

Process Control Systems— Functions and Functional Specification Development

API RECOMMENDED PRACTICE 554, PART 1
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Introduction

Advances in computing and digital communications technologies since the preparation of the first edition of API 554 have had major impacts on the way instrumentation and control systems function as compared with historical designs. The advances have also radically changed the way that the design and specification of such systems must be approached and have created major issues relative to system design and system security. These issues are as follows.

- The repurposing and relocation of central control room.
- Advances in computing power, software standards, and communications standards have resulted in many of the functions historically implemented in stand-alone process control and historization computers being integrated within the process control systems (PCSs). This has greatly expanded the scope of PCS design and blurred the division between real time control and historization functions and higher-level information systems that provide input to business and maintenance systems. The control systems engineer is challenged to maintain a design that allows communications between the control and the business networks but that also maintains safe and reliable operations.
- Advances in field instrumentation design leading to the general use of smart digital field instrumentation. Further advances in field bus and related technologies allow these smart instruments to communicate directly with the PCSs or with each other. These instruments not only transfer information about the basic process measurement but also communicate diagnostic information about the health of the device or other secondary information derived from the primary measurements. The smart devices enable very real, albeit basic, “distributed control” across the various real-time devices within the control domain. The degree of such distributed control shall be considered, if it’s within the corporate policy.
- Further developments in standardization of operating systems and software practices have enabled use of standard computer components and peripherals operating on standard operating systems. This has resulted in a developing trend away from control systems applications being implemented on proprietary hardware and software systems, and instead being implemented on standard personal computer, workstation, and network communication products running widely available operating systems.
- This standardization has reduced the cost and increased the flexibility of the systems. It has also resulted in greater exposure of the PCS to external interference and requires additional support to keep the operating systems current and secure. Security and virus protection are major concerns of newer PCSs and must be addressed at both the design and operational phases.
- The integration of the human machine interface and communication networks for the PCS and the safety instrumented system (SIS).
- The addition of “wireless process networks” is bringing new challenges and it is transforming the way the information generated in the field sensors is transmitted and the way the facilities are designed.

The result of all these technical advances is that PCSs are no longer entirely based upon proprietary closed hardware and software systems offered by a single vendor. While these implementations are still available and form the preponderance of the existing installed base, there is a very strong trend away from closed systems provided by one vendor, to more open systems based upon industry standard hardware and software which have both proprietary and open system components.

These trends result in a far greater flexibility in selection of the control functions and the control hardware.

These trends place greater responsibility upon the design engineer and user to understand the interaction between PCSs and the business functions of an organization: to select and specify the functions that are necessary for a given application; and to implement those functions in a safe, reliable, cost effective, and maintainable manner.

API 554 consists of three documents to better define the processes required to properly scope, specify, select, install, commission, operate, and maintain PCSs. This recommended practice is not intended to be used as a purchase specification, but recommendations are made for minimum requirements that can be used as a specification basis.

Process Control Systems— Functions and Functional Specification Development

1 Scope

1.1 General

This recommended practice (RP) addresses the processes required to successfully implement process control systems (PCSs) for oil and gas production, refinery, and petrochemical services. The major topics addressed are listed below.

- *Part 1.* The basic functions that a PCS may need to perform, and recommended methodologies for determining the functional and integration requirements for a particular application.
- *Part 2.* The practices to select and design the installation for hardware and software required to meet the functional and integration requirements.
- *Part 3.* The project organization, skills, and management required to execute a process control project and then to own and operate a PCS.

Figure 1 shows the general overall scope of oil and gas production, refinery process control, and the associated automation functions, as well as the portions of which this recommended practice addresses.

The general scope of the material covers general industrial process control topics that are applicable to oil and gas production, refineries, and petrochemical facilities.

The user is cautioned to fully consider the requirements of the particular applications and circumstances that may exist and carefully apply the concepts described in this RP as appropriate. This document is not intended to present a tutorial on the subjects discussed, but rather to aid the reader in identifying and understanding the basic concepts of PCSs. The references provided within the document direct the reader to publications that describe one or more subjects in greater detail than is necessary or desirable for the purposes of this document.

