Access control	IEC 1131-2 3.8.1 IEC 1131-4 Table 1	– On-line modifications to parameter (recipe data) facilities as related to requirements and authorization levels – Security aspects – Qualification for access levels

4.12.2 *User's application software*

The user (figure 1b) is responsible for defining the application software requirements and establishing the responsibility for verification. The user should delegate personnel to be trained and to undertake responsibility for the PC system application programming and maintenance. These activities should commence as early as is practical.

4.13 *Selection for the environment*

To minimize performance problems due to environmental conditions, PC systems should, whenever possible, be selected (hardened) to meet the limits listed in IEC 1131-2.

4.13.1 *Environmental considerations*

The environmental limits are listed in clauses 2 and 3 of IEC 1131-2 and associated type tests are in clause 6. Table 13 lists the areas which need to be considered when selecting the PC system to meet the environmental conditions.

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Table 13 – Environmental considerations

Critieria	Reference	Comments and considerations
Radiated electro-magnetic fields	IEC 1131-4 Annex A IEC 1131-2 3.9.1	– Shielding/enclosures – Proper earthing – Suppressors and filters
Electrostatic discharge	IEC 1131-4 Annex B IEC 1131-2 3.9.1	– Suppressors and filters – Separation of power and signal lines – Housing/earthing practice
Conducted noise	IEC 1131-2 3.9.1	– Use proper wire size – Separation of power and signal lines
Vibration	IEC 1131-2 2.1.3.1	– Shock mount to absorb vibration/shocks
Temperature range	IEC 1131-2 2.3.1	– Temperature control to meet manufacturer's temperature range
Humidity	IEC 1131-2 2.3.2	– Guard against humidity/moisture
Atmospheres	IEC 1131-2 2.1.1.4, 2.2	– Air pollution control to pollution degree
Shock	IEC 1131-2 2.1.3.2	– Shock mount to absorb vibration/shock
Altitude derating	IEC 1131-2 2.1.1.6	– Derating PC system
Lighting		– Provide proper protection as recommended by the manufacturer

4.13.2 *Ways of conditioning the environment of the PC system*

The PC manufacturer publishes specifications covering installation considerations which typically include environmental considerations such as temperature, vibration, electrical noise susceptibility, humidity, etc. In order to help assure adequate performance, these manufacturer's recommended parameters should not be exceeded.

In situations where the user's environment and the specified limits of the PC system do not agree, it shall be the responsibility of the user to provide an environment in which the equipment can operate satisfactorily, or to select equipment which is suitable for the environment.
The majority of PC units are what is classified as an open equipment, as defined in 1.4.20 of IEC 1131-2. They are designed to be installed in a suitable enclosure on the plant floor. Table 14 and annex C help to create the environment needed.

Table 14 – Conditioning the environment

Criteria	Reference	Comments and considerations
Minimize effect of environment		– Eliminate by relocating, replacing, removing, filtering, grounding, shielding, etc. – Locate PC system in conditioned area
Earthing the PC system	IEC 1131-4 7.2.1, 7.2.2	Follow the manufacturer's suggested earthing procedures and also the suggested method of connections and cabling. Electrical noise should be minimized
Installation	IEC 1131-2 Clause 2 IEC 1131-4 Clause 7 Annex C	Follow the manufacturer's installation recommendations

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4.14 *Economic trade-offs*

In specifying a PC system, cost trade-offs are made in respect to several issues. Some of these include:

- hardware and software implementation: when cost is the driving factor, it is better to perform as many functions as possible in software to minimize the amount of hardware required, i.e., PID in MPU through multi-channel analog I/O;
- response time: when speed is the most important factor, special purpose modules may be available to perform the function in the minimum amount of time;
- increased availability may increase cost;
- topology: usually distributed system can increase availability and maintainability but may be more costly than a local implementation;
- conditioning the environment: refer to 4.13, selection for the environment;
- ease of upgrade.

4.15 *External output devices not covered in the PC standard*

Compatibility between the PC's inputs and outputs and the external devices should be verified. The user should take into account the variation of the characteristics of the circuits in the ON and OFF states (e.g. addition of a shunt resistor to increase the output current in the ON-state).

Output devices may have a leakage current in the OFF-state. The user should make sure that there is no possibility for this current to trigger high-impedance external circuits, and the converse may be true with sensors connected to PC inputs.

If the protective conductor is connected to other equipment as well as to the PC, then interference may occur. To eliminate interference, inputs and outputs of the PC should be galvanically isolated from:

- one another;
- other networks;
- other earthed parts which are not connected via an equipotential bonding conductor with the PC.

4.16 *Commissioning test plan*

At the conclusion of the PC system application engineering, a commissioning test plan should be made. The purpose of this commissioning test is to verify that the user's control objective and requirements are met by the PC system as it is installed (refer to clause 8 of this part for more details).

4.17 *Documentation*

The volume and type of documentation which is needed for an automated system depends on the type and extent of the plant. The following list describes types of documentation. The required selection should be made individually for each application.

Location diagrams/tables	–	diagrams of important process equipment;
	–	allocation of electrical components (e.g. sensors, PC, peripherals).
Block/survey diagrams	–	electrical system;
	–	PC system;
	–	control system;
	–	controlled system.

