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Automation systems and integration — Integration of advanced process control and optimization capabilities for manufacturing systems

Part 1: Framework and functional model

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National foreword

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Automation systems and integration — Integration of advanced process control and optimization capabilities for manufacturing systems —

Part 1: Framework and functional model

Systèmes d'automatisation et intégration — Intégration de contrôles de processus avancés et capacités d'optimisation des systèmes de fabrication —

Partie 1: Cadre de travail et modèle fonctionnel

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Case postale 56 • CH-1211 Geneva 20
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 5, *Interoperability, integration and architectures of automation systems and applications*.

ISO 15746 consists of the following parts, under the general title *Automation systems and integration — Integration of advanced process control and optimization capabilities for manufacturing systems*:

— *Part 1: Framework and functional model*

The following parts are planned:

— *Part 2: Activity models and information exchange*

— *Part 3: Validation and verification*

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Introduction

As a crucial part of manufacturing systems with increased complexity, the automation and control applications enabled by advanced process control and optimization (APC-O) methodology and solutions perform the operations directed by production planning and scheduling. ISO 15746 deals with the integration of APC-O with manufacturing operations management (MOM) and with automation and control of manufacturing process and equipment.

The following IEC 62264 functionalities related to manufacturing are hierarchically structured in a functional model, as shown in Figure 1.

a) Level 0 defines the actual physical processes.

b) Level 1 defines the activities involved in sensing and manipulating the physical processes. Level 1 typically operates on time frames of seconds and faster.

c) Level 2 defines the activities of monitoring and controlling the physical processes. Level 2 typically operates on time frames of hours, minutes, seconds and sub-seconds.

d) Level 3 defines the activities of the work flow to produce the desired end products. It includes the activities of maintaining records and coordinating the processes. Level 3 typically operates on time frames of days, shifts, hours, minutes and seconds.

e) Level 4 defines the business-related activities needed to manage a manufacturing organization. Manufacturing-related activities include establishing the basic plant schedule (such as material use, delivery and shipping), determining inventory levels and making sure that materials are delivered on time to the right place for production. Level 3 information is critical to Level 4 activities. Level 4 typically operates on time frames of months, weeks and days.

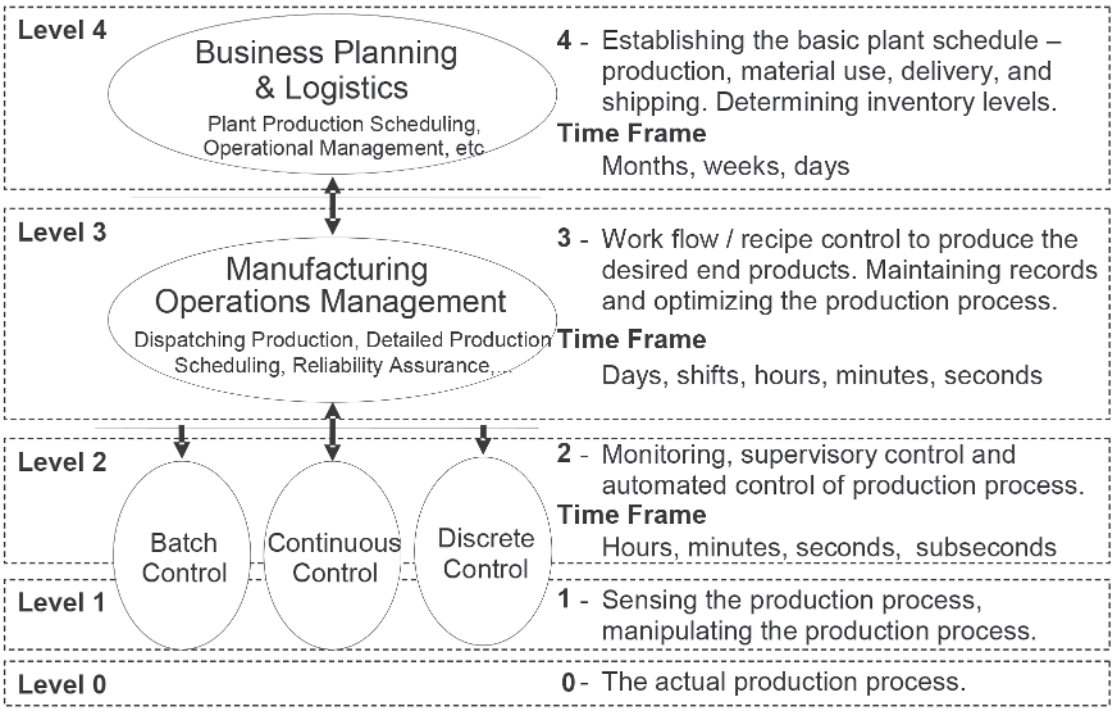

Figure 1 — Functional hierarchy

ISO 15746 mainly focuses on the integration of APC-O capabilities into control activities (Level 2) and MOM (Level 3), in Figure 1.

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The APC-O system within Level 2 interacts with the MOM system of Level 3. It shall provide the information of the production processes to the MOM system, and in return accepts and executes the corresponding operational commands from the MOM system. The APC-O system within Level 3 samples measurement signals and monitors behaviour, and in return controls the operational systems within Level 2.

Automation solutions composed of software and hardware are provided by different suppliers to accomplish APC-O capabilities. Due to the diversity of development environments and the variety of demand focus, the automation solutions from various suppliers are isolated and relatively independent. These differences make the integration of automation solutions difficult. Consequently, the customers may purchase different automation solution components with redundant and duplicated functions, resulting in a waste of resources and limited interoperability. This part of ISO 15746 offers a reference interoperability framework for APC-O. It is intended to maximize the integration and interoperability of automation solutions.