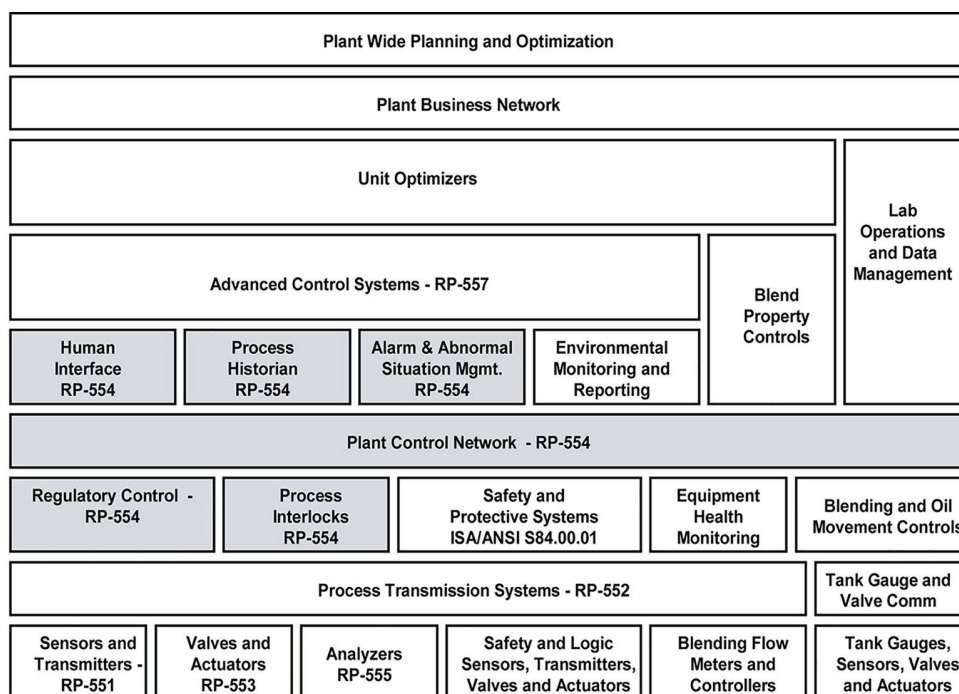


Figure 1—Refinery Control and Automation Functions

1.2 Document Organization

This document is organized to follow the sequence of activities associated with the typical life cycle of a PCS as summarized in Table 1.

The life cycle phases as they apply to PCSs are listed below.

- *Appraise*. Develop business goals and requirements and identify basic functions required. This step is often also referred to as the concept stage.
- *Select*. Further develop business goals and functions into a PCS's scope definition. This step is often part of the early portion of front-end engineering design (FEED).
- *Define*. Finalize PCS's scope definition, select hardware and software, and prepare all applicable design drawings and specifications, and procure other hardware and equipment. This step often forms the bulk of FEED.
- *Execute*. Develop detailed design and procurement, construction/installation, testing, and commissioning.
- *Operate*. Commission, operate, and maintain.

API 554 consists of three parts, each focusing on a major aspect of PCSs. The three parts and the areas that they cover are as follows:

- *Part 1, Process Control System Functions and Functional Specifications*. Covers the basic functions that a PCS may need to perform, and describes recommended methodologies for determining the functional and integration requirements for a particular application.
- *Part 2, Process Control System Design*. Covers the hardware and software applied to PCSs and provides recommendations for implementation. Design considerations and references to design practices for control centers and other control system buildings and enclosures are also provided.
- *Part 3, Process Control System Project Execution and Ownership*. Covers project organization, skills and work processes required to first execute a process control project and then to own and operate a PCS.

The portions of API 554 that deal with each phase of the life cycle are identified in Table 1.

