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# Fossil Fuel Power Plant Simulators — Functional Requirements

ANSI/ISA-S77.20 — Fossil-Fuel Power Plant Simulators – Functional Requirements

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# 1 Scope

This standard establishes the functional requirements for several types of fossil-fuel power plant control room simulators primarily used for operator training. It sets criteria for the degree of hardware replication and software modeling detail, performance, and functional capabilities of the simulated control room instrumentation. This standard does not completely address stand-alone DCS-based trainers/simulators, nor simulators used for engineering or test purposes such as part-task training devices intended for specialized training. 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.

# 2 Introduction

The use of simulators in the training of fossil-fuel power plant operators has increased dramatically over the past several years. However, the type of simulator used to provide this training varies widely from application to application. It is difficult to define a fossil-fuel power plant simulator because a wide variety of simulator configurations have been purchased and implemented. This standard will, therefore, define requirements for three distinct variations:

1) The full scope, high realism simulator

2) The "reduced scope" high realism simulator

3) The "generic" simulator

Detailed definitions for each type are provided in Appendix A of this standard.

It should be emphasized that this classification of fossil power plant simulators into three distinct types has been done as an aid to practical application of this standard. In reality, the scope of simulators available today can be represented by a "continuum" rather than as distinct classes. Features described for one classification of simulator might be incorporated into a specification for another classification. The primary factors in determining what should be incorporated into any particular simulator are:

1) The specific training objectives; and

2) The requirements of the end user.

# 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 CRT's 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 Appendix 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 Startup—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 Appendix 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 decrease 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 faster 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 software and additional spare capacity for background tasks and future expansion. Spare capacities for computational power and memory should be applied to individual computer systems.

3) **Printers and terminals:** Separate printers should be provided for control room specific functions such as data logging and simulator development listings. Industry standard CRT terminals should be provided for simulation software maintenance and system console functions.

## 5.6 Simulator computer systems software

The simulator computer software shall include the following:

1) **Operating system software:** The simulator shall utilize the computer vendor's operating system software in an unmodified form. This operating system shall be a real time multi-programming system. The software shall be easily updated or replaced with future operating systems that may be supplied by the computer vendor.

2) **Plant simulation software:** The plant simulation software shall be written in a high level language. The software shall be designed in a consistent and well documented format. A modular framework shall be employed in the program design to permit program additions or deletions without destruction of the overall program. The plant simulation software shall be designed such that the simulator response will be the same as that of the reference plant within the performance requirements for the simulator. The mathematical model equations shall be derived, where possible, from the basic laws of physics and thermodynamics. The simulation software shall interface and respond to all input signals from the control station and shall provide output signals to all control displays.

3) **Instructor station software:** All software required to support the instructor station functions shall be supplied. The software shall be written in such a manner that minimal instructor training is required for performing the functions.

4) **Development software:** Utility and development software shall be provided to allow development of the simulator software. Consideration should be given to the provision of an on-line background software development capability. The software shall include, as a minimum, a Macro Assembler, an optimized high level language compiler with a runtime support library, a full screen editor, an object code linker, and an interactive debugger.

5) **Diagnostic and test software:** Diagnostic and test software shall be included to perform on-line and off-line diagnoses of simulator hardware faults. Diagnostic programs shall be provided to assist in the detection/repair of the computer system and all peripherals.

# 6 Performance criteria

## 6.1 Steady-state operation

The simulator accuracies shall be related to full power plant load and interim power levels for which valid reference plant information is available. The parameters displayed on the control panels may have the instrument error added to the computed values. During testing, the accuracy of computed values shall be determined for a minimum of three points over the power range:

1) The simulator instrument error shall be no greater than that of the comparable meter, transducer, and related instrument system of the reference plant.

2) Principal mass and energy balances shall be satisfied. Examples are:

   a) steam flow to generate electrical power;

   b) feed water flow to steam flow; and

   c) main and auxiliary steam systems.

   As a minimum, the simulator-computed value of critical parameters for steady-state, full power operation with the reference plant control system configuration shall be stable and shall not vary more than 2% of the measuring instrument range as observed in the reference plant. Consideration should be given to specifying the allowable deviation of individual critical parameters in process units.

3) The simulator-computed values of critical parameters shall agree within 2% of the reference plant parameters explicitly stated in process units at greater than 25% load and shall not detract from training. Typical critical parameters are defined in 6.1.1.

4) The calculated values of noncritical parameters pertinent to plant operation that are included on the simulator control room panels shall agree within the ranges of 10% of the reference plant parameters and shall not detract from training.

### 6.1.1 Critical parameters

Critical parameters are those related to plant principles of energy and mass balance. Typical critical parameters are as follows:

1) Main steam flow and pressure

2) Feedwater flow

3) Generated electrical power

4) Process steam flows, LP, IP, and HP

5) Superheat and reheat spray flow

6) Superheat outlet temperature and pressure

7) HP turbine inlet temperature and pressure

8) HP turbine first-stage pressure

9) Hot reheat temperature and pressure at the reheater outlet

10) Condenser pressure

11) Fuel flow

12) Combustion air flow

Consideration should be given to other parameters, such as environmental parameters.

### 6.2 Transient operations

Transient operations include malfunctions, abnormal operations, and any non-steady-state plant condition. Simulation performance under transient conditions shall meet the following criteria:

1) Where applicable, it shall be the same as the plant start-up test procedure acceptance criteria.

2) The observable change in the parameters shall correspond in direction to those expected from a best estimate for the simulated transient and shall not violate the physical laws of nature.

