IEC STANDARDS FOR PLC

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Chapter: 1 Introduction

1.1 Standards

Universally or widely accepted, agreed upon, or established means of determining what something should be.

A standard is a document, established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context.

Standards make sure that products work together safely and as intended. They are also needed by test labs to check that products are safe to use; governments rely on them to protect citizens from unsafe products.

We may not be aware of them, but we use standards every day, in all aspects of our daily lives – in communications, media, healthcare, food, transport, construction, furniture, energy…

Standards provide:

- **Safety and reliability** – Adherence to standards helps ensure safety, reliability and environmental care. As a result, users perceive standardized products and services as more dependable – this in turn raises user confidence, increasing sales and the take-up of new technologies.

- **Support of government policies and legislation** – Standards are frequently referenced by regulators and legislators for protecting user and business interests, and to support government policies. Standards play a central role in the European Union's policy for a Single Market.

- **Interoperability** – the ability of devices to work together relies on products and services complying with standards.

- **Business benefits** – standardization provides a solid foundation upon which to develop new technologies and to enhance existing practices. Specifically standards:

- Open up market access
- Provide economies of scale
- Encourage innovation
- Increase awareness of technical developments and initiatives

- **Consumer choice** - standards provide the foundation for new features and options, thus contributing to the enhancement of our daily lives. Mass production based on standards provides a greater variety of accessible products to consumers.

1.2 IEC Standards

Millions of devices that contain electronics, and use or produce electricity, rely on IEC International Standards and Conformity Assessment Systems to perform, fit and work safely together.

Founded in 1906, the IEC (International Electrotechnical Commission) is a not-for-profit, non-governmental the world’s leading organization for the preparation and publication of International Standards for all electrical, electronic and related technologies. These are known collectively as "electrotechnology".

IEC provides a platform to companies, industries and governments for meeting, discussing and developing the International Standards they require.

An International Standard is a standard adopted by an international standards organization and made available to the public. The definition given in all IEC standards reads: "A normative document, developed according to consensus procedures, which has been approved by the IEC National Committee members of the responsible committee in accordance with Part 1 of the ISO/IEC Directives."

The IEC is one of the bodies recognized by the World Trade Organization (WTO) and entrusted by it for monitoring the national and regional organizations agreeing to use the IEC's international standards as the basis for national or regional standards as part of the WTO's Technical Barriers to Trade Agreement.

All IEC International Standards are fully consensus-based and represent the needs of key stakeholders of every nation participating in IEC work. Every member country, no matter how large or small, has one vote and a say in what goes into an IEC International Standard.

The IEC promotes world trade and economic growth and encourages the development of products, systems and services that are safe, efficient and environmentally friendly.

IEC standards cover a vast range of technologies from power generation, transmission and distribution to home appliances and office equipment, semiconductors, fibre optics, batteries, solar energy, nanotechnology and marine energy as well as many others. The IEC also manages three global conformity assessment systems that certify whether equipment, system or components conform to its International Standards.

The IEC charter embraces all electrotechnologies including energy production and distribution, electronics, magnetics and electromagnetics, electroacoustics, multimedia, telecommunication and medical technology, as well as associated general disciplines such as terminology and symbols, electromagnetic compatibility (by its Advisory Committee on Electromagnetic Compatibility, ACEC), measurement and performance, dependability, design and development, safety and the environment.

The IEC is made up of members, called national committees, and each NC represents its nation's electrotechnical interests in the IEC. This includes manufacturers, providers, distributors and vendors, consumers and users, all levels of governmental agencies, professional societies and trade associations as well as standards developers from national standards bodies. National committees are constituted in different ways. Some NCs are public sector only, some are a combination of public and private sector, and some are private sector only. About 90% of those who prepare IEC standards work in industry.

