INTERNATIONAL STANDARD

IEC 61131-1

Second edition
2003-05

Programmable controllers –

Part 1:
General information

Automates programmables –

Partie 1:
Informations générales

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PROGRAMMABLE CONTROLLERS –

Part 1: General information

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61131-1 has been prepared by subcommittee 65B: Devices, of IEC technical committee 65: Industrial-process measurement and control.

This second edition of IEC 61131-1 cancels and replaces the first edition published in 1992 and constitutes a technical revision.

The text of this standard is based on the following documents:

FDIS	Report on voting
65B/484/FDIS	65B/487/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

IEC 61131 consists of the following parts under the general title: *Programmable controllers.*

Part 1: General information

Part 2: Equipment requirements and tests

Part 3: Programming languages

Part 4: User guidelines

Part 5: Communications

Part 6: Reserved

Part 7: Fuzzy-control programming

Part 8: Guidelines for the application and implementation of programming languages for programmable controllers

The committee has decided that the contents of this publication will remain unchanged until 2007. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual version of this standard may be issued at a later date.

INTRODUCTION

This Part of IEC 61131 constitutes Part 1 of a series of standards on programmable controllers and their associated peripherals and should be read in conjunction with the other parts of the series.

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

The purposes of this standard are:

Part 1 establishes the definitions and identifies the principal characteristics relevant to the selection and application of programmable controllers and their associated peripherals;

Part 2 specifies equipment requirements and related tests for programmable controllers (PLC) and their associated peripherals;

Part 3 defines, for each of the most commonly used programming languages, major fields of application, syntactic and semantic rules, simple but complete basic sets of programming elements, applicable tests and means by which manufacturers may expand or adapt those basic sets to their own programmable controller implementations;

Part 4 gives general overview information and application guidelines of the standard for the PLC end-user;

Part 5 defines the communication between programmable controllers and other electronic systems;

Part 6 is reserved;

Part 7 defines the programming language for fuzzy control;

Part 8 gives guidelines for the application and implementation of the programming languages defined in Part 3.

PROGRAMMABLE CONTROLLERS –

Part 1: General information

1 Scope

This Part of IEC 61131 applies to programmable controllers (PLC) and their associated peripherals such as programming and debugging tools (PADTs), human-machine interfaces (HMIs), etc., which have as their intended use the control and command of machines and industrial processes.

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

The functionality of a programmable controller can be performed as well on a specific hardware and software platform as on a general-purpose computer or a personal computer with industrial environment features. This standard applies to any products performing the function of PLCs and/or their associated peripherals. This standard does not deal with the functional safety or other aspects of the overall automated system. PLCs, their application programme and their associated peripherals are considered as components of a control system.

Since PLCs are component devices, safety considerations for the overall automated system including installation and application are beyond the scope of this Part. However, PLC safety as related to electric shock and fire hazards, electrical interference immunity and error detecting of the PLC-system operation (such as the use of parity checking, self-testing diagnostics, etc.), are addressed. Refer to IEC 60364 or applicable national/local regulations for electrical installation and guidelines.

This Part of IEC 61131 gives the definitions of terms used in this standard. It identifies the principal functional characteristics of programmable controller systems.

2 Normative references

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

IEC 61131-2, *Programmable controllers – Part 2: Equipment requirements and tests*[1]

IEC 61131-3:2003, *Programmable controllers – Part 3: Programming languages*

[1] To be published.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
application programme or user programme
logical assembly of all the programming language elements and constructs necessary for the intended signal processing required for the control of a machine or process by a PLC-system

3.2
automated system
control system beyond the scope of IEC 61131, in which PLC-systems are incorporated by or for the user, but which also contains other components including their application programmes

3.3
field device
catalogued part to provide input and/or output interfaces or to provide data pre-processing/post-processing to the programmable controller system. A remote field device may operate autonomously from the programmable controller system. It can be connected to the programmable controller using a field bus

3.4
ladder diagram or relay ladder diagram
one or more networks of contacts, coils, graphically represented functions, function blocks, data elements, labels, and connective elements, delimited on the left and (optionally) on the right by power rails

3.5
programmable (logic) controller (PLC)
digitally operating electronic system, designed for use in an industrial environment, which uses a programmable memory for the internal storage of user-oriented instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic, to control, through digital or analogue inputs and outputs, various types of machines or processes. Both the PLC and its associated peripherals are designed so that they can be easily integrated into an industrial control system and easily used in all their intended functions