3) The simulator shall not fail to cause an alarm or automatic action if the reference plant would have caused an alarm or automatic action, and, conversely, the simulator shall not cause an alarm or automatic action if the reference plant would not have caused an alarm or automatic action.

4) The overall system transient characteristics' time shall be within 20% of the reference plant when under the same operating conditions.

Malfunctions and transients not tested in accordance with 1) - 4), shall be tested and compared to best estimate or other available information and shall meet the performance criteria of 2).

## 7 Simulator testing

### 7.1 Simulator performance testing

Simulator performance shall be established by preparing a simulator performance test, conducting the test, and comparing the simulator's performance with the simulator design data within the requirements of Section 6 (Performance criteria). Testing shall be conducted and a report prepared for each of the following occasions:

1) Completion of initial construction

2) Simulator design changes that result in significant simulator configuration or performance variations. When a limited change is made, a specific performance test on the affected systems and components shall be performed.

The intent of simulator performance testing is to:

a) verify overall simulator model completeness and integration;

b) verify simulator performance against the steady-state criteria of 6.1 (Steady-state operation); and

c) verify simulator performance against the transient criteria of 6.2 (Transient operations) for a benchmark set of transients.

### 7.2 Simulator hardware testing

Simulator hardware testing shall include all trainee environments provided by the simulator. These are:

1) Panel/control station simulation:

   a) control and piping mimics;

   b) location and spacing of control panels; and

   c) size, shape, and configuration of panel/control panels.

2) Control of the panels:

   a) identification labels on meters, recorders, switches, controllers, etc.;

   b) annunciator labeling and terminology; and

   c) form and units of displayed plant information.

3) Control room environment:

   a) location and availability of plant communication systems;

   b) location and intensity of control room lighting; and

   c) type and level of noise for the plant equipment.

### 7.3 Simulator system testing

Simulator system testing shall include simulator system training capabilities and simulator computer performance. These include the following:

1) Simulator control features:

   a) Run/freeze simulator models

   b) Initialization of initial conditions

   c) Inserting and removing malfunctions

   d) Manipulating external parameters and remote functions

   e) Backtrack

   f) Record and playback

   g) Snapshot

   h) Slow time

   i) Fast time

   j) Trainee monitoring

2) Initial conditions:

   a) Cold start

   b) Hot start

c) Hot start after unit trip

d) Turbine on turning gear

e) Ready for turbine synchronization

f) Half load

g) Full load

3) Malfunctions:

a) Control valve failures

b) Primary sensing element failures

c) Heat exchanger fouling

d) Utility systems failure

e) Tube/pipeline rupture

4) Simulation computer performance:

a) Spare computation time

b) Spare memory capacity

## 8 Design control

The simulator shall be designed and maintained using a consistent design control strategy to meet the following objectives:

1) Ensure that the simulator meets the functional/performance requirements given in the technical specification.

2) Ensure that the simulator meets the training objectives.

3) Ensure that the design of the simulator can be traced at all times to a database that defines all critical features of the reference plant. The reference plant need not be a physical plant, but could be a hypothetical plant, provided a consistent set of data is maintained.

4) Ensure that any changes made to the simulator, either during initial design and manufacture or subsequent to its being placed in service, are carried out in a controlled way and are subject to appropriate levels of review and approval.

The design control strategy shall include the following activities:

1) Review and verification of the initial design against the simulator's technical specifications.

2) Establishment of a deficiency review plan to identify and correct discrepancies in the simulator.

3) Review of the simulator's performance with respect to the technical specifications.

4) Maintenance of the reference plant design and performance database that allows simulator design traceability.

5) Establishment of a system to identify, request, approve, and implement changes to the simulator. This system should maintain configuration control and traceability to the reference plant.

# 9 Documentation

Simulator documentation shall be provided to allow the simulator staff to install, operate, and maintain the simulator over its life cycle. Documentation requirements may vary, depending upon the type of simulator considered. Guidelines for documentation requirements for each type of simulator are given in Appendix D.

## 9.1 Instructor documentation

The instructor documentation should provide the simulator instructors with sufficiently detailed information to start up, shut down, and operate the simulator during a training session.

The documentation should include an overview of the plant and of the systems simulated. It should provide the instructor with a clear understanding of the plant model simulation capabilities and limitations as well as the simulated operating procedures. It should also include the information necessary for the instructor to fully understand the simulator training features and to effectively apply them in a training exercise. As a minimum, the instructor documentation should include the following:

1) Simulator operational manual

2) Instructor manual

## 9.2 Software documentation

The software documentation should provide the simulator software staff with the information necessary to maintain and modify the simulator software.

The software documentation should include information that is related to the computer vendor software, instructor station software, plant simulation software, executive software, and the software tools necessary for software modification and maintenance.

As a minimum, the software documentation should include the following:

1) Reference manuals for all computer vendor software.

2) Reference manuals for all simulator vendor tools necessary for software modification and maintenance.

3) Plant model functional specifications, including simulation diagrams, simplifications, scope of simulation, and interfaces.

4) Plant model detailed design documentation, including model derivation and assumptions, algorithm development, block diagrams or flow charts, and data calculations.

### 9.3 Hardware documentation

The simulator hardware documentation should provide the hardware maintenance staff with sufficiently detailed information to maintain, modify, and troubleshoot the simulator hardware.

