ENGINEERING AND CONSTRUCTION STANDARD

FOR

PROGRAMMABLE LOGIC CONTROLLERS (PLC)

FIRST EDITION

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FOREWORD

The Iranian Petroleum Standards (IPS) reflect the views of the Iranian Ministry of Petroleum and are intended for use in the oil and gas production facilities, oil refineries, chemical and petrochemical plants, gas handling and processing installations and other such facilities.

IPS is based on internationally acceptable standards and includes selections from the items stipulated in the referenced standards. They are also supplemented by additional requirements and/or modifications based on the experience acquired by the Iranian Petroleum Industry and the local market availability. The options which are not specified in the text of the standards are itemized in data sheet/s, so that, the user can select his appropriate preferences therein

The IPS standards are therefore expected to be sufficiently flexible so that the users can adapt these standards to their requirements. However, they may not cover every requirement of each project. For such cases, an addendum to IPS Standard shall be prepared by the user which elaborates the particular requirements of the user. This addendum together with the relevant IPS shall form the job specification for the specific project or work.

The IPS is reviewed and up-dated approximately every five years. Each standards are subject to amendment or withdrawal, if required, thus the latest edition of IPS shall be applicable

The users of IPS are therefore requested to send their views and comments, including any addendum prepared for particular cases to the following address. These comments and recommendations will be reviewed by the relevant technical committee and in case of approval will be incorporated in the next revision of the standard.

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GENERAL DEFINITIONS:

Throughout this Standard the following definitions shall apply.

COMPANY:

Refers to one of the related and/or affiliated companies of the Iranian Ministry of Petroleum such as National Iranian Oil Company, National Iranian Gas Company, National Petrochemical Company and National Iranian Oil Refinery And Distribution Company.

PURCHASER:

Means the “Company” where this standard is a part of direct purchaser order by the “Company”, and the “Contractor” where this Standard is a part of contract documents.

VENDOR AND SUPPLIER:

Refers to firm or person who will supply and/or fabricate the equipment or material.

CONTRACTOR:

Refers to the persons, firm or company whose tender has been accepted by the company.

EXECUTOR:

Executor is the party which carries out all or part of construction and/or commissioning for the project.

INSPECTOR:

The Inspector referred to in this Standard is a person/persons or a body appointed in writing by the company for the inspection of fabrication and installation work.

SHALL:

Is used where a provision is mandatory.

SHOULD:

Is used where a provision is advisory only.

WILL:

Is normally used in connection with the action by the “Company” rather than by a contractor, supplier or vendor.

MAY:

Is used where a provision is completely discretionary.

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PART 1

ENGINEERING STANDARD

FOR

PROGRAMMABLE LOGIC CONTROLLERS (PLC)

0. INTRODUCTION

In this Standard, the following conceptual control levels has been assumed; levels 3 through 7 is for ESD, and levels 1 and 2 are considered for sequential and batch control.

Level 1

Level 1 system is not emergency shut-down and will be considered for sequential control system.

Level 2

Level 2 system is not emergency shut-down and will be considered for batch control system.

Level 3

A level 3 shut-down would occur when on upset condition on a single unit requires that unit to be shut-down with no other unit affected and the rest of process continues the stable operation with no loss of production. This level of control is the last chance which prevents damage to the process, personnel or any other type of hazards.

Level 4

A level 4 shut-down would occur if an upset in one system directly causes the shut down of one or more parts of the system. This level of shut-down would cause the loss of production from one production train.

Level 5

Level 5 shut-down are initiated by external non-process conditions, such as; feed stop to the plant, fuel stop to the plant system, or output stopage of the plant.

Level 6

Level 6 shut-downs would be initiated by external non-process factors, such as; gas detection in a safe area, main and emergency power generating equipment stoppage, AC circuits of uninterruptible power supplies (UPS) inverters stoppage and some DC important systems switching off, etc.

Level 7

A level 7 shut-down involves the shut down of every electrical system and the isolation of every battery with exception of the fire water pump start and control batteries. This level of shut-down is only considered during major gas leaks, blowouts, etc., where there is a danger that most of the installation will be covered by a gas cloud. Initiation of a level 7 shut-down will be performed by manual Emergency Shut-down Switch by the operator.

1. SCOPE

This Standard covers the minimum requirements and specific constraints to be fulfilled in engineering activities and procedures in designing Programmable Logic Controllers (PLC) for Iranian Petroleum Industries projects, including:

- Application of PLC for ESD system
- Application of PLC for sequential control and batch process control.
- Application of PLC for interlocking including safety circuits.

Note 1:

This standard specification is reviewed and updated by the relevant technical committee on Mar. 2002. The approved modifications by T.C. were sent to IPS users as amendment No. 1 by circular No. 164 on Mar. 2002. These modifications are included in the present issue of IPS.

Note 2:

This is a revised version of this standard, which is issued as revision (1)-2013. Revision (0)-1996 of the said standard specification is withdrawn.

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

NEMA (NATIONAL ELECTRICAL MANUFACTURER'S ASSOCIATION)

IA2	"Programmable Controllers"

ANSI (AMERICAN NATIONAL STANDARD INSTITUTE)

X 3.28	"Communication Control Characters"
ANSI/EIA 310	"Racks, Panels and Associated Equipment"
ANSI/TIA/EIA-232-F	"Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange"

US MIL (MILITARY STANDARDS)

MIL-STD-806B	"Graphic Symbols for Logic Diagrams"

IEEE (INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS)

IEEE 91	"Graphic Symbols for Logic Functions"
IEEE 802	"Telecommunications & Information Exchange between System-Local & Metropolitan Area Networks Specific Requirements"

IEC (INTERNATIONAL ELECTROTECHNIQUE COMMISSION)

IEC 61131-1	"Programmable Controllers - Part 1: General Information"
IEC 61131-2	"Programmable Controllers – Part 2: Equipment Requirements and Tests"
IEC 61131-3	"Programmable Controllers – Part 3: Programming Languages"
IEC TR 61131-4	"Programmable Controllers – Part 4: User Guidelines"
IEC 61131-5	"Programmable Controllers – Part 5: Communications"
IEC 61131-7	"Programmable Controllers – Part 7: Fuzzy Control Programming"
IEC TR 61131-8	"Programmable Controllers – Part 8: Guidelines for the Application and Implementation of Programming Languages"
IEC 60947-5-1	"Low-voltage Switchgear and Controlgear –Part 5-1: Control Circuit Devices and Switching Elements – Electromechanical Control Circuit Devices"

BSI (BRITISH STANDARD INSTITUTION)

BS EN 61508	"Functional Safety of Electrical/Electronic/Programmable Electronic Safety"
BS EN 61511	"Functional Safety-Safety Instrumented System for the Process Industry Sector"

API (AMERICAN PETROLEUM INSTITUTE)

API 554	"Process Control Systems- Part 2: Process Control System Design"

ISA (THE INSTRUMENTATION, SYSTEMS AND AUTOMATION SOCIETY)

ISA-88-01	"Batch Control Part 1: Models and Terminology"
ISA-88-02	"Batch Control Part 2: Data Structures and Guidelines for Languages"

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-G-IN-260	"Engineering and Installation Standard for Indicating Lights, Alarms and Protective Systems"
IPS-M-IN-290	"Material and Equipment Standard for Programmable Logic Controllers (PLC)"

3. GENERAL ENGINEERING REQUIREMENTS

3.1 System Design Considerations

3.1.1 PLCs considered for emergency shutdown system shall be either dual redundant or two-out-of-three (triple redundant) configuration in order to increase availability and decrease the risk of system outage in a manner that a single failure within PLC does not jeopardize plant safety. For detail refer to clause 8.