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System function charts	–	function block diagrams;
	–	interaction of function blocks.
Schematic circuit diagrams	–	functional presentation of circuits, software
modules;	–	signal paths;
	–	signal connections.
Programming documentation	–	print-outs;
	–	statement lists;
	–	cross-reference list;
	–	input/output/flag reference list.
Power circuitry diagrams	–	incoming power supplies;
	–	power circuitry of actuators;
	–	fused outgoing circuits.
List of operational equipment	–	bill of material;
	–	ordering codes;
	–	list of suppliers;
	–	spare part list;
	–	list of data sheets, engineering manuals,
	–	service manuals.
Item designation tables	–	criteria of applied item designation;
	–	item designation tables/lists.
Interface tables	–	connection to supervisory systems;
	–	connection to subordinated systems;
	–	connection to other equipment.
Physical drawings	–	dimensions and mounting templates.
System descriptions	–	control/controlled/automated system;
	–	methods of operation;
	–	manual of installed system;
	–	operators' manual.
Function checklist	–	list/tables for functional checks;
	–	signalling diagrams;
	–	safety/protection verification list.
Miscellaneous	–	reliability data;
	–	certificates;
	–	maintenance schedule;
	–	qualified personnel list;
	–	emergency plan;
	–	equipment and documentation traceability;
	–	application software fault report and change notices.

5 Safety/protection related considerations

5.1 *Introduction*

The purpose of this clause is to provide the user with general guidelines on safety/protection practices in the use of PCs. This clause is not intended to provide comprehensive guidance on the use of PCs as part of a designated safety related system (SRS).

The use of PCs in SRS requires special measures. The following are examples of typical factors that should be considered when a PC is used in an SRS. The list is not exhaustive but is intended to indicate the types of technical issues that should be addressed. If a PC is to be used in an SRS, the user should

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refer to the PC manufacturer for detailed advice, in addition to any safety related installation standards or guidelines which may be available.

5.1.1 *Safety/protection considerations*

Safety/protection considerations include:

- personnel;
- controlled equipment and related processes;
- controlling equipment, i.e. PCs and associated equipment;
- wiring (flammability, insulation temperature, size, etc.);
- environment;
- others, depending on installation.

5.1.2 *General recommendations*

In order to help maintain generally accepted safety/protection practices, the following recommendations should be considered:

- applicable safety/protection installation codes, standards and guidelines;
- understanding the potential risks associated with equipment failures;
- full use of the available standards and recommended practices of this document;
- PC manufacturer's installation instructions.

WARNING:

- As in any solid-state control system, failure of certain components can result in uncontrolled and/or unpredictable operation. System level failure modes and associated back-ups should be considered. The manufacturer of the PC should be consulted as necessary;
- prior experience with non-PC types of control systems;
- systems analysis, including operator and maintenance related issues;
- redundancy, back-up and successful verification of independent PC control action where failure may cause potential death and/or personal injury, property damage.

5.1.3 *Safety related systems*

Reference to international standards on SRS may be considered, as appropriate.

5.2 *Safety/protection features*

When designing the PC system hardware, software, and associated peripherals, safety/protection should be taken into account at the system analysis stage. Safety/protection features should be an integral part of the PC system selection process.

5.2.1 *Failure modes*

A PC system design requires optimization of performance, safety/protection and economy. Within that understanding, failure modes may include the following categories:

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- potential danger to personnel, environment, process or machinery;
- degrading the efficiency of the controlled system;
- missing recognition of process anomaly and/or alarm;
- missing recognition of possible malfunctions of input or output.

5.2.2 *Levels of response to achieve safety/protection features*

Response options which should be determined at the system analysis stage may include:

- alarms of anomalies or malfunctions;
- shutting down the system and disconnection of energy source to the controlled process;
- forcing the process to a defined standby mode;
- shutting down the PC in a safe and predictable manner and providing an acceptable back-up.

NOTE—The probability of correctness in the system response should be carefully analyzed.

5.2.3 *Examples of safety/protection control features*

- Prevention of uncontrolled automatic system start-up.
- Detection of movable guard positioning.
- Control of hydraulic/pneumatic cylinder movement.
- Control for machines with automatic and manual operation modes.
- Detection for light-barriers.
- Braking of electronically controlled motors.
- Acceptable functionality of redundant circuits.
- Comparator circuits.
- Energy storage relief mechanism.
- System level simulation and/or off-line dry run for overall effectiveness of safety/protection features.
- For I/O functions, mechanical or PC-independent hardwired redundancy may be advisable.
- De-energizing STOP circuits, independently of the PC, to help assure that broken wires or corroded contacts do not compromise safety/protection.

5.2.4 *Diagnostics for safety/protection*

Techniques and precautions used to help detect faults may include (see 3.4.3 of this part):

- operating system checks;
- read/write checks on memories;
- timing checks;
- redundancy of PC, power supplies, chassis, I/O, etc.;
- watch dog timer(s).

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5.2.5 *Protective earthing*

Protective earthing serves to help minimize the potential risk for electric shock hazards. The user should follow manufacturer's recommendations and national/local installation codes when applying protective earthing techniques (refer to clause 7).

5.3 *Software aspects of safety protection*

Faults, or errors, in the user's application software may potentially compromise safety/protection. Such possible occurrences may not be apparent or occur only in special situations. The following considerations in 5.3.1 to 5.3.4 are recommended.