The documentation should include an overview that describes the simulator configuration and its component hardware, including cross-references to system specific documents. As a minimum, the documentation should include the following for each simulator component:

1) Operational manuals

2) Installation manuals

3) Maintenance and repair manuals

4) Full set of drawings

5) Wiring lists

## 10 Applicable standards

The following codes and standards are applicable to a fossil-fuel power plant simulator:

Design and Manufacture of Class 1E Instrumentation and Electric Equipment for Nuclear Power Generating Stations, Standard Quality Assurance Program Requirements for [SH07765], IEEE 467-1980

Development of Human Factors Review Guidelines for Fossil-Fired Steam Generating Systems (RP 1752), EPRI-C8-3745-1984

Display Design for Dispatch Control Centers in Electric Utilities (RP 2475), EPRI RS EL-4959

Display Design for Dispatch Control Centers in Electric Utilities: Handbook (RP 2475), EPRI RS EL-4960

Electromagnetic Susceptibility of Process Control Instrumentation, SAMA:PMC 33.1

Electrical Measurements in Power Circuits, Master Test Code for [SH00588], (Reaff. 1972), IEEE 120 - 1955

Graphic Symbols for Electrical and Electronic Diagrams, IEEE315-1975

Hardware Testing of Digital Process Computers, ANSI/ISA-RP55.1-1975 (Reaff. 1983)

Human Factors Guidelines for Fossil Power Plant Control Rooms (RP 2710), EPRI TR 101814-1992

Human Factors Review of Electric Power Dispatch Control Centers (RP 1354), EPRI TR EL-1960, Vol. 1-5

IEEE Guide for Surge Withstand Capability (SWC) Tests, IEEE 472

IEEE Standard for Software Quality Assurance Plans, ANSI/IEEE STD 730-1985

Industrial Controls and Systems, NEMA ICS-1978

Installation, Inspection, and Testing Requirements for Class 1E Instrumentation and Electric Equipment at Nuclear Power Generating Stations (Revision of IEEE Std. 336-1977), IEEE 336-1980

Instrumentation Symbols and Identification, ANSI/ISA-S5.1-1984 (Reaff. 1992)

Local Area Network, IEEE STD 802.3-1985

Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System (ANSI/IEEE), Guide for [SH08904], IEEE 81-1983

Metal-Clad and Station-Type Cubicle Switchgear, ANSI C37.20.2

Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position, ASTM D 635-1991

National Electric Code, ANSI/Cl-1987

National Electric Code, ANSI/NFPA 70-1981

National Electrical Safety Code [SH10652], IEEE C2-1987

Pre-Operational Testing Programs for Class 1E Power Systems for Nuclear Power Generating Stations, Guide for Planning of [SH10298], IEEE 415-1986

Programming Language Fortran, ANSI X3.9-1978

Protection of Electronic Computer/Data Processing Equipment, ANSI/NFPA No. 75-1976

Reference Designations for Electrical and Electronics Parts and Equipment (ANSI/IEEE) [SH02006], IEEE 200-1975

Resistance Measurements, Standard Test Code for [SH07187], IEEE 118-1978

Reference Ambient Conditions for Test Measurements of Electrical Apparatus, Recommended Practice for the Selection of [SH08425], IEEE 3-1982

Rubber Insulated Wire and Cable Transmission and Distribution of Electrical Energy, NEMA WC-3

Safety Standards for Electronic Data Processing Units and Systems, ANSI/UL-1984

Specification of General Requirements for a Quality Program, ANSI-ASQC C.1-1985

Standard Annunciator Sequence Designations, ISA-S18.1-1979 (Reaff. 1992)

Standard for Tests for Flammability of Plastic Parts in Devices and Appliances, UL, UL-94

Standard Quality Assurance Program Requirements for the Design and Manufacture of Class 1E Instrumentation and Electric Equipment for Nuclear Power Generating Stations, IEEE 467-1980

Structural Welding Code, AWS, D1.1

Temperature Limits in the Rating of Electrical Equipment, General Principles for [SH00018], IEEE 1-1969

Tests and Test Procedures, NEMA, ICS-109

## 11 References

Analytical Simulator Qualification Methodology, Electric Power Research Institute, EPRI NP-3873.

Nuclear Power Plant Simulators for Use in Operator Training, ANSI/ANS-3.5-1985.

## Appendix A Three types of simulators

*(This appendix is not a part of ISA-S77.20 Fossil-Fuel Power Plant Simulators — Functional Requirements.)*

This appendix describes three types of simulators and lists the key defining characteristics of each:

**A.1 Full-scope, high-realism simulator:** The full-scope, high-realism simulator is an exact duplicate of a power plant control room, containing duplicates of all actual controls, instruments, panels, and indicators. The unit responses simulated on this apparatus are identical in time and indication to the responses received in the actual plant control room under similar conditions. A significant portion of the expense encountered with this type of simulator is the high fidelity simulation software that must be developed to drive it.

The completeness of training using a full-scope simulator is obviously much greater than that available on other simulator types since the operator is performing in an environment that is identical to that of the control room. Experienced operators can be effectively retrained on this simulator because the variety of conditions, malfunctions, and situations offered do not cause the operator to become bored with the training or to learn it by rote.

The major drawback of a full-scope, high-realism simulator is its high cost and long lead time, typically two to three years. Relative advantages and disadvantages of the full-scope simulator are shown in Table A.1.