3.1.2 Power supply

3.1.2.1 The PLC system voltage supply shall be considered to be 110 VAC or 24 VDC as specified in the project data sheets. Other supply voltages may be considered by user approval.

3.1.2.2 Considering the clause 3.1.2.1 incoming power supplies to the PLC system and to the externally power I/O modules shall be as shown in table 6 in IEC 61131-2. For UPS voltage quality refer to IPS-M-EL-176.

3.1.2.3 Voltage harmonics

AC Voltage is in terms of the total r.m.s. voltage values measured at the point of entry to the equipment. Total r.m.s. content of true harmonics (integral multiple of nominal frequency) less than 10 times nominal frequency may reach 10% of the total voltage. Harmonic and other frequency content for higher frequencies may reach 2% of the total voltage. However, to provide constant comparative results, the equipment shall be tested at the third harmonic only (10% at 0° and at 180° phase angle).

The total content of harmonics of the power supply to the PLC system may be affected when the energy source output impedance is relatively high with regard to the input impedance of the PLC system power supply. Sizing a dedicated power source such as an inverter for a PLC system may require an agreement between the user and the manufacturer. The use of line conditioner should be considered. For more information refer to IEC 61131-2.

3.1.3 PLC system self test and diagnostics requirements

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

The following shall be provided:

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

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

RIOSs shall be capable of operating an alarm signal on an alarm output (for example, through a digital output module) in the event of loss of power or loss of normal communication with the MPU and go to a predetermined state. For more information refer to IEC 61131-2.

3.1.4 All factors likely to cause the PLC breakdown should be identified and design precautions shall be taken to eliminate all weaknesses, in order to ensure reliable PLC operation in ESD or trip system application. The PLC system shall have a reliable fail-safe configuration, in addition to redundancy for all inputs, MPU (Main Processing Unit), power supplies, outputs, and communication hardware.

3.1.5 For plants with identifiable process areas, each capable of operating as independent unit, the process areas shall be categorized by nature of operation, size, hazard and location and each category shall be allocated with it’s independent trip system. The plant’s "trip system" therefore shall consist of a number of independent smaller systems, reflecting the plant’s independent process areas.

3.1.6 Vendor shall be requested to provide a detailed "failure mode and effects" analysis to be evaluated for compliance with the project requirements.

3.1.7 In designing the PLC "elementary diagram" and subsequently selecting the manufacturer and sizing the PLC, the scan time shall be carefully considered.

3.1.8 In case that, a single input or output requires faster scan time than the PLC, then PLC system shall be considered to have special instructions that interrupt normal scan and produce an immediate update on I/O.

3.1.9 It should be noted that the redundancy shall be of hardware implemented fault tolerant type with; fast switch-over time, software simplification, and tractable failure analysis.

3.1.10 PLCs with suitable configuration may be considered for sequence and batch control systems as detailed in article 7.0.

3.1.11 Consideration shall be given to the temperature rise caused by heat from the power supplies, memories, etc., which will produce excessive temperature inside the cabinet. In such condition inside temperature may be driven 10 to 20°C higher than environmental temperature.

3.1.12 For inductive load inputs, a capacitor across the secondary side of the disconnect switch supplying power to the inductive load should be provided for outrush problem.

3.1.13 Program development software tools shall be provided by Vendor, enabling the applications programmer and user to develop, edit or debug application logic or programs. Software shall conform to IEC 61131-3 requirements.

3.1.14 Name plate requirements

For all equipment, as a minimum, the information marked on the device shall identify the manufacturer (the company bringing the product to market) and the device. The remaining information shall be provided in the data sheet. See Clause 7 of IEC 61131-2.

The following information shall be provided by the manufacturer:

- Manufacturer’s name, trade mark or other identification
- Model/catalogue number, type designation or name
- Software serial number and/or revision level and firmware revision, where applicable
- Hardware serial number or series and/or revision level and date code or equivalent.

3.1.15 Electromagnetic compatibility (EMC) requirements

As potential radiating equipment, the installed PLC system and other devices may emit conducted and radiated electromagnetic interference.

As potential receiving equipment the PLC system may be effected by externally generated conducted interference, radiated electromagnetic fields and electrostatic discharges.

The requirements of "Emission" and "EMC immunity" are intended to characterize the EMC performance of the PLC system equipment and are the responsibility of the manufacturer. The user, advised by the manufacturer, is responsible for the electromagnetic compatibility of the product as installed. For more details refer to IEC 61131-2.

3.1.16 Safety requirements

For following items safety requirements of the PLC systems equipment such as MPU, RIOS, permanently/non-permanently installed peripherals, power supplies, I/O modules, communication interfaces and memory subsystems shall be considered:

- Protection against electrical shock
- Protection against the spread of fire
- Limited power circuits
- Clearance and creepage distances requirements
- Flame-retardant requirements for non-metallic materials
- Temperature limits
- Enclosures
- Field-wiring terminals constructional requirements
- Provisions for protective earthing
- Wiring
- Switching devices
- Components
- Battery requirements
- Maximum voltage and minimum voltage
- Markings and identification
- Requirements for safety type tests and verifications
- Requirements for safety routine tests and verifications
- Requirements for information on safety

For detail of each above mentioned items refer to the IEC 61131-2.

3.1.17 Peripherals requirements

Peripherals which are not a permanent part of the PLC-system shall cause no malfunction of the system when making or breaking communication with an operating system.

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

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

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

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

It shall be possible to upload the application program to the data media and verify on line, that the record is functionally equivalent to it, and means shall be provided to prevent unauthorized use of these functions (hardware or software).

For more details refer to IEC 61131-2.

3.1.18 Memory battery back-up

Power back-up for volatile memories shall be capable of maintaining stored information for at least 300 h under normal use, and 1000 h at a temperature not greater than 25°C when the energy source is at rated capacity. (For power back-up needing replacement, the rated capacity is the value used to designate the procedure and time interval for replacement.)

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

It shall be possible to change or refresh power back-up without loss of data in the backed-up portions of memory.

If a memory back-up battery is provided, a warning of "low battery voltage" shall be provided.

For more information refer to IEC 61131-2.