5.3.1 *User software assurance safety/protection program*

A quality control plan for user software is needed to help assure thorough examination from a safety/protection point of view. Software testing needs to be performed both by the software author(s) and by the PC control system user. Independent testing and evaluation of user's application software is also recommended.

5.3.2 *Aspects of converting relay control to a PC system*

The conversion of electromechanical relay control to a PC program needs to take into account any safety/protection differences in the two types of controllers and applications. One-to-one conversion of an electromechanical ladder diagram to a PC program may adversely affect safety/protection.

5.3.3 *Modification of software*

Every modification of user's application software needs a suitable re-evaluation test to help ensure that safety/protection is not compromised, defeated, or by-passed. The user should keep change records of each modification.

Critical application program software may be made unalterable on the plant floor by storing that portion of the program on read only memory or by making the portion unalterable by utilizing the PC manufacturer's lockout abilities, if provided.

5.3.4 *Documentation*

Safety/protection operation may be compromised when available documentation is incomplete or not up to date.

5.4 *Inputs and outputs (I/O)*

To help assure input and output signal integrity, the following aspects in 5.4.1 and 5.4.2 should be considered.

5.4.1 *Safety/protection I/O considerations*

To minimize the effects of malfunctioning signals, the following should be considered:

- loss of I/O signals (open- or short-circuit conditions);
- operational degradation of input or output devices;
- off-state leakage current of semiconductor devices used as outputs, which may cause a potential electric shock hazard under certain situations;
- polarity of I/O devices;

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- inductive and/or capacitive loads to an output semiconductor device may present a damaging voltage and/or current spike upon interruption; e.g., built-in anti-surge diodes may become ineffective;
- semi-conductor outputs used as a source of signal driving a high-impedance load may require a minimum load current in order to turn on and remain in the ON state;
- interference with I/O signals by nearby power lines and other sources of EMI;
- noise on sensitive analog signal lines.

5.4.2 *Forcing of inputs and outputs*

Many PCs allow forcing of inputs and outputs independent of programmed logic in order to test software or the system. Care must be taken to insure that:

- forcing operations do not impair safety/protection, which must be adequately guarded by use of PC-independent safety/protective interlocks;
- forced inputs and outputs are to be returned to normal status upon completion of testing.

5.5 *Personnel safety/protection*

Safety/protection of personnel is based on careful planning. In addition to standard industrial safety/protection practices, the following should be carefully exercised:

- the controlling and controlled equipment are to be operated and protected as per manufacturer's information and local codes;
- care needs to be taken to help guard against unintended movement of machine parts or unintentional contact with electrically live parts.

5.6 *Safety/protection awareness*

Safety/protection awareness is achieved through knowledge of the system and its overall operation, including failures and malfunctions. Training to achieve this may be enhanced by careful planning and commitment on the part of the user. Regular review and refresh courses for system operators are also recommended.

5.6.1 *Manufacturer's recommendations*

All required system level safety/protection related recommendations made by the PC manufacturer should always be followed. Any safety/protection related questions specific to the PC should always be directed to the manufacturer.

5.6.2 *Safety/protection during maintenance*

Whenever possible, maintenance should be performed with the equipment not in operation and disconnected from all sources of power. If maintenance must be performed while the PC and controlled systems are in service, safety related practices and codes must be followed.

6 Pre-installation system testing

Pre-installation procedures should check the PC's software and hardware before their installation on site. Tools for checking or simulation are necessary.

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6.1 *Defining the test configuration*

The test configuration could be the complete system or any separate part of it (or at least a good representative system), depending on the practical test situation. Typical units to be connected include main processing unit, I/O racks, operator panels and communications equipment. Peripheral units such as PADTs (programming and debugging tools) and TEs (test equipment) should be included. The test set-up should be connected using manufacturer-specified cables.

Where possible and appropriate, system testing should be performed at the system vendor's premises. All known hardware and software faults and omissions should be corrected and retested before acceptance. The system should be monitored for initialization, start-up, and shut-down operation.

6.2 *User application-related testing*

6.2.1 *Simulation*

Pre-installation simulation is done without connecting the PC to the automated system. In the case of a complex system, a process simulator may be required.

Simulation should include the following as a minimum:

- I/O frequency range (bandwidth) and response time;
- PC power supply ON/OFF switching;
- external faults (emergency stop, run mode change, etc.).

6.2.2 *Software testing*

Testing of user application software should include:

- procedure for software loading, reloading, making back-up copies and archiving;
- checking application modules (e.g. mathematics) and interaction of the separate modules using PADTs and TEs;
- system initialization and restart routines (cold, warm, hot);
- simulation of expected error conditions (communication lines, operator mistakes, etc.);
- boundary conditions (e.g., I/O address range +1, -1);
- test to criteria on table 7.

6.3 *Verification of system-supporting features*

Diagnostic tools should include the following:

- on-line and off-line;
- automatic error detection;
- presentation on displays and/or printers.

User documentation should include:

- manufacturer's system manuals;
- application-specific documents;
- spare parts list.

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7 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 may be recognized as the selection phase. During installation, it is important to update all engineering and application documents according to how equipment is assembled or modified on site.