With an aging population and at least 650 million people globally who are affected by some kind of disability, accessibility has become an important topic. But a small accident like a broken finger or a bad back can temporarily disable anybody. The IEC has published a report that is used by manufacturers to guide them in the design of products that are accessible to as many people as possible.

The IEC publishes International Standards for the millions of devices that contain electronics or use, produce, or store electricity.

These include such products as:

- ✓ Nanotechnology, superconductivity
- ✓ Electronic components, microchips, circuit boards, computers
- ✓ Plugs and sockets, cables, switches, insulating materials
- ✓ All kinds of batteries and fuel cells
- ✓ Household equipment such as fridges, hair dryers, microwave ovens, toasters, TVs
- ✓ Private and public transportation, including metros, electric cars, trains, buses, planes, ships

Electric power generation: Smart Grid, photovoltaics, wind turbines, marine energy, power lines, transformers and much, much more.

The work is done in TCs and SCs (Technical Committees and Subcommittees) by close to 10000 experts in more than 1000 Working Groups.

The IEC not only defines safety parameters for these products but also those of efficiency, interconnectivity (how products work with each other), quality and performance, how a device interferes with others, how environmentally-friendly it has been produced and how it should be recycled. It also prepares symbols, such as the "on/off" sign and + /– on batteries, and it helps engineers to speak the same language.

1.3 Programmable Logic Controller

A programmable logic controller, PLC or programmable controller is a digital computer used for automation of typically industrial electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures. PLCs are used in many industries and machines. PLCs are designed for multiple analogue and digital inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed-up or non-volatile memory. A PLC is an example of a "hard" real-time system since output results must be produced in response to input conditions within a limited time, otherwise unintended operation will result.

Before the PLC, control, sequencing, and safety interlock logic for manufacturing automobiles was mainly composed of relays, cam timers, drum sequencers, and dedicated closed-loop controllers. Since these could number in the hundreds or even thousands, the process for updating such facilities for the yearly model change-over was very time consuming and expensive, as electricians needed to individually rewire the relays to change their operational characteristics.

1.3.1 Programming

PLC programs are typically written in a special application on a personal computer, and then downloaded by a direct-connection cable or over a network to the PLC. The program is stored in the PLC either in battery-backed-up RAM or some other non-volatile flash memory. Often, a single PLC can be programmed to replace thousands of relays.

Under the IEC 61131-3 standard, PLCs can be programmed using standards-based programming languages. A graphical programming notation called Sequential Function Charts is available on certain programmable controllers. Initially most PLCs utilized Ladder Logic Diagram Programming, a model which emulated electromechanical control panel devices (such as the contact and coils of relays) which PLCs replaced. This model remains common today.

IEC 61131-3 currently defines five programming languages for programmable control systems: function block diagram (FBD), ladder diagram (LD), structured text (ST; similar to the Pascal programming language), instruction list (IL; similar to assembly language) and sequential function chart (SFC). These techniques emphasize logical organization of operations.

While the fundamental concepts of PLC programming are common to all manufacturers, differences in I/O addressing, memory organization and instruction sets mean that PLC programs are never perfectly interchangeable between different makers. Even within the same product line of a single manufacturer, different models may not be directly compatible.

Chapter: 2 IEC 61131

IEC 61131 is an IEC standard for programmable logic controllers. It was known as IEC 1131 before the change in numbering system by IEC.

The PLCopen Technical Committee 1, TC1, deals with Standards. The main focus of this activity is upon the IEC 61131-3 standard, as developed by the International Electrotechnical Committee. Since IEC holds the copyright, there are no downloadable versions of it available.

IEC 61131-3 provides the basis for PLCopen. This standard is part of the International Standard IEC 61131, providing a complete collection of standards on programmable controllers and their associated peripherals.

The purposes of this standard are:

- To establish the definitions and identify the principal characteristics relevant to the selection and application of PLCs and their associated peripherals;
- To specify the minimum requirements for functional, electrical, mechanical, environmental and construction characteristics, service conditions, safety, EMC, user programming and tests applicable to PLCs and the associated peripherals.