3.2 Document Requirements

3.2.1 For each project, detailed logic sequence shall be designed and prepared by the engineering body in charge of the system design with "ladder diagram" representation. Symbols used in preparation of ladder diagram shall be based on IEC 61131-3.

3.2.2 In specifying the PLC for each project the above mentioned logic diagrams shall be prepared and attached to the IPS-M-IN-290 in addition to any specific technical requirements.

3.2.3 An I/O list shall be prepared by the engineering body amended to the specification sorted according to the type of I/O (i.e. discrete, digital, analog, etc.).

3.2.4 For batch and sequence control applications, in addition to the above documents, "timing diagrams" shall also be prepared for the project.

4. SIZING AND SELECTION OF INPUT/OUTPUT

4.1 I/O Selection

In addition to I/O selection criteria, interfaces and peripherals are also discussed in this section.

4.1.1 General requirement

4.1.1.1 Field connections shall be considered via; screw terminal blocks, connector cable assemblies, or other type of quick disconnect connectors according to the specific application.

4.1.1.2 Special I/O modules shall be considered in applications where single PLC can not meet the scan time requirements.

In this case, single I/O unit shall be considered for each process area, as far as practical.

4.1.1.3 It is desirable to have limited variety of I/O interfaces cards from the spare and diagnostics view point. On the other hand employing only a single size module would cause either unused I/Os, or produce a considerably bulkier interface system, which in both cases it will probably result in mismatched and more costly system.

4.1.1.4 I/O module types, quantities, and respective signal levels shall be selected as the applications and projects job specifications.

4.1.1.5 I/O modules shall be capable of being inserted into or removed from their rack without disturbing external wiring.

4.1.1.6 It shall be possible to install different types of I/O modules in any given rack, irrespective of their voltage levels.

4.1.1.7 The I/O system design shall allow for removal and/or install of any failed module, whether redundant or non redundant, without affecting the operation of any other modules.

4.1.2 I/O feature checklist

The following checklist is some important features to be considered for evaluating PLC system, as a minimum and should be indicated by Vendor.

- Total I/O
- Number of Discrete I/O
- Number of Analog I/O
- Number of Digital word I/O
- Number of Special I/O
- Limit on overall mixture of discrete, analog, digital oriented, and special I/Os

4.1.2.1 Total I/O and distribution

The overall capability of the system shall be considered primarily by the processor/language combination and secondarily by the limits on the system configurations (that may apply when mixing discrete, analog word-oriented, and special type I/O).

4.1.2.2 Discrete I/O

This item shall be considered to verify the variety of discrete input and output signals that can be handled as well as any restriction in terms of processing or physical accommodation.

For digital input/output modules the following items shall be considered:

1. The voltage/current operation regions and rated values and operating ranges for digital I/O shall be based on IEC 61131-2.
2. Each input and output channel shall be provided with a lamp or equivalent means to indicate the state 1 condition when the indicator is energized.
3. For outputs (current sourcing) stated by the manufacturer to be protected the following items shall be considered:
   - The output shall either withstand and/or the associated protective device shall operate to protect the output for all steady-state values of output current greater than 1.1 the rated value.
   - After resetting or replacement of the protective device alone, as applicable, the PLC system shall return to normal operation
   - Optional restart capabilities may be selected among the 3 following types:
     - Automated restart protected output: a protected output which automatically recovers after the overload is removed;
     - Controlled restart protected output: a protected output which is reset through signals (for example, for remote control)
     - Manual restart protected output: a protected output which implies a human action to recover (the protection may be fuses, electronic interlocks, etc).
4. For outputs (current sourcing) stated by the manufacturer to be short-circuit proof the following items shall be considered:
   - For all output currents greater than $I_{e\ max}$ (continues maximum rated value) and up to 2 times the rated value I_e, the output shall operate and withstand temporary overload(s). Such temporary overload(s) shall be specified by the manufacturer.
   - For all output currents prospectively above 20 times the rated value, the protective device shall operate. After resetting or replacement of the protective device alone, the PLC system shall return to normal operation.

- For output currents in the range of 2 times to 20 times I_e or for temporary overload(s) beyond the limits specified by the manufacturer (first item), the module may require repair or replacement.

5. For outputs stated by the manufacturer to be non-protected, if the manufacturer recommends an external protection device, then the outputs shall meet all the requirements stated for the short-circuit-proof outputs.
6. Electromechanical relay outputs shall be capable of performing at least 0.3 million operations with the load specified for AC-15 utilization category (durability class 0.3) according to IEC 60947-5-1.

   The type test is not required if the relay components have been shown to comply with the requirements of IEC 60947-5-1.
7. For more detail refer to IEC 61131-2.

The following subjects shall be also verified in evaluation for discrete inputs and outputs.

a) Inputs

1) Voltage types available

2) Isolation between inputs on each module type and other circuits

3) Number of channels per module

4) Modules, per rack

5) Noise suppression

6) Diagnostics

7) Switching frequency

8) Channel current consumption

9) Time delay

10) Module power consumption

11) Fusing or internal current limiting

12) Maximum cable length (shielded/unshielded)

13) Line monitoring (wire break and short circuit)

14) Optocoupler isolation

b) Outputs

1) Contact types available

2) Voltage types

3) Power or current limits

4) Fusing or internal current limiting

5) Isolation between outputs on each module type and other circuits

6) Channels per module

7) Modules per rack

8) Diagnostics

9) Line monitoring (wire break and short circuit)

10) Switching frequency

11) Module power consumption

4.1.2.3 Analog I/O

For the analogue I/O modules the following items shall be considered:

1. Rated values of signal range and impedance for analogue inputs to PLC-systems shall be as specified in IEC 61131-2.
2. Analogue inputs may be designed to be compatible with standard thermocouples or standard resistive temperature devices (RTDs) such as PT100 sensors. Thermocouple analogue inputs shall provide a method for cold-junction compensation.
3. Rated values of signals range and load impedance for analogue outputs of PLCs shall be as specified in IEC 61131-2.
4. HART communications shall be supported by I/O modules based on the field instruments communication protocols unless otherwise specified in job specification of project.

The following points shall be also verified in evaluation.

a) Inputs

1) Voltage/current ranges available

2) Single/double-ended input availability

3) Channels per module

4) Mixed ranges available in modules

5) Internal calibration capability

6) Resolution

7) Updating times

8) Reverse polarity protection

9) Diagnostic

10) Filtering

11) Characterization

12) Isolation between inputs on each module type and other circuits

13) Conversion time

14) Maximum cable length (shielded/unshielded)

15) Connection of sensors:

- Current (2 wire or 4 wire)
- Impedance (2 wire, 3 wire or 4 wire)

b) Outputs

1) Voltage/current ranges

2) Points per module

3) Mixed outputs capability within modules

4) Calibration capability

5) Resolution of outputs

6) Diagnostic

7) Isolation between outputs on each module type and other circuits

8) Maximum cable length (shielded/unshielded)

9) Short circuit protection

4.1.2.4 Word or register-oriented I/O

a) Inputs

1) Voltage ranges

2) Bits available per word

3) Bits available per module

4) Strobed (multiplexed) availability for inputs

5) Updating time

6) Time slots between strobed channels

b) Outputs

1) Voltage ranges

2) Bits available per word

3) Bits available per module

4) Strobed outputs availability

5) If strobed, is there a single-channel option?