7.1 *Environmental conditions*

The user should ensure care is taken concerning temperature, contaminants, shock, vibration and electromagnetic influence. Refer to IEC 1131-2 for specific environmental requirements. Table 15 describes environmental conditions to be verified during installation.

Table 15 – Environmental conditions

Criteria	Reference	Comments and consideration
Temperature	IEC 1131-2 2.3.1 6.3.4	Check for possible influence of steady or temporary heat sources: – space heater – solar heat – hot goods passing b y
Contaminants	IEC 1131-2 2.1.1.4, 2.1.1.5 IEC 68 IEC 664	Moisture, corrosive gases, liquids and conductive dust can affect the functions of a PC 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	IEC 1131-2 2.1.3 6.3.5	Check for possible effects on site: – engines – compressors – transfer lines – presses, hammers – vehicles
Electromagnetic interference	IEC 1131-2 2.1.2 6.3.6.2	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
Sensitivity to light sources		Normally, light sensitive components are protected. During installation, covering may be removed. Problems may occur due to: – UV rays – photo flashes – direct sunlight – arc light

7.2 *Field wiring*

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

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7.2.1 *Earthing/grounding techniques*

Two different requirements shall be fulfilled during installation:

- protective earth (safety grounding);
- 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 shall be connected to protective earth in accordance with local and national codes.

Functional earthing shall 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 16 describes installation rules of earthing measures.

Table 16 – Installation rules: earthing measures

Criteria	Reference	Comments and considerations
Protective earthing	IEC 1131-2 4.7	– Provide sufficient conductor cross-section for connections to earth – Doors shall have electrical connections according to local and national codes – Verify connections are tight and resistant to vibration and corrosion
Functional earthing	IEC 1131-2 4.8	– 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 PC to earth is not possible, the connection may be made via a suitable capacitor. The capacitor shall correspond to the rated insulation voltage of the PC circuit, and shall have good high-frequency properties. Static charging can be prevented by the use of a high ohm value resistor for discharge – There shall 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 electrical shock hazard. Under no circumstances should the protective earth be disconnected from the PC. Functional earth connections may be temporarily disconnected for servicing and/or maintenance as required.		

7.2.2 *Noise and transient suppression*

Mains, input and output connections to the PC system may conduct noise. Therefore, the following measures should be considered according to PC immunity and the conditions of the electrical environment.

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Table 17 – Installation rules: noise suppression

Criteria	Reference	Comments and considerations
Mains	IEC 1131-2 4.9	– Mains' live conductors should be separately installed from other PC-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
I/Os	IEC 1131-2 3.10 4.3	– 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 PC system – Filtering of susceptible I/O cables may be required – Twisted wire pairs – Use of shielded cables with low inductance cable shields (low-level signals) – Earthing of signal cable shield – 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
Proper PC-function	IEC 1131-2 4.7, 4.8	Correct functional earthing techniques are essential
Noise sources	IEC 1131-2 3.9	Noise damping at emission sources with noise suppressers such as: – RC circuits – zeners – diodes – varistors – others
Noise coupling	IEC 1131-4 Table 13 Table 14	– Separate cables for input, outputs, and power circuits – Minimize the total length of wiring – Use of manufacturer recommended cables and leads
Analog and other noise-sensitive circuits	IEC 1131-2 3.4.1, 3.4.2 Table 13	Use of shielded wires Use of twisted-pair wiring
Routing	IEC 1131-2 4.9	Interference voltage or current noise can enter PCs where connections are made, as well as the power supply connections. The wiring which extends between the PC and these control devices should be properly routed to minimize induced noise on these wires

7.2.3 *Electromagnetic compatibility*

The subject of electromagnetic compatibility (EMC) refers to electromagnetic immunity and emission. The standards relating to EMC are under consideration.

This user guideline will be updated with specific recommendations for EMC regarding the PC system.

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

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Care should be taken to ensure the following:

- magnitude of letters and signs;
- markings shall be indelible;
- fuses, location, type, rating shall be clearly marked;
- accessibility of markings;
- agreement of project site and installation drawings, revision of final documents.

8 Commissioning

The commissioning procedure brings into interaction the PC system, other control equipment and the process. It shall be performed only by qualified persons who have sufficient knowledge of automated processes and equipment, and who are well trained on PCs. The procedure and schedule should be decided before start of commissioning (refer also to clause 5, safety/protection considerations).

8.1 *Installation testing*

Installation testing may be done using an installation report as follows:

- extensively, by reviewing all installation tasks, or
- by a spot check.

As a minimum, the following shall be checked systematically and totally:

- protective earthing;
- functional earthing;
- mains' line fuses and switches;
- compliance with actual service conditions;
- compliance with local and national code.

8.2 *PC system set-up procedures*

8.2.1 *General set-up and checks*

The set-up of the PC system should be carried out in the following steps:

- IEC 1131-2, 3.1, PC system;
- IEC 1131-4, figure 1a.

If the modules have user-selectable options/features (dip-switches, jumpers), they should be set in accordance with the documentation and/or module location.