2.1 Sections of IEC 61131

Standard IEC 61131 is divided into several parts:

Part 1: General Information

Part 2: Equipment Requirements and Tests

Part 3: Programming Languages

Part 4: User Guidelines

Part 5: Communications or Messaging Service Specification

Part 6: Functional Safety

Part 7: Fuzzy Control Programming

Part 8: Guidelines for the Application and Implementation of Programming Languages

Part 9: Single-drop digital communication interface for small sensors and actuators (SDCI)

2.1.1 IEC 61131-1: General Information

IEC 61131-1 is the introductory chapter of the open international standard IEC 61131 for programmable logic controllers. IEC 61131-1 provides definitions of terms that will be used in the subsequent parts of the standard, as well as outlining the main functional properties and characteristics of PLCs.

2.1.2 IEC 61131-2: Equipment Requirements and Tests

IEC 61131-2 specifies equipment requirements and related tests for programmable controllers (PLC) and their associated peripherals. This part specifies:

- Service, storage and transportation requirements for PLCs and their associated peripherals;
- Functional requirements for PLCs and their associated;
- EMC requirements for PLCs and their associated peripherals;
- Safety requirements for PLCs and their associated;
- Information that the manufacturer is required to supply;
- Test methods and procedures that are to be used for the verification of compliance of PLCs and their associated peripherals with the requirements.

2.1.3 IEC 61131-3: Programming Languages

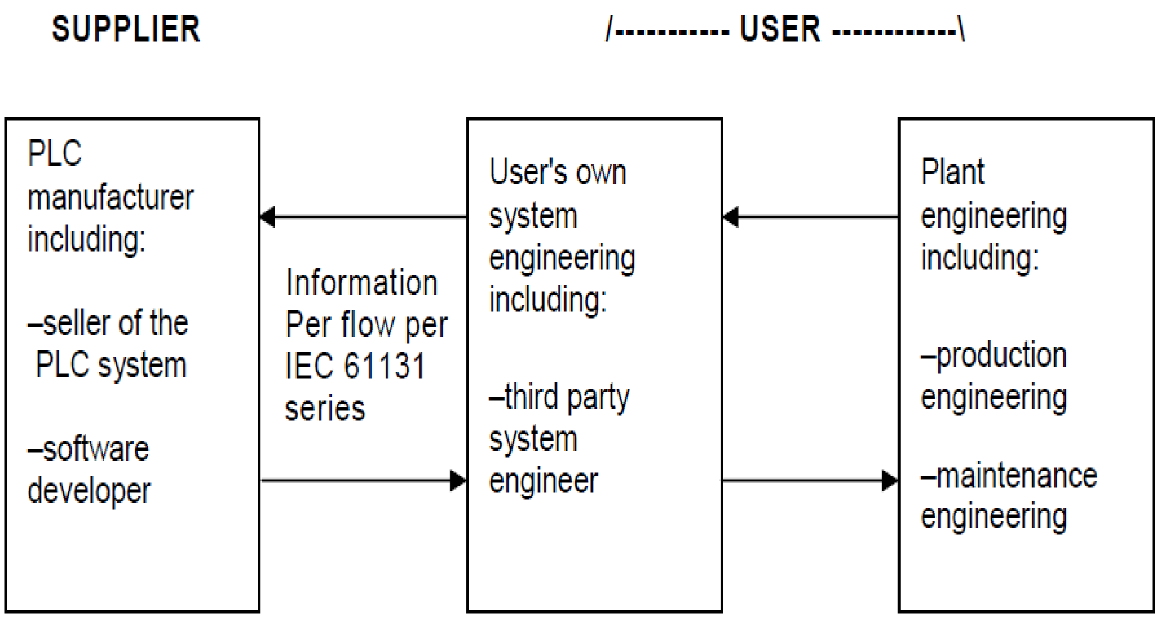
The third part defines, as a minimum set, the basic programming elements, syntactic and semantic rules for the most commonly used programming languages. This includes the graphical languages Ladder Diagram and Functional Block Diagram, and the textual languages Instruction List and Structured Text, as well as means by which manufacturers may expand or adapt those basic sets to their own programmable controller implementations. Sequential Function Chart (SFC) elements are defined for structuring the internal organization of programmable controller programs and function blocks. Also, configuration elements are defined which support the installation of programmable controller programs into programmable controller systems. In addition, features are defined which facilitate communication among programmable controllers and other components of automated systems. The programming language elements defined in this part may be used in an interactive programming environment. The specification of such environments is beyond the scope of this part; however, such an environment shall be capable of producing textual or graphic program documentation in the formats specified in this part.

