

STANDARD
ANSI/ISA77.20.01-2012
Fossil Fuel Power Plant Simulators:
Functional Requirements
Revised 9 February 2012

ANSI/ISA-77.20.01-2012
Fossil-Fuel Power Plant Simulators – Functional Requirements

ISBN 978-1-937560-16-4

Copyright © 2012 by ISA. All rights reserved. Printed in the United States of America. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photocopying, recording, or otherwise), without the prior written permission of the publisher.

ISA
67 Alexander Drive
P.O. Box 12277
Research Triangle Park, North Carolina 27709
www.isa.org

Copyright 2012 ISA. All rights reserved.



Documents
Document Sharing Hub

Preface

This preface, as well as all footnotes and annexes, is included for information purposes and is not part of ANSI/ISA-77.20.01-2012.

This document has been prepared as part of the service of ISA toward a goal of uniformity in the field of instrumentation. To be of real value, this document should not be static but should be subject to periodic review. Toward this end, the Society welcomes all comments and criticisms and asks that they be addressed to the Secretary, Standards and Practices Board; ISA; 67 Alexander Drive; P. O. Box 12277; Research Triangle Park, NC, 27709; Telephone (919) 549-8411; Fax (919) 549-8288; E-mail: standards@isa.org.

The ISA Standards and Practices Department is aware of the growing need for attention to the metric system of units in general, and the International System of Units (SI) in particular, in the preparation of instrumentation standards. The Department is further aware of the benefits to USA users of ISA standards of incorporating suitable references to the SI (and the metric system) in their business and professional dealings with other countries. Toward this end, this Department will endeavor to introduce SI-acceptable metric units in all new and revised standards, recommended practices, and technical reports to the greatest extent possible. *Standard for Use of the International System of Units (SI): The Modern Metric System*, published by the American Society for Testing & Materials as IEEE/ASTM SI 10-97, and future revisions, will be the reference guide for definitions, symbols, abbreviations, and conversion factors.

It is the policy of ISA to encourage and welcome the participation of all concerned individuals and interests in the development of ISA standards, recommended practices, and technical reports. Participation in the ISA standards-making process by an individual in no way constitutes endorsement by the employer of that individual, of ISA, or of any of the standards, recommended practices, and technical reports that ISA develops.

CAUTION — ISA DOES NOT TAKE ANY POSITION WITH RESPECT TO THE EXISTENCE OR VALIDITY OF ANY PATENT RIGHTS ASSERTED IN CONNECTION WITH THIS DOCUMENT, AND ISA DISCLAIMS LIABILITY FOR THE INFRINGEMENT OF ANY PATENT RESULTING FROM THE USE OF THIS DOCUMENT. USERS ARE ADVISED THAT DETERMINATION OF THE VALIDITY OF ANY PATENT RIGHTS, AND THE RISK OF INFRINGEMENT OF SUCH RIGHTS, IS ENTIRELY THEIR OWN RESPONSIBILITY.

PURSUANT TO ISA'S PATENT POLICY, ONE OR MORE PATENT HOLDERS OR PATENT APPLICANTS MAY HAVE DISCLOSED PATENTS THAT COULD BE INFRINGED BY USE OF THIS DOCUMENT AND EXECUTED A LETTER OF ASSURANCE COMMITTING TO THE GRANTING OF A LICENSE ON A WORLDWIDE, NON-DISCRIMINATORY BASIS, WITH A FAIR AND REASONABLE ROYALTY RATE AND FAIR AND REASONABLE TERMS AND CONDITIONS. FOR MORE INFORMATION ON SUCH DISCLOSURES AND LETTERS OF ASSURANCE, CONTACT ISA OR VISIT WWW.ISA.ORG/STANDARDSPATENTS.

OTHER PATENTS OR PATENT CLAIMS MAY EXIST FOR WHICH A DISCLOSURE OR LETTER OF ASSURANCE HAS NOT BEEN RECEIVED. ISA IS NOT RESPONSIBLE FOR IDENTIFYING PATENTS OR PATENT APPLICATIONS FOR WHICH A LICENSE MAY BE REQUIRED, FOR CONDUCTING INQUIRIES INTO THE LEGAL VALIDITY OR SCOPE OF PATENTS, OR DETERMINING WHETHER ANY LICENSING TERMS OR CONDITIONS PROVIDED IN CONNECTION WITH SUBMISSION OF A LETTER OF ASSURANCE, IF ANY, OR IN ANY LICENSING AGREEMENTS ARE REASONABLE OR NON-DISCRIMINATORY.