The commissioning sequence should be: locate, start-up and check PC-system groups in accordance with operating instructions in the following sequence:

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Step

1 Power supply
2 Processing units, communication modules
3 Connection to PADTs and MMIs
4 Program loading, initialization and start
5 Communication to third party devices without I/O modules
6 Communication with I/O modules and remote I/O stations

8.2.2 *Checks of I/O*

The next step is to check the interaction between PC system and process. Caution is imperative and steps should be performed very carefully to prevent hazards to personnel and machinery. It is recommended that field wiring be verified prior to being connected to the PC system.

Checks of I/O

Criteria	Commends and considerations
Binary inputs	Check binary and digital input signals to ensure that physical states of sensors comply with signal latches in PC
Analog inputs	Check analog input signals to ensure agreement of physical values and data received by PC
Binary outputs	Force binary and digital outputs to check for correct output operation
Analog outputs	Functionality

8.2.3 *Check application program*

Activate inputs and outputs by the application program. Where possible, the application program should be activated in sections. (In general, step-by-step start-up of application programs depends on conditions stated in clause 4.)

8.3 *Automated system function tests and fault simulation*

8.3.1 *Automated system function tests*

Commissioning functionality checks of the PC, process and other control equipment should be performed according to commissioning test plan (see 4.16). These tests are normally done after debugging and should cover the PC system operational requirements as set out in clauses 3 and 4 of this report.

Verify that unauthorized local operation is adequately guarded against and that unauthorized PC system level changes are not possible.

8.3.2 *Fault simulation*

Fault simulation helps to verify that user system requirements with regard to malfunctioning components are met. Fault simulation should be performed after system functional tests. Experience shows that most of the faults occur at the I/O and other interfaces to the PC. Some of the probable areas where faults may occur are:

— sensors, contacts, and actuators;
— inputs and outputs;
— field wiring;
— fuses or circuit breakers;
— interruption of mains;
— guards and related motion detection (false alarm or failed alarm);
— interlocks.

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Many faults in the automated system can be detected by the PC system internal check or user program, and should be corrected. Any simulated fault that is not detected by the PC system should be addressed.

8.4 *Commissioning report*

Results of the commissioning test should be submitted to the user and the vendor in a written commissioning report (see 4.16 and annex D). This report should contain descriptions of the main commissioning tasks completed and passed. Commissioning tasks which have not been performed, as well as the ones which failed to pass, should be noted in this report and follow-up action recommended. Exceptions to commissioning tests should be agreed to by all parties concerned and noted in this report. The automated system should not be considered fully commissioned until the commissioning report is accepted as a certification of PC system performance.

9 PC system maintenance

9.1 *Introduction*

Maintenance personnel should understand the design concepts of their PC systems.
The maintenance criteria are presented in table 18.

Table 18 – PC system maintenance

Criteria	Reference	Comments and considerations
Maintenance concepts		Maintainability – concepts including preventive maintenance and the ease of repair of the PC system
	IEC 1131-1 2.4, 4.8	Availability – system availability should be kept high as far as cost permits without sacrificing the safety/protection of the system
	IEC 1131-1 2.34, 3.21, 4.8	Reliability is expressed as the MTBF (mean time between failure) and its value should be greater than that of user requirements. Generally, the higher the reliability, the greater the availability
		Fault avoidance – concepts including the environmental condition, fool-proof operation guide and adequate debugging of the software.
	IEC 1131-1 2.23, 3.19	Fault tolerance – concepts including redundancy and error checking
Preventive maintenance methods		– Periodic inspection – Life estimation of the equipment – Schedule replacement – Restocking of the spare parts
MTTR (mean time to repair)		A major system objective is to minimize MTTR. Methods include: – diagnostics – error checking – alarms – availability of spare parts – ease of repair

9.2 *Maintenance programs*

It is not possible to establish a single maintenance program to serve all classes of equipment within the scope of this report. Maintenance programs should be established giving consideration to the operation and the service conditions, and the applications of the PC equipment, as well as to the maintenance instructions and recommendations of the equipment manufacturer.

The following factors should be considered when formulating a maintenance program:

- maintenance must be performed by qualified personnel familiar with the design, operation, and hazards involved with the user system;
- care shall be taken in servicing electrostatic-sensitive equipment. The manufacturer's recommendations for these components should be carefully followed;

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— safety/protection during maintenance is described in 5.6.2;
— maintenance records should be kept to allow traceability of maintenance activities.

9.3 *Preventive action*

Table 19 describes preventive action which should be taken by the user.

Table 19 – Preventive maintenance
(in accordance with manufacturer's recommendations)

Criteria	Reference	Comments and considerations
Replacement		Replaceable components: – batteries – dust filters – fuses – markings – others
Alignment and adjustment		– Disk drive – Tape loader – Printer – Sensor (e.g., proximity switches) – Limit switches
Checking		– Spare parts condition (function, batteries) – Mechanical contacts conditions (corrosion, contamination, damage) – Terminal screws condition (loose, corrosion, etc.) – Integrity of protective and functional earthing – Cabinet doors are secure and ventilation ducts are not blocked – Redundant functions – Communication system
Data back-up		System data should have periodic back-up
Cleaning		Dust filter cleaning
Calibration		Analog modules, thermocouple modules, etc.

9.4 *Hardware maintenance*

If equipment conditions indicate the necessity for repair or replacement, the manufacturer's instruction manual should be followed carefully. Diagnostic information within such a manual should be used to identify the probable source of a problem and to formulate repair procedure. User field repair of the PC system should be limited to field wiring and other manufacturer recommended tasks.