## Table A.1 — Advantages and disadvantages of the full-scope simulator

| Advantages | Disadvantages |
|---|---|
| 1. Duplicate of unit control room. | 1. Highest cost. |
| 2. Capability limited only by capability of instructor. | 2. Longest lead time. |
| 3. Any condition or malfunction possible in real plant can be replicated on the simulator. | 3. Highest overhead and maintenance costs. |
| 4. Effective training for experienced operators. | 4. No portability. |
| 5. Up to four trainees may operate simulator at once. | 5. Requires special environmental controls/equipment. |
| 6. Virtually all instructor aids are available. | 6. Specially trained computer technician advisable. |
| 7. Plant operating procedures can be validated on simulator. | 7. Large space required for housing simulator. |
| 8. Spare time on simulator is highly marketable. | 8. Highest training cost per hour per trainee of all types of simulators. |
| 9. Can be used for instrumentation and control training. | 9. Requires dedicated, highly qualified instructors. |
| | 10. Simulator must be upgraded each time the plant is modified. |

**A.2 Reduced-scope, high-realism simulator:** If cost were not a prime consideration, a full-scope, high-realism simulator would probably be the choice of most installations. One means to reduce the cost of the simulator is to limit the scope of both hardware and software simulation. Although such a simulator is not identical to an actual control room, all key instrumentation, controls, and plant models (typically 80% or more) are included. Instrumentation may be identical to that installed in the real plant or a reasonable likeness thereof.

This type of simulator is usually designed to be a partial replica of a particular plant and control room and is reduced in scope in that only selected portions of the control room and plant systems are included.

All major plant systems and controls are modeled to provide a high degree of realism to the operators, but only those auxiliaries that directly affect the primary operation of the plant are replicated. Other systems that might have controls and indicators on the panels but do not directly affect most plant operations are not included at all.

The training benefits received are similar to those of the full-scope simulator but at a significantly reduced acquisition cost. Because of the reduction in the complexity of the system modeling, a smaller, less exacting computer system can be used to drive the simulation.

Since the entire control room is not replicated, the space needed for this type of simulator is less than that required for the full-scope model. Even though the simulator does not duplicate the actual control room, trainees should still feel that they are operating an actual plant because of the similarity of the controls and the response of the simulation.

The cost of such a reduced-scope, high-realism simulator will be determined by the completeness, depth, and fidelity of the simulation, the degree of original software development and engineering, the operator interface requirements, the degree of interchangeability, and the number of simulation options. Typically 85% to 95% of the typical plant controls and systems would be modeled, with high realism in about 90% of these systems. Lead time is typically one to two years.

Table A.2 lists the relative advantages and disadvantages of the reduced-scope, high-realism simulator.

**Table A.1 — Advantages and disadvantages of the reduced-scope, high-realism simulator**

| Advantages | Disadvantages |
|---|---|
| 1. Relatively low cost (up to 75% less than full scope simulator). | 1. Limited use in verifying effectiveness. |
| 2. Duplicates critical controls and panels. | 2. Limited number of vendors. |
| 3. Replicated systems and controls have realistic response in real time. | 3. Some control room panels are not replicated and therefore cannot be used for training. |
| 4. Full instructor aids and features may be incorporated. | 4. Relatively long lead time. |
| 5. Simulator may be upgraded and expanded. | 5. Procurer must carefully specify systems for high fidelity simulation. |
| 6. For simulated systems, has all features of full-scope simulator. | 6. Requires well-trained, experienced instructors. |
| 7. Spare time on this type of simulator should be marketable. | 7. Because of reduced scope, it is not possible to satisfy training objectives on non-simulated systems or controls. |
| 8. Any condition or malfunction possible in real plant can be replicated on the simulator. | |
| 9. Effective training for experienced operators. | |
| 10. Can be used for some instrumentation and control training. | |
| 11. Trainee enthusiasm is high because of realism. | |
| 12. Automated performance measurement can be installed. | |
| 13. Authoring capability allows local modifications and creation of special scenarios. | |
| 14. May have ability to test or verify plant procedures. | |

**A.3 Generic simulator:** The generic simulator is the most difficult type to define since the term covers a wide range of possible simulator configurations. For the purposes of this standard, a simulator is considered generic if the operator interface has not been designed to replicate or closely resemble an actual power plant control room configuration.

It should be noted that by this definition, a simulator that completely replicates a particular control room's instrumentation and controls but utilizes generic simulation models, is still considered a generic simulator. Similarly, a simulator that employs plant-specific software models but utilizes CRT-based control stations in lieu of the panel boards installed in the actual plant is also considered generic.

# Appendix B General modeling requirements

*(This appendix is not a part of ISA-S77.20 Fossil-Fuel Power Plant Simulators — Functional Requirements.)*

The fidelity and realism of a power plant simulation is directly related to the quality and suitability of the mathematical models that describe the plant processes. Differences between the three types of simulators should be found primarily in the level of detail and in the degree of plant specificity, not in the realism of the simulation. Therefore, the following general modeling requirements apply to all three types of simulators covered by this standard.

Modeling requirements for a power plant training simulator are unique and should cover, as a minimum, the following areas:

1) Scope of simulation
2) Modeling techniques
3) Simulated range of operations
4) Real-time capabilities
5) Modularity

**B.1 Scope of simulation:** The scope of simulation is the primary cost driver in a training simulator. The scope is defined by the plant systems to be simulated, the components and phenomena to be simulated for each system, and the level of detail to be represented for each component.

To achieve the right balance between simulator costs and training value, it is essential to first define the training objectives. A preliminary definition of the scope of simulation should be established and included in the simulator specifications. A more detailed scope of simulation is then developed during the simulator system design phase and finalized with the detailed functional specifications.

Guidelines to establish the scope of simulation are as follows:

a) Systems, components, and phenomena that are associated directly or indirectly with plant responses that are observable and/or controllable by the trainee should be modeled explicitly.

b) Lumping of plant components (i.e., combining several identical components into a single component of equivalent capacity and performance), should be allowed only if consistent with the required simulated operating procedures.

c) Local equipment (i.e., equipment that cannot be operated directly from the control room) should be simulated if necessary to perform the normal and abnormal simulated operating procedures, consistent with the training objectives.