ISA REQUESTS THAT ANYONE REVIEWING THIS DOCUMENT WHO IS AWARE OF ANY PATENTS THAT MAY IMPACT IMPLEMENTATION OF THE DOCUMENT NOTIFY THE ISA STANDARDS AND PRACTICES DEPARTMENT OF THE PATENT AND ITS OWNER.

ADDITIONALLY, THE USE OF THIS DOCUMENT MAY INVOLVE HAZARDOUS MATERIALS, OPERATIONS, OR EQUIPMENT. THE DOCUMENT CANNOT ANTICIPATE ALL POSSIBLE APPLICATIONS OR ADDRESS ALL POSSIBLE SAFETY ISSUES ASSOCIATED WITH USE IN HAZARDOUS CONDITIONS. THE USER OF THIS DOCUMENT MUST EXERCISE SOUND PROFESSIONAL JUDGMENT CONCERNING ITS USE AND APPLICABILITY UNDER THE USER'S PARTICULAR CIRCUMSTANCES. THE USER MUST ALSO CONSIDER THE APPLICABILITY OF ANY GOVERNMENTAL REGULATORY LIMITATIONS AND ESTABLISHED SAFETY AND HEALTH PRACTICES BEFORE IMPLEMENTING THIS DOCUMENT.

THE USER OF THIS DOCUMENT SHOULD BE AWARE THAT THIS DOCUMENT MAY BE IMPACTED BY ELECTRONIC SECURITY ISSUES. THE COMMITTEE HAS NOT YET ADDRESSED THE POTENTIAL ISSUES IN THIS VERSION.

The following people served as Voting members of ISA77 in developing this standard:

NAME	COMPANY
J. Weiss, Managing Director	Applied Control Solutions LLC
L. Altcheh	Israel Electric Corp.
J. Batug	PPL Generation LLC
G. Cohee	Applied Control Systems
D. Crow	Invensys Foxboro
M. Cushing	Siemens Process Instrumentation
R. Eng	Hitachi Power Systems America
A. Erickson	Bibb & Associates
A. Gavrilos	ABB Inc.
J. Gilman	JFG Technology Transfer LLC
W. Hocking	Invensys Process Systems*
R. Hubby	Robert N. Hubby Consulting
H. Johansen	Bechtel Power Corp.
D. Lee	ABB Inc.
X. Lou	Alstom Power
G. McFarland	Emerson Process Management
J. Olson	Tennessee Valley Authority
M. Pandya	Southern Company Services Inc.
D. Roney	URS Corporation
W. Shin	BC Hydro
M. Skoncey	First Energy Generation Corp.
L. Somak	SRP
T. Stevenson	Constellation Energy
C. Taft	Taft Engineering Inc.
P. Toigo	Burns & McDonnell
J. Vavrek	Sargent & Lundy LLC
A. Zadiraka	Consultant

ISA 77 would like to recognize Allan Zadiraka and Alex Leckich as co-chairmen of ISA77.20, who were instrumental in completing this document.

This standard was approved for revision by the ISA Standards and Practices Board on 9 February 2012.

NAME	COMPANY
D. Dunn, Vice President	Aramco Services Co.

E. Cosman, Vice President-Elect
D. Bartusiak
P. Brett
J. Campbell
M. Coppler
B. Dumortier
J. Federlein
J. Gilsinn
E. Icahan
J. Jamison
K. Lindner
V. Maggioli
T. McAviney
R. Reimer
S. Russell
N. Sands
H. Sasajima
T. Schnaare
J. Tatera
I. Verhappen
R. Webb
W. Weidman
J. Weiss
M. Widmeyer
M. Wilkins
D. Zetterberg

The Dow Chemical Co.
ExxonMobil Research & Engineering
Honeywell Inc.
ConocoPhillips
Ametek Inc.
Schneider Electric
Federlein & Assoc. Inc.
NIST/MEL
ACES Inc.
EnCana Corporation Ltd.
Endress+Hauser Process Solutions AG
Feltronics Corp.
Jacobs Engineering
Rockwell Automation
Valero Energy Corp.
DuPont
Yamatake Corp.
Rosemount Inc.
Tatera & Associates Inc.
Industrial Automation Networks Inc.
ICS Secure LLC
Consultant
Applied Control Solutions LLC
Kahler Engineering Inc.
Yokogawa IA Global Marketing (USMK)
Chevron Energy Technology Company

Copyright 2012 ISA. All rights reserved.