It is strongly recommended that repair of modules (e.g., replacement of components on printed circuit boards) should be done by the manufacturer or an authorized service organization. The level of field repair recommended by the manufacturer should be followed. Unauthorized repairs may void the manufacturer's warranty.
Replacement parts should be in accordance with the recommendations of the equipment manufacturer. Care must be taken to replace modules/units to the proper revision level. Replacement parts should be inspected for deterioration due to "shelf life" and for signs of rework or wear which may compromise critical operations or safety/protection.

After performing maintenance on the system, restarting should be in accordance with safety/protection procedures (see clause 5). For extensive revisions, refer to clause 8.

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9.5 *Software maintenance*

For PC user application software subject to modification, users should consider the following:

- before modifying the software, the current program should be archived, if not already done;
- after re-installing the modified software, a re-evaluation test should be performed, and the commissioning test of clause 8 may need to be performed.

Application software modifications should be subject to procedures that are equivalent to those applied to the original software engineering, documentation and testing.

Only authorized and qualified personnel should be permitted to make software modifications, according to originally established criteria.

9.6 *Maintenance and inspection example*

Annex E presents examples of periodic maintenance and inspection of the programmable controller system.

9.7 *Manufacturer recommended upgrades*

Manufacturer recommended upgrades should be consistent and compatible with clauses 4 and 5, installed as described in clause 7 and commissioned as described in clause 8, including a commission report on changes made.

9.8 *Maintenance spare parts*

To minimize MTTR, stocking of the following spare parts may be considered:

- batteries;
- fuses;
- dust filters;
- sensors;
- limit switches;
- input/output modules;
- power supply, if necessary;
- main processing unit, if necessary;
- memory cassette, if necessary;
- communication module, if necessary;
- application-specific module, if necessary.

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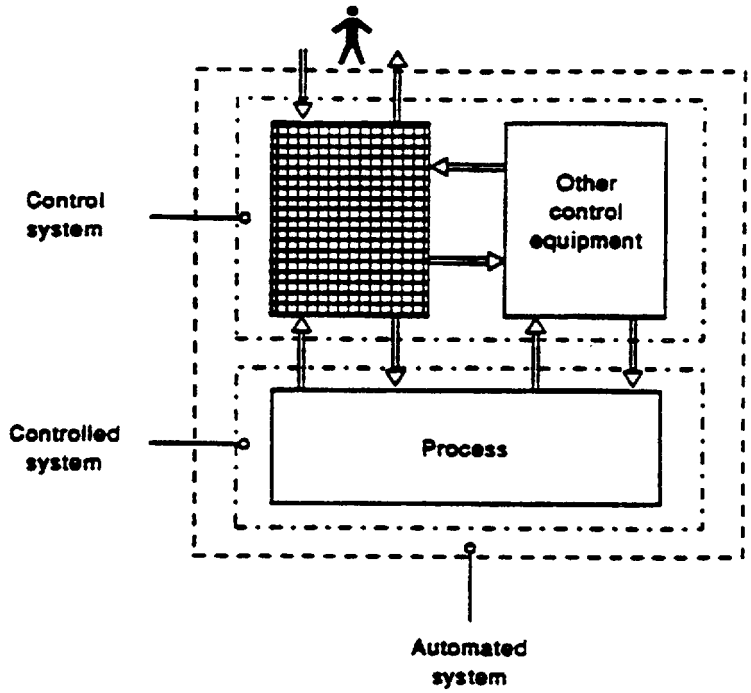