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

3.6
programmable controller system or PLC-system
user-built configuration, consisting of a programmable controller and associated peripherals, that is necessary for the intended automated system. It consists of units interconnected by cables or plug-in connections for permanent installation and by cables or other means for portable and transportable peripherals

3.7
programming and debugging tool (PADT)
catalogued peripheral to assist in programming, testing, commissioning and troubleshooting the PLC-system application, programme documentation and storage and possibly to be used as HMIs. PADTs are said to be pluggable when they may be plugged or unplugged at any time into their associated interface, without any risk to the operators and the application. In all other cases, PADTs are said to be fixed

3.8
remote input/output station (RIOS)
manufacturer's catalogued part of a PLC-system including input and/or output interfaces allowed to operate only under the hierarchy of the main processing unit (CPU) for I/O multiplexing/demultiplexing and data pre-processing/post-processing. The RIOS is the only permitted limited autonomous operation, for example, under emergency conditions such as breakdown of the communication link to the CPU or of the CPU itself, or when maintenance and troubleshooting operations are to be performed

4 Functional characteristics

4.1 Basic functional structure of a programmable controller system

The general structure with main functional components in a programmable controller system is illustrated in Figures 1, 2 and 3. These functions communicate with each other and with the signals of the machine/process to be controlled.

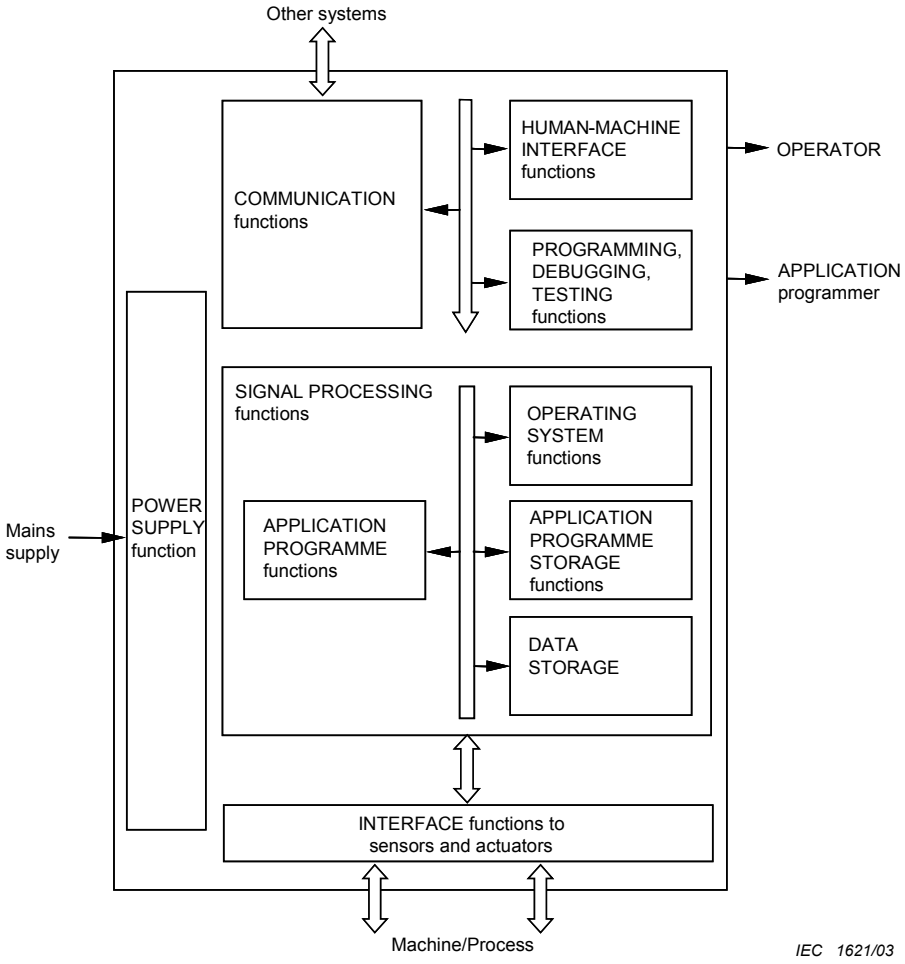


Figure 1 – Basic functional structure of a PLC-system

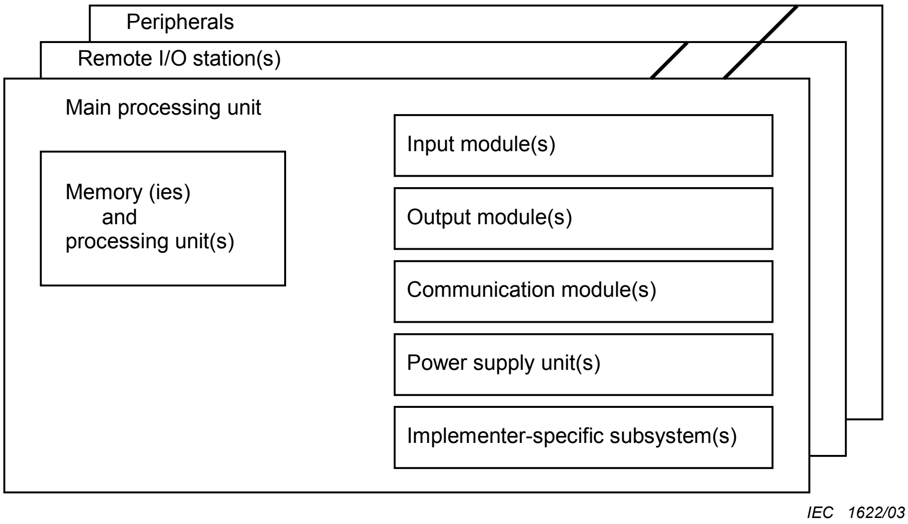
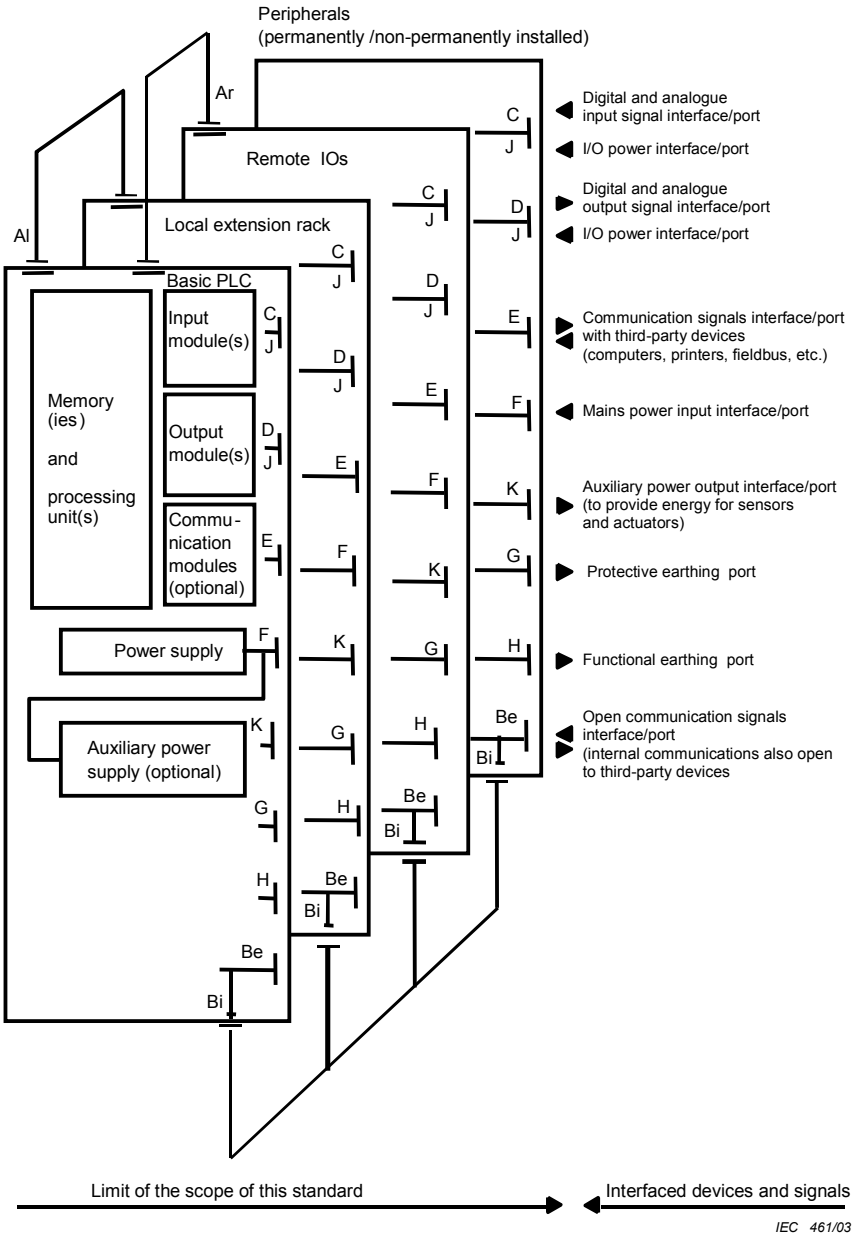