Contents

1	Scope	9
2	Purpose	9
3	Definitions	9
4	General elements of a simulator	10
5	General requirements.....	10
5.1	Simulator capabilities.....	10
5.2	Trainee environment	11
5.3	Systems to be simulated	12
5.4	Training capabilities.....	12
5.5	Simulation computer system hardware	13
5.6	Simulator computer systems software.....	14
6	Performance criteria	15
6.1	Steady-state operation	15
6.2	Transient operations	16
7	Simulator testing.....	16
7.1	Simulator performance testing	16
7.3	Simulator system testing	17
8	Design control.....	17
9	Documentation.....	18
9.1	Instructor documentation.....	18
9.2	Software documentation.....	18
9.3	Hardware documentation	18
Annex A	-- Three types of simulators.....	21
Annex B	-- General modeling requirements	25
Annex C	-- General data requirements	29
Annex D	-- Specific documentation for three types of simulators	35
Annex E	-- Simulation versus stimulation	39
Annex F	-- Related Standards.....	41

Copyright 2012 ISA. All rights reserved.

1 Scope

The scope of this standard is to address the simulation of fossil fuel power plants typically consisting of:

- Boiler, turbine, and balance of plant with steaming capacities of 200,000 lbs/hr (25 kg/s) or greater
- Combustion turbine or combined cycle combustion turbine capacity of greater than 100MWs
- Associated or interactive processes

This standard will address high-fidelity process and control logic models, highly replicated user interfaces, highly functional instructor tools, high-realism physical fidelity trainee environments, simulator platform considerations, and minimum levels of documentation.

2 Purpose

The purpose of this standard is to establish the functional requirements for several types of plant-specific, fossil fuel power plant control room simulators. It sets minimum criteria for the degree of software modeling detail and hardware replication, performance, and functional capabilities of the simulator control room operator interfaces. This standard does not address DCS tie-back simulators, or simulators used primarily for engineering purposes. This standard does not establish criteria for the use of simulators in training programs.

Operating and training practices and procedures differ considerably among the various organizations that operate fossil fuel plant control room simulators, however, the goals of personnel safety, maximum equipment availability and lifetime, and efficiency of operations are common to all. Therefore, this standard is intended to provide flexibility in both design and use.

3 Definitions

The following definitions are included to clarify their use in this standard and may not correspond to the use of the word in other texts.

design control: A design approach that ensures that the initial simulator design and any subsequent changes to it are carried out in a systematic, controlled, and documented manner.

fidelity: The degree of both physical and functional realism.

functional fidelity: The degree of similarity between the simulator and the reference plant relative to the static and dynamic response of the equipment and controls.

part-task simulator: A simulator that incorporates detailed modeling of a single or very limited number of specific reference plant components or subsystems. Such a simulator demonstrates the expected response of those components or subsystems.

physical fidelity: The degree of similarity between the simulator and the reference plant in the physical design and location of the panels, equipment, instruments, and controls.

reference plant: The specific fossil fuel plant from which the simulator control room configuration, the system control arrangements, and the simulator database are derived.

replicate: To imitate the reference plant in such a way as to copy hardware, processes, and data, but not to the point of making substitution possible,

real time: Simulation of dynamic performance in the same time-based relationships, sequences,

durations, rates, and accelerations as the dynamic performance of the reference plant.

simulation: The mathematical representation/modeling of physical process and control systems.

stimulation: The use of identical instrumentation or computer systems that have been modified to function in a simulator environment.

4 General elements of a simulator

Fossil-fuel training simulators covered by this standard shall consist of the following major elements:

- 1) **Trainee environment:** The trainee environment shall include control panels with instruments, an operator CRT that provides the interface by which the trainee interacts with the system, or a combination of both. The realism of the trainee environment may be augmented by means of a communication system, simulated control room noise, and variations of the control room lighting in response to simulated electrical disturbances. The replication of the trainee environment may vary both in physical fidelity and in scope, depending on the simulator type.
- 2) **Simulation computer:** The simulation computer system shall consist of a general-purpose computer and peripherals that are capable of handling the plant simulation and instructor functions in real time. The simulation computer shall communicate with the control room hardware via a high-speed electronic data interface.
- 3) **Instructor station:** The instructor station provides a means by which the instructor can control simulator operations and monitor the trainee(s). The instructor station should include, as a minimum, a CRT and a keyboard. It may include additional CRTs and a remote wireless station, strip-chart recorders, and other devices that enhance its capabilities.
- 4) **Simulator software:** The simulator software shall include, as a minimum, the following software programs:
 - a) Software plant models, which simulate continuously in real time the behavior of the simulated reference plant(s) systems over the entire range of normal, abnormal, and emergency conditions. The fidelity and extent of simulation of the plant systems may vary, depending upon the type of simulator. (See Annex A.)
 - b) Instructor station software, which provides the instructor with the necessary simulator control and trainee monitoring functions
 - c) Development and maintenance software necessary to update the plant models
 - d) Computer operating systems and utility software
- 5) **Spare parts, tools, and documentation:** The simulator should include all hardware, software, and documentation necessary to support simulator maintenance and updates.