Figure 1a

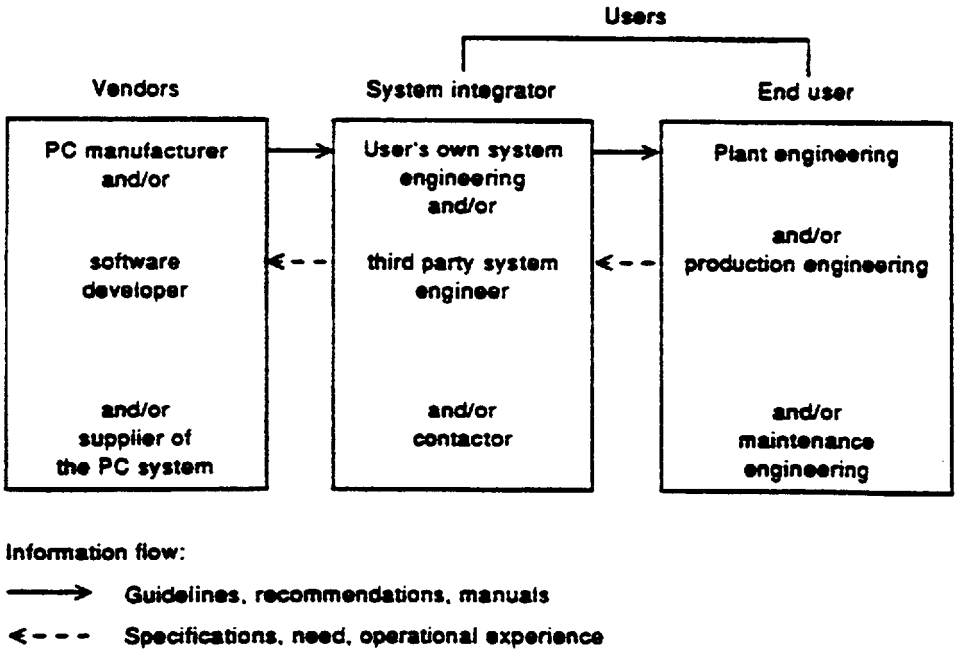


Figure 1b

Figure 1 – Scope of user guidelines

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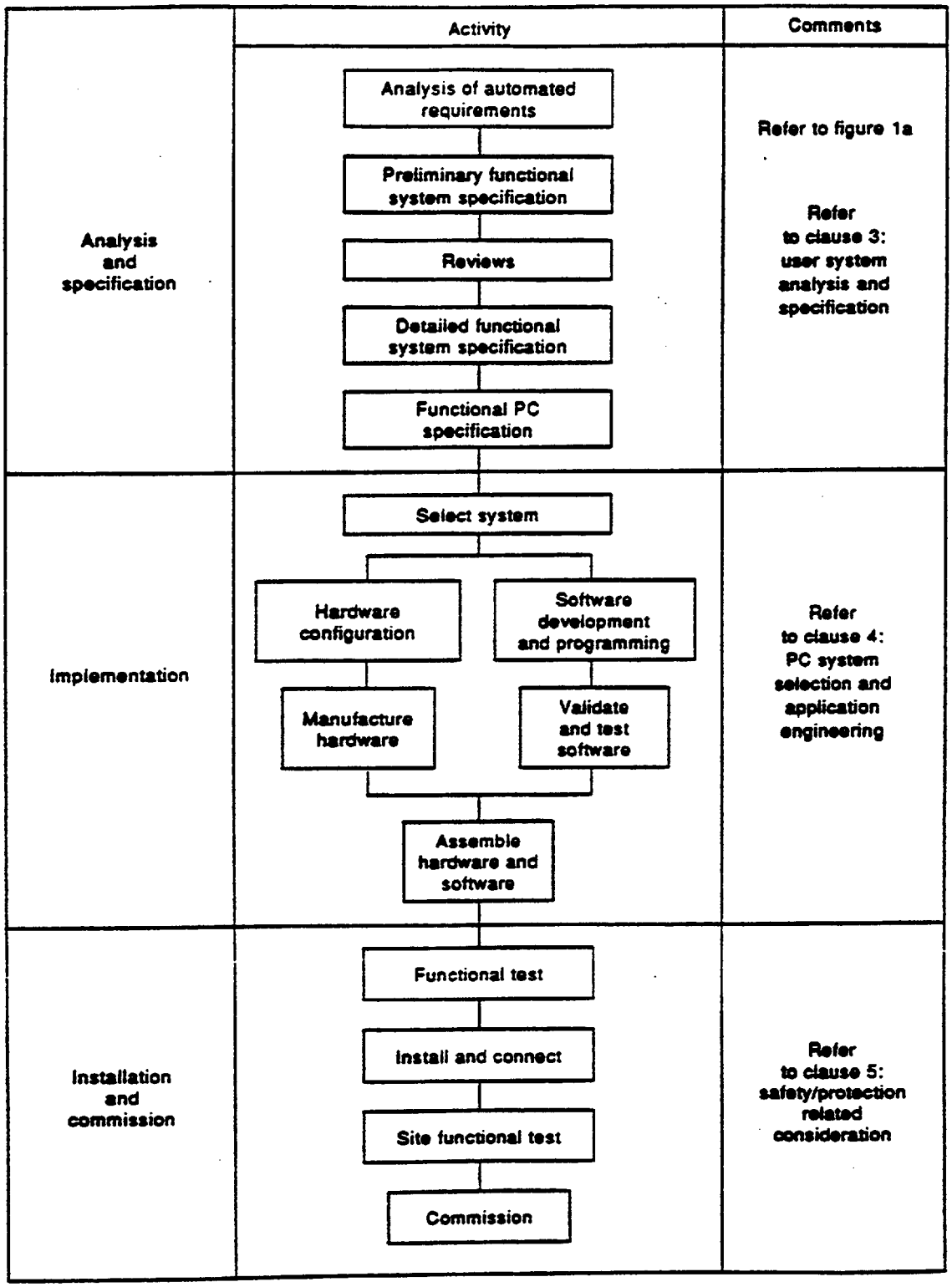


Figure 2 – PC systems – Specify design and installation cycle

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Annex A

Radiated electromagnetic field classes

PCs are to be tested according to 6.3.6.2.2 of IEC 1131-2 and can be operated at the environmental classes listed below.

Class 1: Low-level electromagnetic radiation environment, such as levels typical of local radio/television stations located at more than 1 km and levels typical of low power transceivers.

Class 2: Moderate electromagnetic radiation environment, such as portable transceivers, that can be relatively close to the equipment but not closer than 1 m.

Class 3: Severe electromagnetic radiation environment, such as levels typical of high power transceivers in close proximity to the control equipment.

Class 4: Open class for situations involving very severe electromagnetic radiation environments. The level is subject to negotiation between the user and the manufacturer or as defined by the manufacturer.

Class 4 is beyond the requirements of IEC 1131-2. If the PC application exceeds class 3 requirements, negotiation between user and manufacturer is necessary.