6) Refresh time

7) Time-Slots between strobed channels

4.1.2.5 Special I/O

a) ASCII output

1) Limits to message sizes

2) Baud rates available

3) Rate change under software control

4) Connection type (RS 232, RS 422 or 20 mA loop)

5) Simplex or duplex (should be duplex)

b) Counter input

1) Voltage range

2) Maximum rate

3) Up/down count availability

c) Thermo-Couple input

1) Number of points

2) Cold junction compensation capability

3) Linearization capability

d) RTD Input

1) Number of points

2) Two**,** three and four Wire availability

3) Linearization capability

e) PID I/O

1) Number of loops available

2) Cascading capability

3) Operator access

4) Software access limits

5) Status data availability and operator display capability

6) Alarms count available

7) Mathematical functions available

8) Dead band

9) Diagnostics availability and capability

10) Update time and rate range

4.1.2.6 Remote I/O

Requirements for voltage drops and interruption of the power supply(ies) for remote input/output stations (RIOSs) shall be as specified in IEC 61131-2.

In case of loss of communication with the MPU application program, RIOSs shall be able to fix the states of their outputs to specified values, within specified delays and without passing through unspecified states and be capable of providing a fault indication signal.

The MPU system shall provide the user's application program with relevant information on the current status of RIOSs.

For more details refer to IEC 61131-2.

The following subjects shall be also verified:

1) Number of remote channels

2) Points per remote channel

3) Limits on I/O mix in remotes

4) Size option (number of modules)

5) Transmission medium to remotes

6) Number of remote racks

7) Baud rate

4.1.2.7 Physical specification

1) Environmental limits

2) Environmental effects on capability of I/O

3) Geographical distribution capability of I/O

4) I/O replacement capability without disturbing the field wiring

5) If special terminals needed for multicore connections

6) Special connectors for word-oriented (parallel) I/O

7) I/O compatibility with other PLCs

4.1.3 Estimating I/O requirements

4.1.3.1 The following four principal factors shall be considered in defining the I/O requirements for each project application:

- The geography of the plant and the distribution requirement of I/O.
- The I/O types required.
- The number of I/O points required within each different type.
- The extent to which the application requirement has been defined and consequently the spare capacity requirement for future expansion.

4.1.3.2 When the control room is remote from some of the units (i.e., tank farm, utilities, etc.) the PLC chosen shall have remote I/O capability via twisted pair or other type of data link to replace the multiple I/O wiring.

4.1.3.3 When push-buttons, switches, and solenoids are remote from each other geographically, then the location of the remote I/O racks shall be optimally considered for ease of installation and maintenance.

4.1.3.4 For remote I/O estimation, the required number of I/O at each location shall be determined. Comparing this value with vendors' remote I/O capability will determine the number of remote I/O racks required. In estimating the remote I/O rack, the constraint on the I/O mix within a rack, shall also be considered.

4.2 Sizing the I/O Modules

The following requirements shall be considered in sizing the I/O system after selection of the Vendor.

4.2.1 In sizing I/O modules, I/O capacity and inputs and outputs mixture limitation within the capacity shall be considered.

This final capacity shall be considered in defining the size of PLC for the application.

4.2.2 For I/O module sizing, the ability to use a common side for inputs or the need to provide individual isolated inputs shall be considered on module selection and consequent sizing.

4.2.3 At final stage of sizing and selection, the number of modules required at each location shall be carefully determined, considering all above requirements, to include spare capacities. The spare channels shall be distributed in the overall modules.

4.2.4 In sizing the I/O module, the I/O estimated shall be allocated in raw form and then adjusted for a 20% spare count. Fractions shall be rounded upwards in calculating the number of modules required.

4.2.5 Issues such as; installation convenience, stocking of spare parts and their interchangeability, and the prospects of expansion shall be carefully examined and considered in choosing between 16-bit modules and 32-bit modules and mixture of both irrespective of the initial cost of the modules (unless very large number are involved).

4.2.6 Printer port and programmer port modules shall be considered in parallel I/O rack selection and sizing.

5. CPU SELECTION AND MEMORY SIZING

5.1 CPU Selection

The capabilities of the programmable controllers are determined by programmable functions which are summarized in Table 1 as a minimum.

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)

5.1.1 Processor

5.1.1.1 The choice of the processor shall be determined by the magnitude and complexity of the I/O task.

5.1.1.2 The processor specification shall be carefully examined for I/O capacity, the applications program instruction set, memory options, and scan speed, environmental limits and power requirements.

5.1.1.3 The total I/O capacity of the PLC system must be considered very carefully, especially as the application load approaches the upper limit of the PLC. Under these circumstances, a larger model of the vendor PLC system shall be selected.

5.1.2 Processor checklist

The most noticeable items to be evaluated and checked for processor selection are commented herein below. Special block functions which are used in smart I/O modules are not included in this general list.

5.1.2.1 Scan time

Instruction execution times can be used to estimate program scan time.

5.1.2.2 Memory size options.

5.1.2.3 Memory type options.

5.1.2.4 Read Only Memory (ROM) programming method.

5.1.2.5 Memory use: Words per instruction or element.

5.1.2.6 Memory overhead.

5.1.2.7 Memory map, fixed or assignable.

5.1.2.8 Word size.

5.1.2.9 Requester size.

5.1.2.10 Diagnostics: programs shall be checked against the following subjects:

- Start-Up
- Run time
- Diagnostic lights
- Fault indications
- Fault relays available

5.1.2.11 Processor control registers.

5.1.2.12 I/O maximum capacity.

5.1.2.13 Programmer port availability.

5.1.2.14 Communication ports available.

5.1.2.15 Operating modes available:

- Run
- Outputs disabled
- Program/key control availability of the; input/output forcing, requester

5.1.3 Language

5.1.3.1 Ladder diagram (LD) language environment can provide many advanced procedures using block functions and data tables which may be considered when the specific application requires. In addition the instruction list (IL), structure text (ST), function block diagram (FBD) and sequential function chart (SFC) may be used. For more details refer to IEC 61131-3.

5.1.3.2 At existing plants where computer already exists or at new projects which DCS will be employed, use of higher level languages may be considered matching with the DCS or computer languages employed.

5.1.3.3 It is highly recommended to select programming tools available on the PLC system. In selecting a programming tool which is not standard supply of the manufacturer, the following features of the program should be considered:

- Fundamental array of programming, editing, and register operations,
- Presentation philosophy (menus and key redefinitions),
- Inherent provision for documenting program while writing,
- Production of records (written, disc, tape, etc.),
- Communications capability (can it sit on the network),

- Other non-programming uses.