This part of ISO 15746 is intended to help:

— identify an approach to assist the providers and system integrators of APC-O systems and related automation solutions components in verifying the interoperability of the components used to construct the automation solutions to meet application lifecycle requirements during designing, developing, implementing, testing, validating, installing and maintaining the automation solutions;

— identify the criteria to help users in choosing the appropriate automation solutions, such as APC-O modules, to meet their requirements;

— outline the concepts and conceptual framework elements that will be sufficient to address the identified problems and opportunities;

— reduce the time and cost in defining and describing the application requirements, as well as, in developing and implementing automation solutions based on APC-O systems.

The target users of this part of ISO 15746 include users and providers of the APC-O solutions, such as project solution suppliers, automation systems integrators, production departments of companies, process engineers, independent software testing organizations, implementation and consulting service organizations of APC-O software, and relevant governments and academic organizations.

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Automation systems and integration — Integration of advanced process control and optimization capabilities for manufacturing systems —

Part 1: Framework and functional model

1 Scope

This part of ISO 15746 establishes a framework and general functionality of a method for integration of advanced process control and optimization (APC-O) capabilities for manufacturing systems. The goal is to reduce the cost and risk associated with developing and implementing integrated APC-O capabilities.

The scope of this part of ISO 15746 is limited to specifying the set of concepts, terms, definitions and the associated rules for describing the required functional capabilities of APC-O units.

The following are outside the scope of this part of ISO 15746:

— definition and specification of an interface or communication protocol between APC-O capabilities;

— requirement and restriction of a specific technical specification when developing and implementing APC-O systems;

— strategy and method of a certain APC-O system.

2 Terms and definitions

2.1
advanced process control
APC
control strategy to cope with processes characterized by *large time delays* (2.18), non-minimum phase, non-linearity, loop instability and multi-variable coupling

Note 1 to entry: APC enhances basic process control by addressing particular performance or economic opportunities in the process.

EXAMPLE MPC, Adaptive control, Inferential control.

2.2
advanced process control and optimization
APC-O
collection of *advanced process control* (2.1) and *optimization* (2.13) strategies

2.3
controller
functional unit consisting of electronic devices or realized by computers (or digital systems), which is used to execute the specified control strategies

2.4
data driven model
model (2.11) developed through the use of data derived from tests or from the output of investigated process

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2.5
expert control
control strategy based on rule set and reasoning process, which adopts the knowledge and ideas to the problem for control implementation

2.6
first principle model
model (2.11) reflecting physical and chemical laws, such as mass balance and energy balance

2.7
performance indicators
category of quantized and pre-authorized benchmarks that reflect the realization of the goals

2.8
physical sensor
physical equipment or converter that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument

Note 1 to entry: These days, instruments are mostly electronic.

EXAMPLE Flowmeter; pressure transmitter.

2.9
manipulated variable
input variable of the control system, which is used to manipulate the controlled variable

2.10
model predictive control
predictive control
comprehensive closed loop optimized control strategy which combines a dynamic *model* (2.11) for predicting future behaviour of the process, a continuous implementation of the control action based on on-line repeated *optimization* (2.13) and a feedback correction for the model error

EXAMPLE Model Algorithmic Control (MAC); Dynamic Matrix Control (DMC); Generalized Predictive Control (GPC).

2.11
model
abstract description of reality in any form (including mathematical, physical, symbolic, graphical or descriptive) that presents a certain aspect of that reality

[SOURCE: ISO 19439:2006, 3.47]

2.12
manufacturing operations management
MOM
activities within Level 3 of a manufacturing facility that coordinate the personnel, equipment and material in manufacturing

[SOURCE: IEC 62264-3:2007, 3.1.11, modified — Notes have been deleted; abbreviated term has been added.]

2.13
optimization
decision-making strategy to meet the business objective under a weighted set of conditions and concerns

2.14
soft sensor
virtual device using mathematical *model* (2.11) of sensing function to estimate process parameters using other known variables as inputs

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2.15
statistical process control
strategy which uses statistical methods to monitor and control the manufacturing process in order to improve and maintain the system performance

2.16
steady state
equilibrium state at which the output variables are time-invariant

2.17
system identification
method, based on the observation of inputs and outputs, used to generate a *model* (2.11) of the system from a set of models by suitably adjusting model parameters

Note 1 to entry: The key factors of system identification include model structure, observed information and objective function.

2.18
time delay
time period that starts from when there is variation of the input variable until it influences the system output variable

Note 1 to entry: Time delay is also referred to as deadtime.

3 Abbreviated terms

APC advanced process control

APC-O advanced process control and optimization

KPI key performance indicator

MOM manufacturing operations management

OPM object process methodology

PID proportional-integral-derivative

PLS partial least squares

4 Concepts and capabilities

4.1 Background concepts

Process control is one of the most important branches of industrial automation. It aims at the control problems of process parameters, such as temperature and pressure. It covers a diversity of industrial fields, such as petroleum, chemicals, electric power, metals, textiles, building materials, light industry, nuclear energy, and pharmaceuticals.

With the development of modern industries, controlled objects are becoming increasingly sophisticated, which brings along with it new difficulties and challenges, such as multiple time varying parameters, large time delays, high nonlinearity, and complex coupling among input and output variables. Normal single loop control strategies can no longer achieve the desired objective of modern industrial automatic control. Since the 1970s, with the development of control theory and technology, a series of APC-O strategies have been proposed, such as multi-loop control and optimization strategy based on a system model, control strategy based on artificial intelligence and supervisory control strategy based on stochastic statistical analysis. The typical examples of APC-O include multivariable model predictive control, gain-based optimization, adaptive control, expert control and stochastic statistical process control.

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