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Annex B

Electrostatic discharge (ESD)

PCs are described according to 6.3.6.2.1 of IEC 1131-2.

Class 1: Location with controlled relative humidity. The relative humidity is in general about 35 %. The floors are covered with anti-static carpets.

Class 2: Locations where relative humidity is not controlled. The relative humidity may be as low as 10 %. The floors are covered with anti-static carpets.

Class 3: Locations where relative humidity is not controlled. The relative humidity may be as low as 50 %. The floors are covered with synthetic carpets.

Class 4: Locations where relative humidity is not controlled. The relative humidity may be as low as 10 %. The floors are covered with synthetic carpets.

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Annex C

Enclosures for equipment

C.1 Enclosure design

The enclosure shall be designed so that, when it is opened and other protective means, if any, are removed, all parts requiring access for installation and/or maintenance prescribed by the manufacturer are readily accessible. Sufficient space shall be provided inside the enclosure for the accommodation of external conductors, from their point of entry into the enclosure to the terminals, to ensure adequate connection. Space requirements may also be established by applicable installation codes.

The exposed parts of a metal enclosure shall be electrically connected to the other accessible conductive parts of the equipment and connected to a terminal which is then connected to a protective earthing conductor. Functional earthing connections should also be considered, where appropriate.

Where critical safety/protective spacings may be compromised, the removable parts of the enclosure shall be firmly secured to the fixed parts by a device, such that they cannot be accidentally loosened or detached.

When an enclosure is so designed as to allow the covers to be opened without the use of tools, means shall be provided to prevent loss of the fastening devices.

C.2 Insulation of metallic enclosure

Metallic enclosures shall be so arranged as to reduce the risk of accidental contact between the enclosure and live parts during opening and closing of the enclosure. If, for this purpose, the enclosures are partly or completely lined with insulating material, this lining should be securely fixed to the enclosure.

C.3 Degrees of protection of enclosed equipment

Enclosed equipment (such as peripherals which are not a part of the permanent installation and enclosed PC assemblies) shall comply with the requirements of IEC 529. See 4.5.3.1 of IEC 1131-2.

C.4 Ventilation

Enclosures should have adequate ventilation or means of removing heat from the PC equipment enclosed therein. Ventilation openings should be furnished with appropriate dust filters.

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Annex D

Commissioning report

D.1 Sample report

Customer name: _____

Plant identification: _____

Plant location: _____

System identification: _____

Name of project manager: _____

Commissioning company: _____

_____

Name: _____

Division: _____

D.2 Approval

	Customer	Vendor
Division:	_____	_____
Name:	_____	_____
Date:	_____	_____
Signature:	_____	_____

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D.3 Checking and reporting list

	Yes	No	Scheduled	To be done by
– Documentation complete				
– Missing documents				
– Revise documents				
– PC system assembly in accordance with specification				
– Missing components/modules				
– Mounting and wiring complete				
– Missing tasks				
– Mains and power supplies checking report (value, tolerance, noise earthed, non-earthed, interaction of coupled power supplies) is signed and attached				
– Environmental conditions checking report (temperature, vibration, contamination) is signed and attached				
– MMI checking report (signalling, monitoring, handling) is signed and attached				
– Application software back-ups exist				
– Software and software documentation (print-out) are in accordance with each other				
– Software on line test report (functionality, real-time check) is signed and attached				
– Main processing unit test				
– Check on report communication lines is signed and attached				
– Program loading, starting, restarting test report is signed and attached				
– Digital I/O including peripherals test report is signed and attached				
– Analog I/O test report, including peripherals and wiring, is signed and attached				
– Emergency operations test report is signed and attached				
– Test report regarding functionality of diagnostic features is signed and attached				
– Expert available in user's staff with knowledge in application and installed PC system				
– Additional comments				

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D.4 The following standards (national, local, company) were applied:

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Annex E

Maintenance and inspection example

E.1 Frequent inspection

The following may be checked daily.

Check item	
Base unit mounting conditions	
Mounting conditions of I/O unit, etc.	
Connecting conditions	
Processing	"POWER" LED
	"RUN" LED
	"INPUT" LED
	"OUTPUT" LED

E.2 Inspection at long intervals

The following may be checked at longer intervals (every six months to one year). If the equipment has been moved or modified or wiring has been changed, then an inspection is due.

Check item	
Loose terminal screws	
Ambient environment	Ambient temperature Ambient humidity Atmosphere
Line voltage check	
Mounting conditions	Looseness, play ingress of dust or foreign material
Connecting conditions	Distances between solderless terminals
Corrosion	Terminals and safety protection
Battery	
Fuse	

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Annex F

PC specification contents list

The specification is prepared to define the PC operational, hardware and software requirements. The following items should be considered and included as applicable:

- general description of system and system application;
- life-cycle plan;
- hardware and interface requirements;
- software, functional requirements;
- software, documentation requirements;
- software, listing requirements (software print-out);
- hardware/software, testing requirements;
- application, safety/protection requirements;
- documentation requirements;
- software maintenance and updating;
- training;
- maintenance responsibility;
- spare parts requirements and spare parts philosophy;
- engineering and production schedule;
- review meetings;
- delivery and shipment requirements.

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