5.2 Memory Sizing and Selection

Various types of memories may be used such as 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 program 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 program 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.

The next step to be considered comprise of decision about memory size and types.

5.2.1 Memory selection

5.2.1.1 Small PLC (applied for very stable and well-defined tasks) shall use ROM (Read Only Memory) to write the application program instead of RAM (Random Access Memory).

5.2.1.2 The following option for medium systems may be considered according to the application requirements. This application of memory system shall use the combination of RAM and Programmable read-only memory (EPROM/UV-PROM, EEPROM) and Flash memory card to retain the application and data.

5.2.1.3 Larger systems including plant sequence control system and ESD (Emergency Shut-Down) system shall use battery-backed RAM.

5.2.2 Memory sizing

5.2.2.1 Basically, sizing shall be based on evaluating program needs, allowing some extra memory for scratch pad and future expansion.

5.2.2.2 Basic minimal functional amount of memory shall be carefully examined in sizing the memory considering the requirements in the following paragraphs. Vendors shall be requested to declare this amount of memory in their proposal.

5.2.2.3 In evaluating the memory size of vendors, the basic allotment required by the executive program (operating system) and scratch pad shall be carefully checked for further total memory sizing.

5.2.2.4 Manufacturers may provide crude estimate of memory requirements based on the I/O totals which are only approximate. This estimation shall be carefully exercised, if it is close to the limit of the PLC's memory (which means the system is undersized).

5.2.2.5 For exact sizing, the estimation shall be based on the logic diagram included in the specifications considering the instruction required for each element. The manufacturers shall be requested to provide information concerning the number of words used in each instruction, to be used for memory size estimation.

5.2.2.6 The estimation obtained in 5.2.2.5 shall be added to the space required by the input and output data tables (with consultation of the manufacturer), considering the memory expansion and the amount of memory requirements as stated in 5.2.2.1, 5.2.2.2. Generally, the internal memory shall be sized such that at least 50% spare memory is available after definition of the I/O tables and entry of the application program.

5.3 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.

6. COMMUNICATION SELECTION

The principle Communication system to be selected for a PLC system covers one of the following:

- Network Communication
- Data transfer

6.1 Networking

6.1.1 For PLC system participating in a network with other PLCs, Computers or DCSs; the selection shall be limited to PLC manufacturers that provide industrial networking scheme. In this regard, MAP compatible systems with open architecture are the preferred choice.

6.1.2 In selecting any other networking scheme, compatibility of the network to the DCS or the computer system shall be carefully examined.

6.2 Data Transfer

6.2.1 For limited communications, such as data transfer between PLCs or for logging alarms, some manufacturers provide parallel ports on their processor which may be selected for specific applications. It should be remembered that in this configuration PLC's are daisy-chained for one-to-one conversations but do not provide full networking.

6.2.2 The common data transfer method to be selected for single PLC system is ASCII I/O module for printer or alarm transfer with time stamped capability. The selection shall be carefully made to match the output port parameters with the intended receiving device, e.g., RS 232/RS 422, and software side that includes baud rates, start and stop bits, parity, etc.

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

7. BATCH CONTROL REQUIREMENTS

7.1 General

A recipe is an entity that contains the minimum set of information that uniquely defines the manufacturing requirements for a specific product. Recipes provide a way to describe products and how those products are produced. Recipes are organized hierarchically, with various categories of information at each level. The recipe entity is the construct that is used to represent the tight coupling of the data at a particular level. For more details refer to ISA-88-01.

7.1.1 Automated batch process control shall be implemented using PLCs suitable for recipe sequence control with improved reporting capability and high level human machine interfacing (HMI).

7.1.2 Batch control shall be applied to all processes which deliver their products as batches. As an example of these processes, the following are outlined hereunder:

- PVC plant
- Continuous catalytic regenerator (CCR)
- Chemical batch reactors
- Batch blending systems
- Manufacturing fine chemicals
- Solid material handling, such as solid catalysers

7.1.3 It should be recognized that, the automation of a batch process control system can shorten batch cycle time by reduction of time delays between process steps and by the deployment of process equipment more efficiently. Such a reduction, which effectively increases the capacity of the capital equipment, can itself justify automating many batch processes.

7.1.4 The automated batch control system design (both hardware and software) shall be in a manner that:

- In case of an emergency arising form process equipment malfunctioning (i.e., failure of a pump, blockage, of a valve orifice) corrective actions performed by software prespecified instructions.
- Where specific actions are not possible or have not been specified, the control system should put the process in a safe state (hold state) before asking the operator to take appropriate action.

7.1.5 Sequence logic functions required for controlling a batch process shall include the necessary steps for responding to abnormal process/plant conditions occurring due to:

- Product problems (e.g., product off-specification or excessive foaming),

- Unavailability of plant item or raw material (e.g., common discharge line in use by another reactor, air supply pressure low, or product storage tank full).

7.2 System and Data Base Specification Requirements

7.2.1 For an automated batch control system employing PLC or network of PLCs, a set of application-specific data shall be specified by engineering body in charge of the project. These data shall include all configuration data necessary for setting-up data files of right size (by Vendor), and data required by control system.

7.2.2 Typical data required for configuring the system which shall be provided for each batch control system, are listed below:

1) Number of units

2) Types of units

3) Number of phases

4) Number of procedures

5) Number of recipes

6) Number of inputs:

- Hardware switches
- Analog alarm limits
- Flags

7) Number of outputs:

- Hardware
- Flags

8) Number of devices employed, per procedure (recipe)

9) Number of timers employed per procedure (recipe)

10) Maximum number of phases per procedure

11) Maximum number of steps per phase

12) Maximum number of contact input per unit

13) Maximum number of contact output per unit

14) Maximum number of devices per unit

15) Maximum number of timers per unit

16) Maximum number of recipe variable per recipe

17) Contact input scan rate(s)

18) Batch cycle time (time between executions of the batch software)

19) Initialization state of contact outputs at the start of the batch for each phase

7.2.3 Unit Data sheets shall be specified for each unit in a system to include the following minimum data:

1) Unit name with identification number,

2) Unit type,

3) Required number of control consoles (for data entering and monitoring),

4) Required number of announciators for alarming,

5) Required number of alarm printers.

7.2.4 Input switches data sheets and output switches data sheets shall be specified to include the following data for each input switch:

1) Switch tag number (e.g., PSH-101 A)

2) Switch function description (e.g., reactor pressure alarm)

3) Unit name (unit which this switch is associated)

4) Open state mnemonic (e.g., OK, alarm)

5) Closed state mnemonic

6) Switch type (hardware, analog alarm or flag type)

7) Technical specification

7.2.5 Batch units of the plant shall be defined to match process vessels. Occasionally two or more vessels may be considered as a single unit where vessels operate in conjunction with each other where; it is not practical to separate them in different units. Individual pieces of equipment like pipelines and valves shall be usually associated with pertinent process vessels unless plant's flexibility enhancement requires to keep them as separate units.