These simplifications to the plant models should be documented along with their rationale.

**B.2 General modeling techniques:** The mathematical models for the principal plant systems should be derived from the strict application of the laws of mass, energy, and momentum conservation to the simulated equipment. Principal systems are herein defined as those which significantly contribute to the plant heat balance. Examples of such systems include the following:

a) Main fuel system

b) Air and gas system

c) Furnace

d) Boiler and main steam system

e) Turbine and extractors

f) Generators

g) Main condensers

h) Circulating water system

i) Cooling towers

j) Condensate system

k) Feedwater system

l) Heater drains

Laws of conservation can be expressed in a steady-state or in a non-steady-state form. The steady-state form should be used only if the information contained in the time derivative of the equation cannot be perceived by an experienced control room operator under all possible modes of operation. As a guideline, differential equations that represent transients with time constants of 0.5 seconds or less under all conditions can be expressed in the steady-state form. Examples include mass balances in compressed liquids and momentum balances in low inertia fluids (e.g., steam, gas).

To completely represent a plant system, it is necessary to complement the conservation equations with a number of correlations. Examples of correlations follow:

a) Heat transfer and friction loss calculations: The correlations used should be derived strictly from well-accepted engineering correlations, consistent with the dominant heat transfer mechanism or flow regimen under consideration.

b) Fluid properties: Fluid properties can be represented by correlations or table look-up techniques. The accuracy of the fluid property representations should be consistent with the steady-state accuracy requirements over the entire range of simulated operations.

c) Equipment characteristics, such as pump curves and valve characteristics, can be represented by means of correlations fitted to actual data or table look-up techniques. The accuracy of the curve fit or the table look-up should be consistent with the general accuracy requirements, over the entire range of simulated operations.

d) Logic and analog controls should be simulated on a one-to-one basis, consistent with the stated simplifications.

e) The plant electrical system should be simulated on a one-to-one basis, consistent with the stated scope of simulation. In particular, consideration should be given to the level of interaction between the electrical system simulation and the simulated plant components (e.g., effects of bus voltage and frequency).

**B.3 Simulated range of operations:** The plant models should be capable of simulating the entire range of operations. They should also be able to realistically represent normal and abnormal transients resulting from operator action, lack of operator action, or simulated component failures.

Consideration should be given, as a minimum, to the following requirements:

a) A single model should be capable of continuously representing the entire range of simulated operations. Switching between different models that correspond to various operating conditions can detract from training and should be avoided.

b) Fluid properties should be accurate over the entire range of simulated operations, and discontinuities should be avoided.

c) Component failure should be simulated on a first-principles basis. The cause of each malfunction should be modeled explicitly, and its effects should result from the application of first principles and system interactions.

**B.4 Real-time requirements:** A training simulator must operate in real time during any normal or abnormal conditions.

To meet this requirement, the differential, algebraic, and logic equations must be solved at equal time intervals consistent with time constants or delays observable by the trainee. A simulator will operate in real time if the computer is capable of updating all the calculated parameters within the selected time frame.

Under some conditions, numerical solution schemes associated with relatively large, constant time intervals may exhibit an undesirable phenomenon called numerical instability. Numerical integration of the differential equations should be based on a fixed time step algorithm. Numerical schemes should be selected in such a way that a numerically stable solution is obtained during any possible operating condition and for any values of model parameters.

The use of first-order lags, which have no physical foundation except to prevent numerical instability, distorts the model transient response and should be kept to an absolute minimum.

# Appendix C General data requirements

*(This appendix is not a part of ISA-S77.20 Fossil-Fuel Power Plant Simulators — Functional Requirements.)*

The following data requirements apply to a typical full-scope, high-fidelity simulator. Data requirements for a reduced-scope, high-fidelity simulator are similar but limited to a subset that is consistent with the systems simulated. Data requirements for a generic simulator vary. Often, the trainee environment does not replicate a specific control room environment and is designed on the basis of training requirements. Plant models are typically “off-the-shelf" models, and data requirements are limited to some areas of redesign identified to accommodate specific training requirements.

Data requirements can be subdivided into four major categories, that apply to different phases of the simulator design:

1) Control room hardware data required to order instruments and to proceed with panel fabrication; these include panel construction drawings, bills of materials, panel cutouts, plant computer peripheral descriptions, etc.

2) Plant description data required to proceed with the system design; these include P&IDs, control drawings, logic drawings, electrical one-line diagrams, reference manuals, specifications, plant computer reference manuals, operating procedures, and I/O lists.

3) Plant design data required to proceed with the implementation of the mathematical models.

4) Plant operating data required to proceed with the tests of the simulation; examples of such data include steady states at one or several load points and transients (e.g., turbine trip).

**C.1 Control room data:** The control room hardware data is required to procure simulator instruments and to proceed with simulator control room fabrication. The fabrication data is needed for all simulated control room equipment:

a) Control room panel construction drawings, with dimensions

b) Control room panel cutout drawings, with dimensions

c) Control room panel layout drawings, showing location and identification of each instrument

d) Instrument lists, including instrument type, vendor name, model number, scales, number of pens (recorders), transmitter number, and measured variable descriptions

e) Name tags for all instruments, including colors, character styles, dimensions, and location lists

f) Annunciator engraving for all alarms, including colors, dimensions, description, and location

g) Simulator building layout and dimensions

h) Sootblower insert dimensions and layout

**C.2 Plant description data:** The plant description data is necessary to proceed with the simulator system design and the development of the functional specifications.