Table 1—Process Control Systems Life Cycle Overview

API 554 Section Number	Phase	Objectives	Major Inputs	Major Outputs
Part 1, Sec. 2	Appraise/concept design	Document the business goals and basis for the project	Process design, process flow diagrams (PFDs), equipment list, existing systems and infrastructure, layout, business objectives, operations staffing plan, corporate master plan, control system standards	PCS concept design basis
Part 1, Sec. 3, 4	Select/FEED	Develop a functional specification describing the scope of the project, functional requirements, and overall implementation responsibilities	— Design basis, P&IDs, equipment lists, process hazard analysis — PCS concept design basis	PCS functional specification
Part 2	Define/execute (FEED/ detailed design)	— Prepare request for quote, issue, and select a vendor — Specify hardware, I/O layouts and communications — Design control centers, field devices, interconnecting wiring, instrument power — Define control systems interfaces to other systems and hardware	— PCS functional specification — Design standards and practices — Documentation requirements	— Hardware and software selection. — Detailed specifications and installation/ construction drawings
Part 3	Execute—project execution and management	Execute designs to meet cost, schedule, and technical requirements	Project objectives, cost, and schedule	— Complete design drawings and specifications. — Procurement of all materials and equipment. — Implementation and factory acceptance testing of all software based functions
Parts 2, 3	Execute— construction and installation	Install, calibrate, and loop test instrumentation and control systems	— Design drawings and specifications. — Configuration and programming. — Equipment and systems manuals	— Site acceptance testing of all software based functions. — PCSs ready for operation
Part 3	Operate— commission	Prepare process controls system for operation	Performance requirements	— PCSs in operation. — All deficiencies identified and corrected
	Operate— operation	Operate PCS to best operational effectiveness	Performance requirements, consideration of future migrations, upgrades, and managing obsolescence issues	Business revenue and minimal costs
	Operate—maintain	Maintain, preventative maintenance (PM) and repair PCSs	As-built documentation and training	Maximum unit performance and availability

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

API Recommended Practice 552, *Transmission Systems*

3 Terms and Definitions

The following terms and definitions are used in this document. Additional definitions are provided in Parts 2 and 3 when necessary to support the content of those documents.

3.1

batch control

Control functions that occur in a series of complex steps or phases that may combine continuous control, sequence control, and discrete control to execute a processing scheme.

3.2

business network

A digital communications network that is used for general purpose business use such as desktop computing, non-process control database applications or other general purpose applications. Can be referred to as Purdue level 4. Typically, business networks use industry standard communications methods such as Ethernet.

3.3

central control room

CCR

Inhabited facility (typically a building) that houses plant personnel and PCS equipment to permit the operation and coordination of one or more process plants. Control rooms are not always located adjacent to the process equipment being controlled and often centralize operation of multiple process plants or areas. Trends are to locate control centers away from potential blast zones.

3.4

continuous control

Control functions that are continuously and repetitively executed to control the values of process variables such as pressure, temperature, flow, etc. that are part of a continuous process such as a refining process, or within a portion of a process associated with a batch control system.

3.5

control loop

That part of an instrument control system that includes the input sensor, transmitter, communication path, control algorithm, and final control element. Control algorithm may be executed as one of many such algorithms in a PCS or be performed by stand-alone electronic, pneumatic, or mechanical devices.

3.6

control module

A processing module that performs various control and data acquisition functions in a PCS. Typically, this module is used to poll data from system I/O modules, perform basic regulatory or other control functions, and communicate I/O and control information to other modules in the PCS.

3.7

demilitarized zone

DMZ

A physical or logical subnetwork that contains and exposes an organization's external-facing network services to a larger and untrusted network, i.e. the organization's business local area network (LAN) or the Internet. The purpose of a DMZ is to add an additional layer of security to an organization's LAN, by isolating external communications to the process control network.

3.8

discrete control

Control functions that involve on-off operations and interlocks. Discrete control variables are generally associated with thresholds above or below which a control action is taken. The control action is a discrete function such as opening or closing a valve, starting or stopping a motor, etc.

3.9

distributed control system

DCS

A general term used for digital PCs that use multiple processing modules to perform the functional tasks of the system. These modules may or may not be located in physical proximity to one another.

3.10

encryption

The coding and decoding of data transmissions using algorithms and encryption keys that are known only to the sending and receiving devices. A wide variety of encryption techniques and algorithms are available and have varying levels of security associated with them.

3.11

enterprise resource planning

ERP

Systems that are used to identify and coordinate supplies of raw materials, intermediate materials, finished products, consumables, and other material or resources required to operate a manufacturing business.

3.12

Ethernet

A networking standard that is either wireless or uses a single cable consisting of four pairs of wires to connect multiple computing devices together in a manner that does not require that any of the devices be aware of the other devices. Ethernet is an asynchronous communications method that allows messages to collide and provides for a collision detection and a random pause and retry means of allowing multiple devices to communicate. Ethernet standards are defined in the IEEE 1802.x series of standards.

3.13

fieldbus

A digital communication network that connects the field sensors, transmitters, and control actuators together and to either a controller or control network. A field bus network allows devices to send and receive messages over a shared path. Devices may send current measurements and/or diagnostic messages and receive commands or configuration data.