7.3 PLC Engineering for Batch Control

7.3.1 In applications where control failure is not tolerable, sufficient back-up system shall be considered for the PLC system.

7.3.2 PLCs applied for batch control system shall have regulatory control (PID) capability to perform the continuous control of the required batch operations.

The number of controller loops available in the system shall be equal to the numbers defined in the project data sheets plus 20% more control loops for future expansion and trimming of the control system.

7.3.3 PLCs for batch control system shall have suitable Man/Machine interfacing with the operating staff and shall provide minimally the following information about plant and process performance:

- Status of each unit or each part of a unit in terms of phase and steps along with the display of alarm conditions.

- Status of individual inputs and outputs and devices displayed in tabular format or with process graphic displays.

- Bar charts displaying the progress of individual batches, occupation of plant times, critical paths, and so on.

- Trend plots of analog and discrete variables.

7.3.4 The interactive displays for operating staff shall include the following functions minimally:

- Facility for the starting of a batch along with assigning of appropriate recipes,

- Facilities for putting a batch on hold, shutting down the process, and restarting it,

- Acknowledging alarm conditions,

- Displaying of sequence logic functions and the facilities for changing them,

- Displaying of sequence logic messages and the facility for entering data, when required,

- Facility for the manipulation of the states of discrete outputs, devices, and so on, with safeguards to prevent contention problems between operator and control system.

7.3.5 Printers shall be considered for logging alarms and events. The suitable printer shall also be considered to be ultimate backup device for monitors.

7.3.6 For graphic plots such as trend displays, histograms, and so forth, where hard copies or data saving are required, the suitable colored printer shall be considered.

7.3.7 Local operator's stations shall be only considered in areas which need close attention of the operator. It should be noted that; the local displays have little flexibility and does not have graphic display facility. Area classification shall be considered in selecting the local operator station.

8. PLC IN FUNCTIONAL SAFETY APPLICATIONS

When PLCs are required to perform safety functions, it is necessary that special measures be taken to avoid and limit dangerous failures of the functional-safety-related system. Detailed requirements for Safety-Related System (SRS) are contained in IEC 61508 and in emerging sector implementation standards such as the IEC 61511 series.

Each SRS is assigned Safety Functions and is to fulfill the safety functions with a prescribed Safety Integrity Level (SIL) requirement. IEC 61508 categorizes SIL in four levels as listed in Table 2 for Demand Mode and in Table 3 for Continuous Mode.

TABLE 2 – SIL OF DEMAND MODE SAFETY FUNCTIONS

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

TABLE 3 – SIL OF CONTINUOUS MODE SAFETY FUNCTIONS

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

8.1 Safety Functions

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

The safety requirements of a programmable electronic SRS are assigned safety functions. Each safety function required to be carried out by the SRS is specified in terms of Safety Function and

Safety Integrity Level (SIL). The safety functional specification is a description of the required function in terms of the action of the safety-related system under a specific set of circumstances.

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

8.2 Safety Integrity Level (SIL)

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

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

8.3 Requirements on PLCs in a Safety-Related System

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

- Hardware reliability;
- Diagnostic test coverage and test interval;
- Periodic testing/maintenance requirements;
- Hardware fault tolerance; and
- SIL capability.

This information should be obtained from the PLC manufacturer.

8.4 Integration of PLC into a Safety-Related System

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

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

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

- Legal entity (e.g.: company, author(s), etc.);
- Description;
- Tractability to application functional requirements;
- Logic conventions used;
- Standard library functions used (and associated justifications, see above)
- Inputs and outputs; and
- Configuration management including a history of changes.

PART 2

CONSTRUCTION STANDARD

FOR

PROGRAMMABLE LOGIC CONTROLLERS (PLC)

1. SCOPE

This Standard specifies the minimum requirements for installation, mounting, precommissioning and start-up commissioning of the PLC system used in safety interlock, emergency shut-down and batch control operations in Iranian Petroleum Projects.

It should be noted that, the primary source of information about installation requirements is the PLC manufacturer. The manufacturer will usually provide installation notes for each module type and I/O rack as well as for the CPU/memory.

The information mentioned in this Standard shall be considered throughout the project execution in addition to the manufacturer recommendations and project drawings.

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standard and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard.

The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor.

NEMA (NATIONAL ELECTRONICS MANUFACTURERS ASSOCIATION)

ICS 1-108	"Service and Installation Conditions" 1988
IA2	"Programmable Controllers"
ICS 1.1	"Safety Guidelines for the Application, Installation and Maintenance of Solid State Control" 1984

NFPA (NATIONAL FIRE PROTECTION ASSOCIATION)

NFC 70	"National Electrical Code" 1987

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-C-IN-100	"Construction and Installation Standard for General Instruments Field Inspection, Calibration & Testing of Instrument and Instrument System"
IPS-C-IN-190	"Installation and Construction Standard for Transmission Systems"

3. UNITS

This Standard is based on International Systems of Units (SI), as per IPS-E-GN-100 except where otherwise specified.

4. INSTALLATION AND DIAGNOSTICS

4.1 Installation

4.1.1 Location preparation

4.1.1.1 Consideration shall be given to human factors when deciding the details of the PLC location.

The system shall be set at a convenient height for inspection and work on the PLC, and there shall be easy access all around of the PLC equipment.

4.1.1.2 Full advantage shall be taken of existing illumination to provide a well-lighted field of work for the PLC.

4.1.2 Mounting

4.1.2.1 The PLC equipment shall have clear distance from the R.F. or E.M. noise producing equipment, i.e. induction heaters or welding equipment. For electromagnetic compatibility (EMC) requirements and also for EMC information to be provided by manufacturer, refer to IEC 61131-2.

4.1.2.2 The following mentioned items provide a checklist which shall be considered in connection with the cabinet location and mounting:

- Easy access to components.
- Clearance and protection of PLC cabinet cooling fan and vent.
- Compliance with electrical standards as indicated in Section 2 (Reference) herein.
- Suitable electromagnetic shielding.
- Restricting unauthorized access.
- Protection from dust and dirt with provision for adequate cooling.
- Convenient working height of cabinets and consoles.
- Visibility of indicator lights.

4.1.2.3 The following electrical considerations shall be met in executing the wiring of the cabinets and enclosures:

- Providing a well-defined common ground for all cabinets and enclosures.
- Using a common reliable AC source for system and I/O power supplies.
- Segregating auxiliary electromechanical components, such as, starters and relays.
- The wiring shall be at suitable distance, from high energy wiring.
- Each PLC enclosure I/O wiring shall be separated from other cabinets I/O wiring.
- Low level signal wirings shall be separated from all other wiring.
- AC and DC field wiring shall be separated, as much as possible.

4.1.2.4 For mounting and installation of PLC, IPS-C-IN-100 and IPS-C-IN-190 shall also be considered.

4.1.3 I/O wiring

4.1.3.1 All I/O wires and terminals shall be clearly labeled.

4.1.3.2 The input devices shall be wired, so that they switch the hot side of the line. A similar method shall be used for the PLC outputs.