The following data is necessary for all simulated systems:

a) System descriptions

b) Piping and instrumentation drawings

c) Control drawings

d) Functional logic drawings

e) Major equipment specifications (boiler, turbine, generator)

f) Electrical one-line diagrams

g) Plant operating procedures

h) Heat balance diagrams

i) Equipment reference manuals

j) Transmitter list

k) Panel layout drawings, showing location and identification of all instruments

l) Instrument list

m) Control system descriptions

**C.3 Detailed design data:** The plant detailed design data is required in order to proceed with the design and implementation of the mathematical models. The following data is required, where applicable, for all simulated systems and components:

a) Pumps:

- Pump type
- Manufacturer's characteristics, including differential pressure and brake horsepower as a function of flow and RPM
- Rotor locked current
- Motor current at specified flow, pressure, temperature, and RPM conditions
- Start-up/coastdown times
- Specifications of the bus to which the motor is connected
- Pump motor breaker logic

b) Fans:

- Fan type
- Manufacturer's characteristics, including differential pressure and brake horsepower as a function of flow, RPM, and inlet vane position
- Rotor locked current
- Motor current at specified flow, pressure, temperature, RPM, and inlet vane conditions
- Start-up/coastdown times
- Specifications of the bus to which the motor is connected
- Fan motor breaker logic
- Inlet vane characteristics and stroke time
- Inlet vane logic
- Outlet damper characteristics and stroke time
- Outlet damper logic

c) Valves:

- Valve type
- Characteristic

- Valve capacity at specified position and temperature conditions
- Stroke time
- Fail position on loss of control air/power
- Bus specifications
- Valve logic

d) Dampers:

- Damper type
- Damper characteristic
- Damper capacity at specified position and temperature conditions
- Travel time
- Fail position on loss of power/control air
- Bus specifications
- Damper logic

e) Tanks and vessels:

- Shape and dimensions
- Elevations
- Level tap locations and elevations

f) Heat exchangers:

- Design specifications
- Type, shape, and dimensions
- Elevation (liquid heat exchangers only)
- Temperatures, pressures, and flows at specified conditions
- Level tap locations and elevations
- Number of tubes and dimensions

g) Condensers:

- Design specifications
- Shape and dimensions
- Air ejector or vacuum pump specifications and logic
- Vacuum breaker specifications and logic
- Hotwell elevation
- Number of tubes and dimensions
- Level tap locations and elevations

h) Boilers:

- Design specifications
- Boiler drawings showing heat transfer surface arrangement and locations
- Sootblower locations
- Burner specifications
- Drum dimensions and elevations
- Economizer internal volume and total mass
- Downcomer and waterwall internal volumes and total masses
- Superheater/reheater internal volumes and total masses
- Fuel, water, steam, metal, air and gas flows; temperatures and pressures for each major simulated section at specified steady-state and start-up conditions and for given fuel and ambient conditions
- Draft losses at specified steady-state conditions

i) Air preheaters:

- Type
- Arrangement and dimensions
- Design specifications
- Breaker logic
- Temperatures, flows, and draft losses at specified steady-state conditions
- Internal volumes and total mass of the heat transfer surfaces
- Arrangement and dimensions
- Draft losses
- Transmitter locations

j) Precipitators:

- Design specifications
- Draft loss
- Efficiency

k) Stack:

- Dimensions
- Draft loss

l) Burners:

- Burner characteristics (pressure drop versus flow curves at specified temperature)

m) Sootblowers:

- Locations

- Sootblower logic
- Motor current and pressure at specified operating conditions
- Specifications and operating manual
- Efficiency (cleanup time at specified conditions)

n) Safety valves:

- Capacity
- Set point and dead band

o) Turbines:

- Design specifications
- Turbine thermal kit
- Control valve curves
- Control and logic drawings and descriptions
- Inertia or coastdown curves
- Critical speeds
- Transmitter locations
- Actual start-up charts (steam and metal temperatures, vibrations, differential expansion, pressure)
- Steam and metal temperatures, pressure, flows, extraction pressures, extraction flows, differential expansion at specified steady-state conditions

p) Generators:

- Design specification
- Generator curves
- Transmitter locations
- Damping factor
- Number of poles
- Synchronous reactance
- Stator friction losses
- Armature copper losses
- Stator stray core losses
- Rotor friction losses
- Rotor stray losses
- Field heat losses
- Hydrogen pressure

- Active and reactive power, terminal voltage, currents, and slip at specified steady-state conditions

q) Exciter/voltage regulator:

- Description and drawings
- Specifications
- Manual raise/lower rate
- Auto raise/lower rate
- Field current time constant
- Voltage upper/lower limits
- Voltage regulator gain
- Maximum field current range
- Maximum field voltage range

r) Transformers:

- Impedance
- Transformer turn ratio
- Taps

s) Breakers and relays:

- Type
- Location
- Functional logic drawings
- Specifications

t) Buses:

- Nominal voltage
- List of all equipment connected to each bus

u) Alarms:

- Functional logic drawings
- Set points
- General alarm, acknowledge, and reset sequence
- Flash rates

v) Controllers:

- M/A station descriptions
- Set points
- Function generator curves
- Lead/lag time constants

- Limits
- Proportional gains
- Reset rates
- Set times
- Raise/lower rates
- Output upper/lower limits

w) Transmitters:
- Specifications
- Location
- Fail value on loss of power

x) Burner and turbine protection:
- Functional logic drawings
- Set points
- Time delays
- Operating procedures

y) Miscellaneous trip and protection:
- Functional logic drawings
- Set points
- Time delays

z) Plant process parameter display:
- Display formats
- Display fill sequence and response time
- Detailed operator communication description, including displays, messages, etc.
- Log formats and contents
- List of analog and digital point IDs with descriptions and all applicable attributes

**C.4 Plant performance data:** The plant performance data is useful for fine-tuning against actual plant performance and model validation. This data should not be essential to the design of the simulator if the simulation is based on first-principle mathematical models. However, to verify the fidelity and prediction capability of a simulation model, it is best to validate its response at one or several steady states over the entire operational range and during some well-defined transient situations.