5 General requirements

5.1 Simulator capabilities

The response of the simulator that results from operator action, no operator action, improper operator action, automatic plant controls, and inherent operating characteristics within and without plant malfunctions shall be realistic within the limits of the performance criteria and the functional design specifications derived from the training objectives. (See 6, "Performance Criteria.")

5.1.1 Normal operations

The simulator shall be capable of simulating continuously, and in real time, the operations of the reference plant(s). The simulator shall calculate plant system parameters that correspond to particular operating

conditions, displaying these parameters on the appropriate instrumentation, and shall provide proper alarm or protective system action, or both. The minimum operations that the simulator shall be capable of performing, using only operator action that is normal to the reference plant(s), are as follows:

- a) Plant start-up—cold to 100% load (The starting conditions shall be cold shutdown conditions of temperature and pressure for all systems.)
- b) Start-up from hot standby to 100% load
- c) Turbine start-up and generator synchronization
- d) Boiler/turbine/unit trip followed by recovery to rated load
- e) Plant shutdown from 100% load to hot standby and cool-down to cold shutdown conditions
- f) Operator-conducted testing on equipment or systems as applicable (e.g., turbine valves)

5.1.2 Plant malfunctions

The simulator shall be capable of simulating abnormal and emergency events in real time, including malfunctions and equipment failures to demonstrate inherent plant response and automatic plant control functions. Where the operator actions are a function of the degree of severity of the malfunction (e.g., boiler tube leaks, loss of vacuum, condenser tubes failing, etc.), the simulator shall have adjustable rates for the malfunction to represent the range of plant malfunction conditions. The remaining events shall consist of a variety of malfunctions associated with the fuel supply, furnace air and gas, condensate and feed water, boiler, steam turbine generator, and the electrical and auxiliary support systems.

The malfunctions available shall include both discrete and variable malfunctions that may be applied to plant equipment, controls, and processes. Discrete failures include the failure of plant equipment, such as control elements, to specific states. For example, a control valve may be forced to fail to an open, closed, or an intermediate position. Variable malfunctions include the failure of plant equipment, controls, or processes to a variable state. An artificially imposed variation in heat exchanger fouling or an imposed drift in the signal from a sensing element are typical of variable malfunctions.

The response of the simulator following the insertion of malfunctions shall be compared to actual plant response or to a best-estimate plant response obtained from operating experience or derived from engineering analysis. Where applicable to the malfunction, the simulator shall provide the operator with the capability of taking action to recover the plant, mitigate the consequences, or both. The simulation shall continue until such time as a stable, controllable, and safe condition is attained that can be maintained to cold shutdown conditions, or until the simulator operating limits are reached.

5.1.3 Simulator operational limits

The simulator is designed to operate within realistic normal operating limits. If the simulation goes beyond these limits, misleading training may result. In order to avoid this situation, administrative controls or other means shall be provided to alert the instructor when certain parameters approach values that are indicative of events beyond the implemented model or known plant behavior.

5.2 Trainee environment

5.2.1 Panel/control station simulation (operator interface)

Operational panels should provide controls, instrumentation, alarms, and other operator-machine interfaces that are necessary to conduct normal plant operations (5.1.1) and to respond to malfunctions (5.1.2).

Control panel/stations should be designed to duplicate the size, shape, color, and configuration of the functionally simulated hardware in the reference plant. Deviations in one or more aspects of physical fidelity of the panels should not detract from training. Control room hardware may be simulated or stimulated. In the latter case, consideration should be given to the functionality of the stimulated hardware in nonreal-time modes (i.e., the modifications to the hardware necessary to implement standard simulator functions such as freeze, restore, etc.). (Refer to Annex E for details.)

5.2.2 Interface controls

Meters, recorders, switches, annunciators, controllers, plant computer interface hardware, and other controls or displays that would function during normal operations or malfunctions should be included in the simulator.

All functionally simulated and visually simulated hardware should replicate or closely resemble in appearance and location that found in the reference plant control room and should be functionally identical to it.