4.1.3.3 For inductive load outputs, a capacitor across the secondary side of the disconnect switch supplying power to the inductive load shall be provided for outrush problem.

4.1.3.4 Acceptable wiring practice must be followed for all I/O's of the PLC.

4.1.3.5 Special consideration must be given to execution of analog I/O low-level signal sources such as thermocouples.

4.1.3.6 Where, a voltage divider is used to match a field transmitter voltage range to that of the

PLC's A/D, the resistances shall be chosen so as to use as much current from the field device as is permissible, in order to provide the maximum signal-to-noise ratio at the input.

4.1.3.7 The wirings shall be run in the shortest possible routes.

4.1.3.8 Joining the cables for increasing the cable length shall be avoided.

4.1.3.9 Cabling along vibrating supports or sources shall be avoided.

4.1.3.10 Minimum 10 cm radius shall be used on cable bends for two core cables.

4.1.3.11 Different voltage and types of signals shall be separated, as much as possible.

4.1.3.12 In order to avoid ground loop problems, the shields on shielded cables must be grounded at one end only.

This ground can be conveniently established at the cabinet end of the cable.

4.1.3.13 As each module wiring is completed, check of the wirings shall be performed for mechanical strength by pulling at each connection and verifying the labeling.

4.1.3.14 The spare wires of the field multi cables inside the panel shall be terminated to the spare terminals with tag.

4.2 Precommissioning

There are several phases of precommissioning check-outs that must precede any start-up of the system, namely:

- **a)** Component inspection
- **b)** Clearing (resetting) the PLC
- **c)** Input wiring check
- **d)** Output wiring check
- **e)** Program check
- **f)** Power check
- **g)** Loop check

All of the above checks shall be performed by the contractor and witnessed by the Company's inspectors. A checklist form shall be prepared by the contractor to indicate all requirements of this Standard. Inspector, contractor, and the Company's representative shall sign the forms when the checklists are completed. The Vendor representative shall be present for the tests involving the PLC operation, when specified in pertaining procurement.

4.2.1 Component inspection

4.2.1.1 This inspection shall be performed to ensure that all components of the PLC are present, are correct as to model and type, and are correctly installed in the correct location.

4.2.1.2 CPU/memory unit and the I/O shall be inspected. Correct models of the modules shall be established and adequate addresses shall be checked. If addresses on the I/O rack are created by switch settings on the rack unit then the settings shall be verified for the correct range. The mechanical condition of the modules and wiring shall be checked to ensure that all units are firmly seated and all terminal screws are secured.

4.2.1.3 Wire labels and module types and addresses shall be checked using the PLC's I/O list document.

4.2.1.4 Cables to the remote I/O shall be checked to verify that they are connected to the correct remote terminals.

4.2.1.5 Polarity of power supply connections shall be checked to be correct.

4.2.1.6 Wiring at the field end shall be inspected to establish wire identity and verify that safety precautions have been taken to avoid damage when input devices are actuated during check-out.

4.2.1.7 Output wiring at the field end shall be inspected to establish the wire identity and to verify that the outputs are safe to test.

4.2.2 Clearing (resetting) the PLC

4.2.2.1 PLC application memory shall be blanked to avoid unexpected behavior from residuals. This should be done with the system in the "disable output" mode, if available.

4.2.2.2 Before clearing (resetting) the PLC, it should be made sure that documentation for the diagnostics is available and is the correct revision for the particular PLC model involved.

4.2.2.3 Documentation for CPU run and shutdown procedure shall be checked to be clearly established and documented.

4.2.3 Checking the inputs

4.2.3.1 This check requires that the programming tool and the CPU/memory are both in functioning condition. It is intended to establish that the input wiring is correct, that the input addressing scheme is correct, and that the input field devices and PLC modules function correctly.

4.2.3.2 Before starting, the consequences of manually operating the field devices should be considered and appropriate safety precautions shall be checked, as follows:

1) The PLC shall be set in a nonscanning mode so as to inhibit any action other than shutdown. Then power shall be applied to the system and input devices.

2) Correct function shall be checked by examining the relevant indicator lights on the processor, power supply, and I/O units. All remote I/O’s shall also be checked, accordingly. It shall be verified that, in case of shut-down of any output, the power is removed from the pertinent output device.

3) The programming device shall be connected to the PLC to monitor input status. Each field device shall be actuated manually, and the input status light on the input module and status of the input in the input address register in the memory shall be observed.

- If the wrong module indicates the field changes then the wiring shall be corrected.
- If nothing happens, the fault lies either with the input module, the wiring, or the field device, assuming that all power is correctly applied and that the safety precautions did not accidentally inhibit the action of the field device.
- If the changing input status shown by the module light is not reflected by the status display of the programming device, the address may be incorrect, the module may be defective. CPU problem is unlikely during this check since the system perform an internal check upon power-up and will display a diagnostic light.

4.2.4 Checking the outputs

4.2.4.1 Power shall be applied to the PLC’s processor (with the field device under test disconnected locally) for output tests. Generally, the output check is similar in form and function to the input check.

4.2.4.2 The processor shall be started in the output disabled mode and power shall be applied to the I/O’s. The emergency power-break for the output shall be checked, while all diagnostic lights display are verified to be correct.

4.2.4.3 Each output shall be checked by energizing and observing the module indicator light. It should be noted that; problems here are usually the consequence of addressing problems. Energizing of the output shall be accomplished by using the forcing function of the programming device or by programming a single rung with a convenient local switch as input and a coil with the appropriate address for the output under test. In the latter case, pressing the switch with the processor in the scan mode will provide the test required.

4.2.4.4 The output wiring shall be checked by reconnecting each field device as it is to be tested.

4.2.5 Program check

4.2.5.1 The control program shall be carefully reviewed before it is loaded into the controller for start-up. The review must include all documentation, including any changes to the I/O list or address revisions that occurred during the I/O check. It should be noted that; the program to be loaded may differ slightly from the actual program final form because it contains special rungs for the start-up procedure. Both actual and loading programs must be reviewed.

4.2.5.2 The program review may take place at any time after the initial I/O checks but must precede the start-up.

4.2.5.3 When start-up is initiated, the program as loaded must be compared with the documented copy used for the review. Specially, the output device addresses must be confirmed to be in agreement with the program rung addresses as loaded, as well as making checks for generally valid contact and internal coil addresses.

4.2.5.4 All preset data shall also be checked, e.g., counter and timer loads, time bases, and similar reference data.

4.2.5.5 After the program has been loaded into the PLC and checked, a copy of "AS-BUILT" program listing shall be generated by the processor.

4.3 Start-Up (Commissioning)

The principal requirement for start-up is the establishment of an orderly and documented sequence of events. Depending on the PLC manufacturer, there may be detailed procedures provided in the product manuals. The walk-through can be recommended as an evaluation technique, especially if the review group includes engineers who are familiar with the process but have not been deeply involved in the PLC implementation.