To accomplish this, the following data is useful:

a) Actual plant heat balance data

b) Plant computer printouts and instrument readings at one or several steady-state conditions including full load

c) Charts and trend logs during important transients such as start-up, load changes, load rejection, plant trips, etc.

In the absence of such data, best estimates, good engineering judgment, and operator inputs should be used.

# Appendix D Specific documentation for three types of simulators

*(This appendix is not a part of ISA-S77.20 Fossil-Fuel Power Plant Simulators — Functional Requirements.)*

This appendix provides the recommended content of the documentation to be supplied with each type of simulator.

## D.1 Instructor documentation

The requirements of Table D.1 apply to the documentation of all the simulated plant systems.

**Table D.1 — Instructor documentation requirements**

| | Replica | Limited Scope | Generic |
|---|---|---|---|
| **Simulator operation manual** | | | |
| Simulated plan description | Yes | Yes | Yes |
| Simulated plant operating procedures | Yes | Yes | Yes |
| Malfunction causes and effects | Yes | Yes | Yes |
| **Instructor manual** | | | |
| General description | Yes | Yes | Yes |
| Instructor station operating procedures | Yes | Yes | Yes |

## D.2 Software documentation

### D.2.1 Plant models

The requirements of Table D.2 apply to the documentation of all the simulated plant systems.

**Table D.2 — Simulated plant systems documentation requirements**

| | Replica | Limited scope | Generic |
|---|---|---|---|
| **Functional specifications** | | | |
| System descriptions | Yes | Yes | Yes |
| Assumptions and simplifications | Yes | Yes | Yes |
| Simulation drawings | Yes | Yes | Yes |
| Interfaces with other systems | Yes | Yes | N/A |
| Interfaces with control room equipment | Yes | Yes | Yes |
| Interfaces with instructor station | Yes | Yes | Yes |
| Plant reference data | Yes | Yes | N/A |
| **Detailed design specifications** | | | |
| Symbol dictionaries | Yes | Yes | N/A |
| Equation derivation and simplifications | Yes | Yes | N/A |
| Flow charts, diagrams | Yes | Yes | N/A |
| Data calculations | Yes | Yes | N/A |
| Computer listings | Yes | Yes | N/A |
| **Engineering manual** | | | |
| Nomenclature | Yes | Yes | N/A |
| Symbols | Yes | Yes | N/A |
| Conventions | Yes | Yes | N/A |
| General modeling techniques | Yes | Yes | N/A |
| Standard algorithms, derivations, and simplifications | Yes | Yes | N/A |

### D.2.2 System software documentation

The requirements of Table D.3 apply to project-specific application software other than the plant models such as

1) Instructor station;
2) Plant computer; and
3) Distributed control system.

**Table D.3 — System software documentation requirements**

| | Replica | Limited scope | Generic |
|---|---|---|---|
| **Functional specifications** | | | |
| Functional descriptions | Yes | Yes | Yes |
| Operator-machine interface | Yes | Yes | Yes |
| Hardware requirements | Yes | Yes | Yes |
| Interfaces | Yes | Yes | N/A |
| **Detailed design documentation** | | | |
| Functions | Yes | Yes | N/A |
| Display formats | Yes | Yes | N/A |
| Report formats | Yes | Yes | N/A |
| Input/output formats | Yes | Yes | N/A |
| Error messages | Yes | Yes | N/A |
| Pseudo-code or flow charts | Yes | Yes | N/A |
| Program and file structures | Yes | Yes | N/A |
| Memory and bulk storage requirements | Yes | Yes | N/A |
| Maintenance and modification procedures | Yes | Yes | N/A |
| Listings | Yes | Yes | N/A |

### D.2.3 Software tools documentation

The requirements of Table D.4 apply to all software tools supplied for the modification and maintenance of the simulator software.

**Table D.4 — Software tools documentation requirements**

| | Replica | Limited scope | Generic |
|---|---|---|---|
| **Reference manuals** | | | |
| Purpose | Yes | Yes | N/A |
| Narrative description | Yes | Yes | N/A |
| Function descriptions | Yes | Yes | N/A |
| Error messages | Yes | Yes | N/A |

### D.2.4 Vendor manuals

The requirements of Table D.5 apply to the documentation of all the simulated plant systems.

**Table D.5 — Vendor manuals documentation requirements**

| | Replica | Limited scope | Generic |
|---|---|---|---|
| Operating system | Yes | Yes | Yes |
| Compilers | Yes | Yes | N/A |
| Program development | Yes | Yes | N/A |
| Environment | Yes | Yes | N/A |

## D.3 Hardware documentation

### D.3.1 Computer, peripherals, and I/O equipment

The requirements of Table D.6 apply to all computer and peripheral equipment that is related to:

1) Simulation computers;

2) Instructor station peripherals;

3) Plant computer peripherals;

4) Distributed control systems; and

5) I/O interface.