Providing the Basis

The PLCopen activities are based upon the IEC 61131-3 standard, the only global standard for industrial control programming. It harmonizes the way people design and operate industrial controls by standardizing the programming interface. A standard programming interface allows people with different backgrounds and skills to create different elements of a program during different stages of the software lifecycle: specification, design, implementation, testing, installation and maintenance. Yet all pieces adhere to a common structure and work together harmoniously. The standard includes the definition of the Sequential Function Chart (SFC) language, used to structure the internal organization of a program, and four inter-operable programming languages: Instruction List (IL), Ladder Diagram (LD), Function Block Diagram (FBD) and Structured Text (ST). Via decomposition into logical elements, modularization and modern software techniques, each program is structured, increasing its re-usability, reducing errors and increasing programming and user efficiency.

2.1.4 IEC 61131-4: User Guidelines

A technical report providing general overview information and application guidelines of the standard for the end user of programmable controllers.

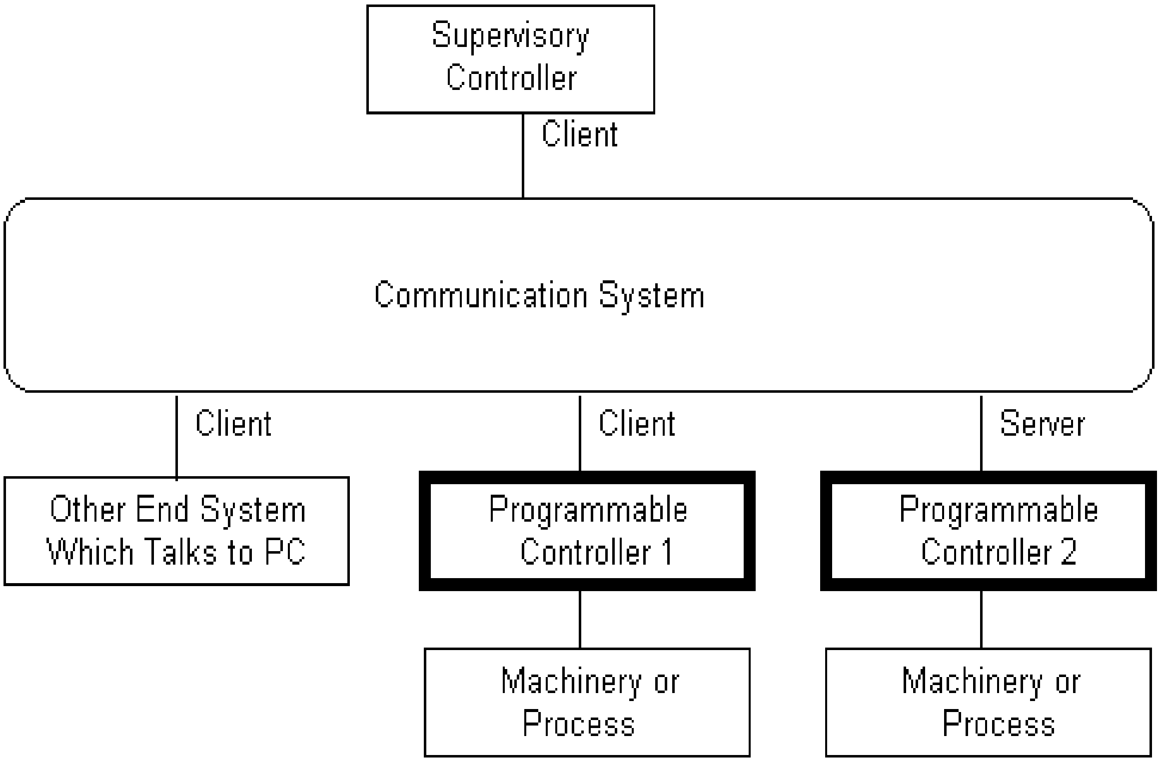


The user needs to supply applications requirement and specifications to the vendor in order to receive suitable products and services from the vendor. The object of this TR then is to assist in this communication, especially from the end-user's perspective. Accordingly, this TR does not detail all the requirements of each and every part of IEC 61131 standard, such as conformance tests. The user should refer to the individual parts of the standard when needed.

The International Standard IEC61131 applies to programmable controllers (PLC) and their associated peripherals. PLCs and their associated peripherals are considered as components of a control system. Therefore, this standard does not deal with the automated system in which the programmable controller system is but one component. However, when applying this User guideline an overall system architecture evaluation is recommended.

2.1.5 IEC 61131-5: Communications or Messaging Service Specification

IEC 61131-5 defines the data communication between programmable controllers and other electronic systems using the Manufacturing Message Specification (MMS), according to International Standard IEC 9506.



Within the full set of the international IEC 61131 standard, part 5 deals with communication. As such it is approved as Standard in 2000, and is available at IEC or at the local representations