5.2.3 Control room environment

Consideration should be given to simulating as much of the control room environment as is reasonable and practical. Attention should be paid to the following environmental factors:

- 1) Location of the auxiliary equipment and furnishings in the control room
- 2) Location and availability of plant communications systems
- 3) Location and intensity of control room lighting
- 4) Type and level of noise/vibration from the plant equipment

The presence of any instructional equipment should be such that it does not interfere with the training process.

5.3 Systems to be simulated

5.3.1 Systems run from the control room

The number of systems included and the degree of simulation response should match that which is necessary in order to perform the reference plant's normal operations (5.1.1) and malfunctions (5.1.2) consistent with training objectives that have been identified.

Functional fidelity of the simulator should be based upon one or more of the following sources:

- 1) Reference plant data
- 2) Data from a similar plant
- 3) A "best estimate" engineering computer analysis (when reference/similar plant data does not exist)

It should be possible to perform control manipulations and observe plant response in a manner similar to that of the reference plant (i.e., software models should be based on real time). Interactions among simulated systems should provide total system integrated responses.

5.3.2 Functions run from outside the control room (remote functions)

Control or component operating functions that are performed outside the control room or provide some input to the simulation models and are necessary to perform the reference plant's normal operations and malfunctions should be simulated.

5.3.3 External parameters

Factors such as ambient temperature that exist outside the control room and affect the operation of the plant should be controllable from the instructor station and should realistically affect plant operations.

5.4 Training capabilities

5.4.1 Instructor interface

The instructor shall interface with the simulator via an instructor station that does not restrict access to either the control room panels or the operator station. Through use of the instructor station, the capability shall exist for the instructor to act in the capacity of an auxiliary operator or other operator who is remote from the control room.

5.4.2 Simulator control features

The simulator shall be capable of freezing the progression of all dynamic simulations at any time,

initializing at predefined states, inserting malfunctions, and manipulating external parameters and remote functions. In addition, consideration should be given to the incorporation of the following features:

- 1) **Backtrack:** the ability to continuously record initialization data for later recovery
- 2) **Record and playback:** a continuous recording of trainee control panel actions for later replay
- 3) **Snapshot:** the ability to store the particular conditions existing at any instant during a training session in order that they may be recalled in the future as an initialization point
- 4) **Slow time:** the ability to provide an apparent increase in the time interval for fast-changing phases of plant operation that are characterized by short time constants (i.e., the simulation runs at a rate that is slower than real time)
- 5) **Fast time:** the ability to provide an apparent decrease in the time interval for less dynamic phases of plant operation that are characterized by long time constants (e.g., warmup, boiler kill, condenser vacuum, water chemistry, etc.)
- 6) **Trainee monitoring:** the provision of a system to monitor and record selected parameters during a training exercise in order to allow an objective evaluation of trainee performance
- 7) **Plant efficiency monitoring:** the ability to calculate and display both the unit heat rate and the effect of operationally controllable parameters on plant performance

5.4.3 Initial conditions

The simulator shall be capable of storing initialization conditions as defined by the training objectives. Selection of these conditions shall be made from the instructor's station. The simulator shall be capable of adding, modifying, or deleting initialization conditions as required.

Typical initialization conditions may include some or all of the following:

- 1) Cold start
- 2) Hot start
- 3) Hot restart after unit trip
- 4) Cold turbine — cold turbine on turning gear
- 5) Hot turbine — ready for synchronization
- 6) Half load
- 7) Full load

Consideration should be given to including some spare initialization points for future use.

5.4.4 Malfunctions

It shall be possible to conveniently insert malfunctions through instructor action or preprogramming.

5.5 Simulation computer system hardware

Computer(s) and associated peripherals shall serve as the control and simulation elements of the simulator. These computer systems and peripherals shall include commercially available components that provide sufficient spare capacity to accommodate the training simulator requirements and background tasks. The computer system(s) shall support a high-level language programming environment.

The control panel input/output interface shall consist of commercially available components and shall be modular in design to facilitate future expansion. I/O transfer rates shall be such that plant responses observed at the control panel(s) are not discernible from those of the reference plant.

In addition, consideration should be given to the incorporation of the following features:

- 1) **Computer(s):** The computer(s) should be current generation machines, modular in design, and should allow direct memory access, priority, and real-time interrupts. Sufficient spare computation time should be included to allow for background tasks and future expansion.
- 2) **Memory:** Main memory and bulk-disk storage should provide sufficient capacity for the simulation