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Selective Catalytic Reduction (SCR) Control Systems

Approved June 3, 2019

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Selective Catalytic Reduction (SCR) Control Systems

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1 Purpose

The purpose of this standard is to establish the minimum design requirements for the functional design specifications of selective catalytic reduction control systems for use in fossil-fired power plants.

2 Scope

This standard will address the control functions associated with the selective catalytic reduction systems on fossil-fired steam boilers greater than 200,000 lbs/hr and combustion turbines greater than 25 megawatts. This includes the outlet NO_x control using ammonia flow control, startup and shutdown logic, bypass/isolation logic, dilution air system control, ammonia storage and delivery system control, and catalyst cleaning systems. Urea to ammonia systems are excluded from the scope of this document.

3 Definitions

The following definitions are provided to clarify their use in this standard and may not be relevant to the use of the words in other texts. For other definitions, please refer to ISA-51.1-1979 (R1993), *Process Instrumentation Terminology*.

3.1

air

the mixture of oxygen, nitrogen, and other gases, which, with varying amounts of water vapor, forms the atmosphere of the earth

3.2

air purge

a flow of air through the furnace, boiler gas passages, and associated flues and ducts that will effectively remove any gaseous combustibles and replace them with air. Purging may also be accomplished by an inert medium.

3.3

alarm

an audible and/or visible means of indicating to the operator an equipment malfunction, process deviation, or abnormal condition requiring a response

3.4

aqueous ammonia

a liquid solution of ammonia and water. Normally the concentration of aqueous ammonia for use in SCRs is below 30%. Typical commercial concentrations are 29% and 19%.

3.5

ammonia slip

ammonia that passes through the SCR without reacting with the NO_x in the flue gas

3.6

anhydrous ammonia

essentially pure ammonia, 99.8% or higher ammonia content, typically referred to as commercial or metallurgical grade. Not diluted with water.

3.7**boiler**

the entire vessel in which steam or other vapor is generated for use external to the vessel. This includes the furnace, consisting of waterwall tubes; the firebox area, including burners and dampers; the convection area, consisting of any superheater, reheater, economizer sections or any combination thereof, as well as drums and headers.

3.8**burner**

a device or group of devices for the introduction of fuel and air into a combustion chamber at the velocity, turbulence, and concentration required to maintain ignition and combustion of fuel

3.9**cascade control system**

a control system in which the output of one controller (the outer loop) is the setpoint for another controller (the inner loop). The outer loop is normally a slow responding process as compared to the inner loop.

3.10**catalyst**

a substance that initiates a chemical reaction and enables it to proceed under milder conditions than otherwise possible

3.11**combustion**

the rapid chemical combination of oxygen with the combustible elements of a fuel, resulting in the production of heat

3.12**combustible**

the heat-producing constituent of a fuel, flue gas, or fly ash

3.13**control loop**

a combination of field devices and control functions arranged so that a controlled variable is measured and compared to the setpoint to create a deviation signal, which is then processed through a controller to produce an output in the form of a manipulated variable to a control actuator

3.14**controller**

any manual or automatic device or system of devices used to regulate a process within defined parameters. If automatic, the device or system responds to variations in a process variable.

3.15**deviation**

the difference between the loop setpoint and the process variable (also called loop error)

3.16**differential pressure flow element**

a measuring element that is inserted in a process flow path and used to create a pressure drop that is proportional to the square of the rate of flow

3.17

drum (steam)

a closed vessel designed to withstand internal pressure. A device for collecting and separating the steam/water mixture circulated through the boiler.

3.18

error

see 3.15 deviation

3.19

excess air

air supplied for combustion in excess of theoretical combustion air

3.20

fail safe

the capability to go to a predetermined state in the event of a specific malfunction

3.21

feedback

a signal produced by a measuring device that is proportional to the magnitude of a controlled variable or position of a control element

3.22

final control element

the component of a control system (such as a control valve) that directly regulates the flow of energy or material to or from the process

3.23

firing rate

the rate of fuel combustion in a boiler

3.24

flue gas

the gaseous products of combustion in the flue to the stack

3.25

fuel

a substance containing combustible material used for generating heat; coal, oil, and gas are fuels referenced in this standard

3.26

fuel trip

the automatic shutoff of a specific fuel as the result of an interlock or operator action

3.27

furnace

an enclosed space provided for the combustion of fuel

3.28

furnace pressure

the pressure of gases in the furnace (see also draft)

3.29**induced draft fan**

a fan exhausting flue gases from the furnace

3.30**instrument**

a device used directly or indirectly to measure and/or control a process variable. The term includes primary elements, final control elements, measuring devices, computing devices, and electrical devices, such as annunciators, switches, and push buttons. The term does not apply to parts that are internal components of an instrument (e.g., a receiver bellows or a resistor).

