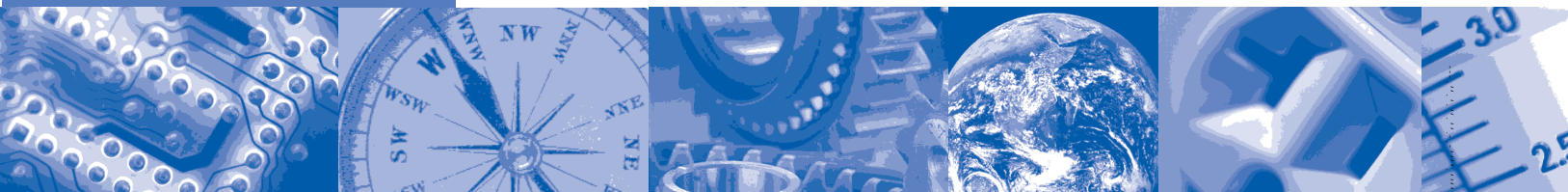


ANSI/ISA-77.20-1993 (R2005)



Fossil Fuel Power Plant Simulators – Functional Requirements



**ISA–The Instrumentation,
Systems, and
Automation Society**

Approved 20 July 2005



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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.