Figure 2 – Programmable controller hardware model (from IEC 61131-5)



Key

Al Communication interface/port for local I/O

Ar Communication interface/port for remote I/O station

Be Open-communication interface/port also open to third-party devices (for example, personal computer used for programming instead of a PADT)

Bi Internal communication interface/port for peripherals

C Interface/port for digital and analogue input signals

D Interface/port for digital and analogue output signals

E Serial or parallel communication interfaces/ports for data communication with third-party devices

F Mains power interface/port. Devices with F ports have requirements on keeping downstream devices intelligent during power-up, power-down and power interruptions.

G Port for protective earthing

H Port for functional earthing

J I/O power interface/port used to power sensors and actuators

K Auxiliary power output interface/port

Figure 3 – Typical interface/port diagram of a PLC-system (from IEC 61131-2)

The CPU function consists of the application programme storage, the data storage, the operating system, and the execution of the application programme functions.

The CPU processes signals obtained from sensors as well as internal data storage and generates signals to actuators as well as internal data storage in accordance with the application programme.

- **Interface function to sensors and actuators**

  The interface function to sensors and actuators converts

  – the input signals and/or data obtained from the machine/process to appropriate signal levels for processing;

  – the output signals and/or data from the signal processing function to appropriate signal levels to drive actuators and/or displays.

  The input/output signals to the interface functions may be coming from special modules which pre-process external sensor signals according to the defined functions contained in the special modules themselves. Examples of such special modules include PID module, fuzzy-control module, high-speed counter module, motion modules and others.

- **Communication function**

  The communication function provides data exchange with other systems (third-party devices) such as other PLC-systems, robot controllers, computers, etc.

- **Human-machine interface (HMI) function**

  The HMI function provides for interaction between the operator, the signal processing function and the machine/process.

- **Programming, debugging, testing and documentation functions**

  These functions provide for application programme generation and loading, monitoring, testing and debugging as well as for application programme documentation and archiving.

- **Power-supply functions**

  The power-supply functions provide for the conversion and isolation of the PLC-system power from the mains supply.

4.2 Characteristics of the CPU function

4.2.1 Summary

The capabilities of the programmable controllers are determined by programmable functions which are summarized in Table 1. They are subdivided for ease of use into application-oriented groups.

Table 1 – Summary of programmable functions

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

4.2.2 Operating system

The operating system function is responsible for the management of internal PLC-system interdependent functions (configuration control, diagnostics, memory management, application programme execution management, communication with peripherals and with the interface functions to sensors and actuators, etc.).

After a power-down or a distortion, the PLC system can restart in three different ways.

a) **Cold restart**

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

b) **Warm restart**

Restart after a power failure with a user-programmed predetermined set of remnant data and a system predetermined application programme context. A warm restart is identified by a status flag or equivalent means made available to the application programme indicating that the power failure shut-down of the PLC-system was detected in the run mode.

c) **Hot restart**

Restart after power failure that occurs within the process-dependent maximum time allowed for the PLC-system to recover as if there had been no power failure.

All I/O information and other dynamic data as well as the application programme context are restored or unchanged.

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

4.2.3 Memory for application data storage

- **Application programme storage**

  The application programme storage provides for memory locations to store a series of instructions whose periodic or event-driven execution determines the progression of the machine or the process. The application programme storage may also provide for memory locations to store initial values for application programme data.

- **Application data storage**

  The application data storage provides for memory locations to store I/O image table and data (for example, set values for timers, counters, alarm conditions, parameters and recipes for the machine or the process) required during the execution of the application programme.