**Table D.6 — Hardware documentation requirements**

| | Replica | Limited scope | Generic |
|---|---|---|---|
| Hardware description manuals | Yes | Yes | Yes |
| Equipment description and layout | Yes | Yes | Yes |
| Assembly drawings | Yes | Yes | Yes |
| Front view centerline drawings | Yes | Yes | Yes |
| Wiring diagrams | Yes | Yes | Yes |
| Connector termination lists | Yes | Yes | Yes |
| Cable tabulation and routine sheets | Yes | Yes | Yes |
| Bills of material and parts list | Yes | Yes | Yes |
| Elementary diagrams | Yes | Yes | Yes |
| Input/output lists | Yes | Yes | Yes |
| Calibration sheets | Yes | Yes | Yes |
| Instrument O&M manuals | Yes | Yes | Yes |
| Diagnostics | Yes | Yes | Yes |

### D.3.2 Site manuals

**Table D.7 — Site manual requirements**

| | Replica | Limited scope | Generic |
|---|---|---|---|
| **Space and environmental requirements** | | | |
| Simulator layout | Yes | Yes | Yes |
| Equipment dimensions | Yes | Yes | Yes |
| Environmental specifications | Yes | Yes | Yes |
| Heat load | Yes | Yes | Yes |
| Power requirements | Yes | Yes | Yes |
| **Site preparation and installation** | | | |
| Floor construction | Yes | Yes | Yes |
| Fire protection | Yes | Yes | Yes |
| Equipment required for installation | Yes | Yes | Yes |
| Electrical requirements | Yes | Yes | Yes |
| Unpacking instructions | Yes | Yes | Yes |

# Appendix E Simulation versus stimulation

*(This appendix is not a part of ISA-S77.20 Fossil-Fuel Power Plant Simulators — Functional Requirements.)*

In a simulator, several methods are available to replicate actual instrumentation. The following discussion and guidelines apply to computer or microcomputer-based instrumentation systems. Three methods are applicable:

1) Stimulation, which uses the actual system hardware and software, modified to function properly in the simulator environment.

2) Simulation, which uses alternate hardware and software programmed to emulate the instrumentation system's operator-machine interface, without necessarily replicating all its functions.

3) Partial simulation, which uses the actual system hardware and software to replicate the operator-machine interface. However, actual functions (e.g., control loops, efficiency calculations) are emulated in the simulation computer.

Selection of the method to be applied for a specific project requires the consideration of a number of technical and cost-related factors. The following provides the user with guidelines to assist in selecting the most suitable method for a specific application.

**E.1 Stimulation:** The stimulation method involves the interfacing of the stimulated system to the simulation computer. The hardware between the two computer systems can be implemented by means of a high-speed parallel data interface, high-speed asynchronous interface, gateways, or a custom-built interface. Software must be provided for communication and synchronization between the two computers. In addition, the stimulated software should be modified to accommodate the following simulator modes of operation:

a) Freeze/run

b) Fast/slow time

c) Backtrack/replay

d) Initial conditions save/load

e) Snapshots

f) Simulated equipment malfunctions

The following are advantages of the stimulation method:

- Stimulated software and configurations are easier to keep up to date with the plant.
- Plant spare hardware can be used for the simulator.
- Stimulation is potentially more cost-effective, since systems are getting more and more complex and, therefore, more costly to emulate.

The following are disadvantages of the stimulation method:

- Possible limitations in the communication throughput between the stimulated system and the simulator may limit update rates to the point that the simulated processes are difficult or impossible to control (distributed control systems).
- Modification to the stimulated software required to accommodate the stimulator modes of operation are strongly dependent on the system internal architecture and can be extensive.

**E.2 Simulation:** In the simulation method, either the simulation computer or a dedicated computer integrated with the simulation computer is used as a substitute for the actual plant hardware. Software must be developed to replicate both the operator-machine interface and the system functions. Functions normally inaccessible to the control room operator (e.g., engineering functions) do not need to be reproduced.

The following are advantages of the simulation method:

- Ease of accommodating simulator modes of operation and malfunctions.
- Cost-effectiveness, especially if emulation software is available "off-the-shelf" and simulation computer resources can be shared.
- Lower hardware maintenance, training, and spare parts costs.

The following are disadvantages of the simulation method:

- The possibility of discrepancies in the actual system.
- Higher software maintenance costs.

**E.3 Partial stimulation:** The partial stimulation method is an attempt to combine the best of both the simulation and the stimulation methods, in that only the operator-machine interface hardware and software are stimulated, while the system functions (e.g., control loops, performance calculations) are simulated on the simulation computer.

Advantages of the partial stimulation method are as follows:

- It is easy to accommodate simulator modes of operation and malfunctions.
- Partial stimulation provides high visual fidelity.
- The lowest combined software/hardware maintenance costs are associated with partial stimulation.

Disadvantages of the partial stimulation method include the following:

- Possible discrepancies between simulated and actual system functions.
- Possible interface throughput limitations for large systems.

The selection of any of these three methods requires a careful analysis of the complete life-cycle costs associated with each for a specific application, including:

1) Hardware equipment;
2) Software design, development, and testing activities, including user involvement (e.g., design reviews, data collection);
3) Hardware and software maintenance and updates;
4) Training; and
5) Documentation.

Other cost-related factors should be considered, where applicable, such as

1) Availability of in-house spare equipment;
2) Importance of visual fidelity versus functionality; and
3) Acceptability of a limited functionality during certain modes of operation (e.g., backtrack/replay).

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