This part 5 describes the way PLCs can communicate to each other. A PLC as used in the context of IEC 61131 may be a real controller or a SoftPLC or any device which supports the programming languages of IEC 61131-3 and the communication defined in IEC 61131-5. This means from PLC-to-PLC, to HMI, Plant control, and even robots and CNC's. Even it can provide communication to intelligent devices via a fieldbus. However, it does not include distributed control or communication to simple I/O devices via a sensor / actuator level bus or fieldbus.

The IEC 61131-5 describes the communication services from the point of view of the programmer and/or user. As such it is a application program interface for PLC communication. For this it provides communication services in the form of functions combined with the concepts and elements of the IEC 61131-3 programming languages.

IEC 61131-5 does not describe a communication bus-system – it defines independent services at a higher level, which can be used in existing communication networks and systems. Pre-requisite for these systems is that they support connections, access to variables and message services, as well as the loading of large data sets. Other communication systems based on other standards or de-facto standards may be used as communication subsystems for IEC 61131-5 too.

2.1.6 IEC 61131-6: Functional Safety

This Part of the IEC 61131 series specifies requirements for programmable controllers (PLCs) and their associated peripherals, as defined in Part 1, which is intended to be used as the logic subsystem of an electrical/electronic/programmable electronic (E/E/PE) safety-related system. A programmable controller and its associated peripherals complying with the requirements of this part is considered suitable for use in an E/E/PE safety-related system and is identified as a functional safety programmable logic controller (FS-PLC). An FS-PLC is generally a hardware (HW) / software (SW) subsystem. An FS-PLC may also include software elements, for example predefined function blocks.

An E/E/PE safety-related system generally consists of sensors, actuators, software and a logic subsystem. This part is a product specific implementation of the requirements of the IEC 61508 series and conformity to this part fulfils all of the applicable requirements of the IEC 61508 series related to FS-PLCs. While the IEC 61508 series is a system standard, this part provides product specific requirements for the application of the principles of the IEC 61508 series to FS-PLC.