- **Memory type, memory capacity, memory utilization**

  Various types of memory are in use: read/write (RAM), read-only (ROM), programmable read-only (PROM), reprogrammable read-only (EPROM/UV-PROM, EEPROM). Memory retention at power failure is achieved by a proper selection of the memory type where applicable (for example, EPROM, EEPROM) or the use of memory back-up for volatile memories (for example, a battery).

  Memory capacity relates to the number of memory locations in Kbytes, which are reserved to store both the application programme and the application data. Memory capacity measurements are:

  – capacity in the minimum useful configuration;

  – size(s) for expansion increments;

  – capacity(ies) at maximal configuration(s).

  Each programmable function used by the application programme occupies memory locations. The number of locations required generally depends on the programmable functions and the type of programmable controller.

  Application data storage requires memory capacity depending on the amount and format of data stored.

4.2.4 Execution of the application programme

An application programme may consist of a number of tasks. The execution of each task is accomplished sequentially, one programmable function at a time until the end of the task. The initiation of a task, periodically or upon the detection of an event (interrupt condition), is under the control of the operating system.

4.3 Characteristics of the interface function to sensors and actuators

a) **Types of input/output signals**

Status information and data from the machine/process are conveyed to the I/O system of the programmable controller by binary, digital, incremental or analogue signals. Conversely, decisions and results determined by the processing function are conveyed to the machine/process by use of appropriate binary, digital, incremental or analogue signals. The large variety of sensors and actuators used requires accommodating a wide range of input and output signals.

b) **Characteristics of the input/output system**

Various methods of signal processing, conversion and isolation are used in input/output systems. The behaviour and performance of the PLC-system depend on the static/dynamic evaluation of the signal (detection of events), storing/non-storing procedures, opto-isolation, etc.

Input/output systems in general display a modular functionality which allows for configuration of the PLC-system according to the needs of the machine/process and also for later expansion (up to the maximum configuration).

The input/output system may be located in close proximity to the signal processing function or may be mounted close to the sensors or actuators of the machine/process, remotely from the signal-processing function.

4.4 Characteristics of the communication function

The communication function represents the communication aspects of a programmable controller. It serves the programme and data exchange between the programmable controller and external devices or other programmable controllers or any devices in an automated system.

It provides functions such as device verification, data acquisition, alarm reporting, programme execution, and I/O control, application programme transfer, and connection management to the signal-processing unit of the PLC from or to an external device.

The communication function is generally accomplished by serial data transmission over local area networks or point-to-point links.

4.5 Characteristics of the human-machine interface (HMI) function

The HMI function has two purposes.

- To provide the operator with the information necessary for monitoring the operation of the machine/process.
- To allow the operator to interact with the PLC-system and its application programme in order to make decisions and adjustments beyond their individual user scope.

4.6 Characteristics of the programming, debugging, monitoring, testing and documentation functions

4.6.1 Summary

These functions are implemented as either an integral or an independent part of a programmable controller and provide for code generation and storage of the application programme and application data in the programmable controller memory(ies) as well as retrieving such programmes and data from memory(ies).

4.6.2 Language

For the programming of the application, there is a set of languages defined in IEC 61131-3.

a) **Textual languages**

1) Instruction list (IL) language
A textual programming language using instructions for representing the application programme for a PLC-system.

2) Structured text (ST) language
A textual programming language using assignment, sub-programme control, selection and iteration statements to represent the application programme for a PLC-system.

b) **Graphical languages**

1) Function block diagram (FBD) language
A graphical programming language using function block diagrams for representing the application programme for a PLC-system.

2) Ladder diagram (LD) language
A graphical programming language using ladder diagrams for representing the application programme for a PLC-system

3) Sequential function chart (SFC)
A graphical and textual notation for the use of steps and transitions to represent the structure of a program organization unit (program or function block) for a PLC-System. The transition conditions and the step action can be represented in a subset of the above-listed languages.

4.6.3 Writing the application programme

- **Generating the application programme**

The application programme may be entered via alphanumeric or symbolic keyboards and, when menu-driven displays are, or a graphical programme entry is, used via cursor keys, joystick, mouse, etc. All programme and data entries are generally checked for validity and internal consistency in such a way that the entry of incorrect programmes and data is minimized.