Some recommendations are presented below, but procedural details will be highly specific to the particular application.

Sometimes special start-up programs are used for a preliminary test of the system and components before initiating the full control:

> **1)** After loading and checking, a preliminary start-up is usual, with outputs disabled to permit preliminary debugging. If the system is large, a segmented start often simplifies matters. The remote I/O that is usually present in such systems can be disabled by disconnecting the communications cable, removing power, using temporary MCRs, or register fencing, as is appropriate.
>
> **2)** The I/O can be enabled with the field devices connected up in sequence, either singly or in groups, depending on the system complexity. Each should be observed for correct action. In some applications, the ability to record the sequence of events using the programming tool may provide considerable assistance.

When the system is operating correctly and at as many intermediate points as is practical, the program in use should be recorded and stored on a loadable medium, such as magnetic tape, CD, Floppy disk.

4.4 Diagnostics

4.4.1 General

PLC manufacturer's provided diagnostic aid will be performed on applying power to the system and concluded by the display of an indicator light on the processor. During this check, the executive RAM and ROM will be tested along with, some other main functions. Any serious failure at this level will cause a fault relay to open, shutting down system power. Less serious problems are usually flagged by an indicator light; the particular problem is then referenced in an error table register. If the system is functioning correctly and the user starts loading a program, there may be two error listings available: one for indication of programming errors, and a second list stored under the label of "processor errors".

Diagnostics, discussed hereunder are; user-called set of diagnostics, initiated by some of programming device optional programs.

4.4.2 Requirements

4.4.2.1 User-Called set of diagnostics shall be called via programming device to check all memory, all interrupts (both internal and programmable), and all communication parts. Failures will be classified by their severity as fatal or nonfatal at this stage. Before initiating the system check, assurance shall be made at this point, that no fatal or nonfatal errors are present.

4.4.2.2 The following operations shall be checked by means of program options provided on the programming device:

> **1)** The display of the programming chart with each coil, contact, analog values etc. Represented together with its current state.
>
> **2)** The ability to perform time scan operations in which a particular program event can be scheduled as a trigger.

This trigger then starts a procedure that records the subsequent order of events, such as input, output, or program induced logic changes, and provide the timing details for the recorded sequences.

The display of any other program present on the system with correct logic state indication.

4.4.2.3 The contents of certain control registers normally used by the CPU and the executive program shall be examined for diagnostic purpose.

4.4.2.4 Similar registers, as 4.4.2.3, but used by intelligent I/O modules shall be inspected.

5. SITE ACCEPTANCE TEST

5.1 General

Test shall involve both process equipment and the control system. The site acceptance test is functional test and may be carried out in stages with procedures similar to the Factory Acceptance Test, but, with the actual process input and outputs connected.

In batch control system, the process shall usually be run dry or with some inert material for one or more batches.

Testing of sequence logic for a multisequence or multiproduct batch plant shall normally be done with one test recipe, or at least a small number, designed to exercise all logic paths. Anyhow, the batch control system shall be separately exercised to run each unique recipe before the recipe is released for normal production.

The VENDOR shall submit SAT Test Procedures for Purchaser's approval prior to the Test. Vendor specialists shall then perform Site Acceptance Test (SAT) in agreed project work schedule.

The following items shall be considered as minimum requirements:

a) Full functional test shall be carried out.

b) The VENDOR shall provide agreed as built documents and drawings following Site Acceptance Test and commissioning.

c) VENDOR specialists shall be responsible to check that the following minimum requirements have been fulfilled:

- Correct installation of cabinets and stations.
- Connection and installation of all System cables and internal cable connections.
- Connection of all power and earthing cables and resistance checks.

d) Vendor shall be required to provide a site-based specialist to perform the following activities as minimum during SAT:

- Operator guidance.
- Loop tuning, Loop checking, Logic and sequence checking, alarm and event checking.
- Control loop configuration amendments.
- Resolve System faults.
- Redundancy check for all items such as; power supplies, CPU, LAN, and others if required.
- Functional tests for trend, and history of control loops.
- Functional tests of all utility programs.
- System integration tests to confirm all functions are operational and dependency between functions is present.
- Functional tests of all VENDORS supplied application software.
- Functional tests of communication with all third party equipment.
- CPU and memory maximum loading capacity checks.

Upon completion of the installation and pre-commissioning checks of Section 4 heretofore, the Site Acceptance Test (SAT) shall be performed. The SAT will be witnessed and signed off by Vendor, Contractor and Company.

5.2 Test Environment

Proper environment shall be prepared for in-process and Site Acceptance Test as outlined hereinafter.

5.2.1 Simulation

5.2.1.1 Both hardware and software shall be prepared to establish an environment equivalent to that encountered in actual use, enabling to find out the greatest member of problems prior to system's placement into service.

5.2.1.2 Simple simulator may be built by; contact inputs and outputs wired to switches and indicators lamps, respectively, to observe the indicator lamps and change switch states accordingly.

5.2.1.3 For timing check, the output-to-input connection may be made through a time-delay relay with delay adjustable over the range of interest. This tests shall be performed to simulate the process plant response, where plant response is critical in logic operations.

5.2.1.4 A simple input-to-output connection, provided that the electrical requirements of both input and output circuits are met, may be employed to simulate a process plant response.

5.2.1.5 High-speed pulse train inputs, typical of the outputs of several types of flow transmitters, may be generated by square-wave generator. Connections shall be made carefully in light of varying electrical requirements found among different input circuits. The pulse generator may be set to generate an output similar to, or faster than, that expected from the plant to speed up testing.

5.2.1.6 Testing of analog loops shall be performed with laboratory-type process simulators or dynamic, lag simulator units.

5.2.1.7 Software simulation shall not be used for the purpose of testing in SAT.

5.2.2 Utilities

5.2.2.1 Software utilities shall be used to enhance the test by providing visibility and access for manipulation of the control system under test.

5.2.2.2 For SAT, the PLC's Vendor shall be requested to provide the following utility programs, for control systems, as required:

- A routine to "dump" the current contents of recipes, unit variables, status bits, I/O files, and so on, to the CRT screen or hard copy for batch control system.
- A subroutine or routine to observe and manipulate data flow among software modules, including between process units with ability to trend these signals on one CRT screen.
- A program in the programming device to force both discrete and analog I/O.
- A program for testing the printer performance.

5.2.2.3 All vendor provide utility programs, as indicated in operating and maintenance manuals shall optimally be used to verify the operatability of PLC system.

6. DOCUMENTATION

At satisfactory completion of the Site Acceptance Test, a final certificate of acceptance shall be prepared by the Vendor/ Contractor. Attached to the acceptance test documents shall be all test records, receipt for PLC's documentation and spare parts plus any other pertinent record regarding the Vendor's/Contractor delivery. These document will become part of certificate of Final Site Acceptance which the Company representative will review for final acceptance certificate issuance.