This Part of the IEC 61131 series addresses only the functional safety and safety integrity requirements of an FS-PLC when used as part of an E/E/PE safety-related system. The definition of the functional safety requirements of the overall E/E/PE safety-related system and the functional safety requirements of the ultimate application of the E/E/PE safety-related system are outside the scope of this part, but they are inputs for this part.

This part applies to an FS-PLC with a Safety Integrity Level (SIL) capability not greater than SIL 3.

The objective of this part is:

• To establish and describe the safety life-cycle elements of an FS-PLC, in harmony with the general safety life-cycle.

• To establish and describe the requirements for FS-PLC HW and SW that relate to the functional safety and safety integrity requirements of a E/E/PE safety-related system;

• To establish evaluation methods for a FS-PLC to this part for the following parameters/criteria:

– A Safety Integrity Level (SIL) claim for which the FS-PLC is capable,

– A Probability of Failure on Demand (PFD) value,

– An average frequency of dangerous failure per hour value (PFH),

– A value for the safe failure fraction (SFF),

– A value for the hardware fault tolerance (HFT),

– A diagnostic coverage (DC) value,

– A verification that the specified FS-PLC manufacturer's safety lifecycle processes are in place,– the defined safe state,

– The measures and techniques for the prevention and control of systematic faults, and

– For each failure mode addressed in this part, the functional behaviour in the failed state;

• To establish the definitions and identify the principal characteristics relevant to the selection and application of FS-PLCs and their associated peripherals.

This part is primarily intended for FS-PLC manufacturers. It also includes the critical role of FS-PLC users through the user documentation requirements. Some user guidelines for FSPLCs may be found in IEC 61131-4.

2.1.7 IEC 61131-7: Fuzzy Control Programming

IEC 61131-7 defines basic programming elements for fuzzy logic control as used in programmable controllers.

A fuzzy control system is a control system based on fuzzy logic—a mathematical system that analyzes analogue input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0 (true or false, respectively).

Fuzzy logic is widely used in a machine control. The term "fuzzy" refers to the fact that the logic involved can deal with concepts that cannot be expressed as the "true" or "false" but rather as "partially true". Although alternative approaches such as genetic algorithms and neural networks can perform just as well as fuzzy logic in many cases, fuzzy logic has the advantage that the solution to the problem can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller. This makes it easier to mechanize tasks that are already successfully performed by humans.

Fuzzy logic was first proposed by Lotfi A. Zadeh of the University of California at Berkeley in a 1965 paper. He elaborated on his ideas in a 1973 paper that introduced the concept of "linguistic variables", which in this article equates to a variable defined as a fuzzy set. Other research followed, with the first industrial application, a cement kiln built in Denmark, coming on line in 1975.

The input variables in a fuzzy control system are in general mapped by sets of membership functions similar to this, known as "fuzzy sets". The process of converting a crisp input value to a fuzzy value is called "fuzzification".

A control system may also have various types of switch, or "ON-OFF", inputs along with its analog inputs, and such switch inputs of course will always have a truth value equal to either 1 or 0, but the scheme can deal with them as simplified fuzzy functions that happen to be either one value or another.

Given "mappings" of input variables into membership functions and truth values, the microcontroller then makes decisions for what action to take, based on a set of "rules", each of the form.

2.1.8 IEC 61131-8: Guidelines for the Application and Implementation of Programming Languages

The Technical Report (TR) provides a software developers guide for the programming languages. This technical report applies to the programming of programmable controller systems using the programming languages defined in IEC 61131-3. It also provides guidelines for the implementation of these languages in programmable controller systems and their programming support environments (PSEs).

2.1.9 IEC 61131-9: Single-Drop Digital Communication Interface for Small Sensors and Actuators (SDCI)

This standard is also known as “IO-Link” (Currently CDIS - Committee Draft IS) and is coupled to a communication interface. Current version is Committee Draft International Standard.

Bibliography

[1] www.PLCopen.org

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