- **Displaying the application programme**

During application programme generation, all instructions are displayed immediately, statement by statement or segment by segment (in the case of a monitor or other large display). In addition, the complete programme can generally be printed. If alternative representation of programming language elements is available, then the display representation is generally user-selectable.

4.6.4 Automated system start-up

a) **Loading the application programme**

The generated programme resides either in the memory of the programmable controller or in the memory of the PADT. The latter requires a programme transfer via down-load or memory cartridge insertion into the programmable controller before start-up.

c) **Accessing the memory**

During start-up or trouble-shooting operations, the application programme and application data storage are accessed by the PADT as well as by the processing unit to allow programme monitoring, modification and correction. This may be done on line (i.e. while the PLC-system is controlling the machine/process).

d) **Adapting the programmable controller system**

Typical functions for adapting the PLC-system to the machine/process to be controlled are:

1) test functions which check the sensors and actuators connected to the PLC-systems (for example, forcing the outputs of the PLC-system);

1) test functions which check the operation of the programme sequence (for example, setting of flags and forcing the inputs);

2) setting or resetting of variables (for example, timers, counters, etc.).

e) **Indicating the automated system status**

The ability to provide information about the machine/process and the internal status of the PLC-system and of its application programme facilitates the start-up and debugging of a PLC application. Typical means are:

1) status indication for inputs/outputs;

3) indication/recording of status changes of external signals and internal data;

4) scan time/execution times monitoring;

5) real-time visualization of programme execution and data processing;

6) fuse/short-circuit protection status indicators.

f) **Testing the application programme**

Test functions support the user during writing, debugging and checking the application programme. Typical test functions are:

1) checking the status of inputs/outputs, internal functions (timers, counters);
2) checking programme sequences, for example, step-by-step operations, variations of programme cycle time, halt commands;
3) simulation of interface functions, for example, forcing of I/Os, of information exchanged between tasks or modules internal to the PLC-system.

g) **Modifying the application programme**

Functions for modification provide for changing, adjusting and correcting application programmes. Typical functions are search, replace, insert, delete, and add; they apply to characters, instructions, programme modules, etc.

4.6.5 Documentation

A documentation package should be provided to fully describe the PLC-system and the application. The documentation package may consist of

a) description of the hardware configuration with project-dependent notations;
b) application programme documentation consisting of
   1) programme listing, with possibly mnemonics for signals and data processed;
   2) cross-reference tables for all data processed (I/Os, internal functions such as internal stored data, timers, counters, etc.);
   3) comments;
   4) description of modifications;
   5) maintenance manual.

4.6.6 Application programme archiving

For rapid repair and to minimize down-time, the user may want to store the application programme in non-volatile media such as flash, PC-cards, EEPROM, EPROM, disks, etc. Such a record needs to be updated after every programme modification so that the programme executing in the PLC-system and the archived programme remain the same.

4.7 Characteristics of the power-supply functions

The power-supply functions generate voltages necessary to operate the PLC-system and generally also provide control signals for proper ON/OFF synchronization of the equipment. Various power supplies may be available depending on supply voltages, power consumption, parallel connection, requirements for uninterruptible operation, etc.

5 Availability and reliability

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

a) **Architecture of the automated system**

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

b) **Architecture of the programmable controller system**

A modular construction in conjunction with suitable internal self-tests allowing rapid fault identification may provide enhancements in the area of maintainability of the PLC-system and therefore of the availability of the automated system. Techniques such as redundancy and fault tolerance may also be considered for special applications.

c) **Design, testing and maintenance of the application programme**

The application programme is a key component of the overall automated system. Most programmable controllers provide enough computing power to permit implementation of diagnostic functions in addition to the minimum control function. Machine/process behaviour modelling and subsequent identification of faulty conditions should be considered.

Adequate testing of the application programme is mandatory. Every modification implies proper design and testing so that the overall availability and reliability are not impaired. The programme documentation shall be maintained and annotated accordingly.

d) **Installation and service conditions**

PLC-systems are typically of rugged design and intended for general-purpose service. However, as for any equipment, the more stressing the service conditions, the worse is the reliability, and benefit in this area may be expected when permitted service conditions are better than the normal service conditions specified in IEC 61131-2. Some applications may require consideration of special packaging, cooling, electrical noise protection, etc., for reliable operation.

Bibliography

IEC 60050-351:1998, *International Electrotechnical Vocabulary (IEV) – Part 351: Automatic control*

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