3.14

field devices

Any sensors, measuring devices, control elements etc. that are used to sense or directly control process conditions. Current technologies allow increased “intelligence” to be added to the field devices, e.g. self-diagnostics, control functions, and network interconnectivity.

3.15

firewall

A combination of hardware and software installed on computers and network connections to prevent undesired messages from a digital network from reaching or passing through the computers. A firewall may also hide the presence of a computer from other computers on the network. See also 3.7, DMZ.

3.16

front-end engineering design

FEED

Engineering activities performed during the identification of project scope and costs. These activities are generally those necessary to develop designs to the point where scope and cost estimates can be supported. In a front-

end engineering design environment, resources are placed early in the project to ensure proper collaboration between disciplines and to address potential issues in the design early enough to correct them.

3.17

gateway

A distributed control system (DCS) or other PCS module that interfaces communications between foreign devices or devices within the PCS that use differing communications technologies in a structured and secure manner.

3.18

hazard and operability analysis

HAZOP

A hazard analysis technique for process plant safety analysis in which potential hazards and existing or necessary safeguards are identified, using a defined set of initiating words to examine conditions on particular nodes of analysis. Can also be known as a process hazard analysis (PHA). Specific procedures for carrying the safety and reliability analysis of control and computer systems are termed as computer hazard and operation analysis (CHAZOP).

3.19

highway addressable remote transducer

HART

A communications protocol which provides a means of device communications using a phase shift carrier imposed over a pair of wires. The wires may be dedicated to the communications path or may also carry standard 4 mA to 20 mA analog signals. HART™ has evolved to a protocol that enables configuration and messaging of the field device in an effective way. See www.fieldcommgroup.org for more details. HART is an example only and its inclusion is not intended to endorse it specifically or limit users from considering other applications.

3.20

human machine interface

HMI

A computing resource for a PCS that is used as an operator's or engineer's interface for displaying data or inputting information or operating commands.

3.21

local area network

LAN

A computer network connecting computers and other electronic equipment to create a communication system. These networks commonly use Ethernet or similar communications methods.

3.22

object linking and embedding

OLE

A Microsoft standard, object linking and embedding, which defines methods for applications to share common data and applications.

3.23

open platform communications

OPC

OPC standards provide a common practice for manufacturers of PCSs to make real time and historical data available to other devices in a structured and deterministic way. OPC UA (Unified Architecture) is much more complex than previous OPC specifications and is designed to:

- use cross-platform capable communication instead of Windows DCOM (reference to Windows is included for background reference only, and not intended to require use of any particular operating system for compliance with this standard);
- combine the OPC DA, A&E, HDA functionality into a single set of services;

- model complex data structures for collaboration with other standards organizations;
- Be implementable on different platforms, from embedded systems to enterprise systems

See <http://www.opcfoundation.org> for additional information.

3.24

open systems

Technologies that are based upon commercially available, often general purpose software and hardware that can be obtained from a variety of sources instead of proprietary software or hardware that can be obtained from only one supplier.

3.25

operability

The characteristics of a PCS that allow the control system to be operated and maintained in a simple and reliable manner but still provide all of the functionality and security required of the system.

3.26

personal computer

PC

A computing resource that has multiple uses. It is intended for use by a single user and may have several noncontrol applications installed.

3.27

process control module

Some type of computing resource, either of proprietary design or a commercially available computer that performs process control-related functions including data acquisition and control functions.

3.28

process control network

PCN

A digital communications network that is used by process control modules, human machine interfaces (HMI), or other process control support computers to communicate with one another. This network may use proprietary or industry standard communications methods.

3.29

process control system (or basic process control system)

PCS (or BPCS)

A computer-based implementation of the control and information functions necessary to operate and manage a specific process unit or area. This includes field instrumentation, the communications between field devices and the control processors, HMI, and any other computers and communications required to support or report upon process performance. It does not include general-purpose business computers and networks, desktop workstations, or other computing resources not used exclusively to operate, configure, or maintain a process unit or area. SIS functions are considered to be separated from the PCS functions but can share communication network components, engineering tools, and HMI.

3.30

process hazard analysis

PHA

A hazard analysis technique for process plants; refer to 3.18 HAZOP for further details.

3.31

process safety management

PSM

A management process that results in process hazards being identified and suitable safeguards established, and that provides management of change (MOC) procedures that ensure that changes to processes are similarly addressed.