3.31**integral control action**

an action in which the controller's output is proportional to the time integral of the error input. When used in combination with proportional action, it previously was called reset action.

3.32**integral windup**

the saturation of the integral controller output in the presence of a continuous error, which may cause unacceptable response in returning the process to its setpoint within acceptable limits of time and overshoot.

3.33**interlock**

a device or group of devices (hardware or software) arranged to sense a limit or off-limit condition, or improper sequence of events, and to shut down the offending or related piece of equipment, or to prevent proceeding in an improper sequence in order to avoid an undesirable condition.

3.34**load**

the boiler power output (rate of energy flow), usually expressed as steam flow of a certain enthalpy or equivalent gross megawatts

3.35**load index**

signal representative of desired output energy flow rate

3.36**master fuel trip (MFT)**

an event resulting in the rapid shutoff of all fuel. (See 3.26 fuel trip.)

3.37**mode (submode)**

a particular operating state of a control system, such as manual, automatic, remote, coordinated, etc. A mode is usually designed to achieve a desired control strategy.

3.38**molar ratio**

the ratio of the number of molecules of each substance involved in a balanced chemical reaction

3.39**nitrogen oxides (NO_x)**

the nitrogen oxides controlled by SCRs are mainly NO and NO₂ and are products of combustion

3.40

protective logic circuits

logic circuits designed to prevent damage to equipment by related system equipment malfunctions, failure, or operator errors

3.41

redundant (redundancy)

duplication or repetition of devices in electronic or mechanical equipment to provide alternative functional channels in case of failure of one of the devices

3.42

selective catalytic reduction (SCR)

a process for reducing the NO_x emissions from power plants by passing the flue gas over a catalyst in the presence of ammonia and oxygen

3.43

setpoint

the desired operating value of the process variable

3.44

shall, should, and may

the word "shall" is to be understood as a requirement; the word "should" as a recommendation; and the word "may" as a permissive, neither mandatory nor recommended

3.45

sootblower

a device used to remove soot from heating surfaces in boilers, typically with high velocity jets of steam or air

3.46

steam header

pipe in which steam output from multiple boilers is collected and then distributed to various steam loads

3.47

theoretical (stoichiometric) combustion air

the chemically correct amount of air required for complete combustion of a given quantity of a specific fuel

3.48

tracking

forcing an inactive control function to follow the active control function so that upon a mode transfer, no process upset occurs

3.49

trip

the automatic removal from operation of specific equipment or the automatic discontinuance of a process action or condition as the result of an interlock or operator action

3.50**turbine**

a machine that converts energy from a moving fluid into rotating mechanical energy to drive a load. In a power plant, a turbine converts energy in the steam into mechanical energy to drive an electric generator (the load) or an auxiliary, such as a boiler feedpump.

3.51**two-out-of-three logic circuit (2/3 logic circuit)**

a logic circuit that employs three independent inputs and whose output of the logic circuit is the same state as any two matching input states

3.52**urea**

an organic compound which can be decomposed into ammonia. Urea is sometimes used as a precursor of ammonia for an SCR.

3.53**vaporizer**

equipment used to convert liquid ammonia into ammonia vapor by adding heat to the ammonia

4 Minimum design requirements for SCR control systems

In order to establish minimum criteria, the SCR control systems specification shall include the following as part of the system design basis:

- Maximum and minimum unit load (steaming capacity)
- Normal operating load range
- Anticipated load changes
- Start-up and shutdown frequency
- Degree of automation
- Boiler auxiliary maximum and minimum capacities
- Type of fuel
- Flue-gas temperatures leaving the boiler
- Seasonal requirements of the SCR, if any

The SCR control systems shall meet operational requirements and correctly interface with the process. To accomplish this objective, the following requirements are defined for minimum system design:

- Process measurement requirements
- Control and logic requirements
- Final control device requirements
- System reliability and availability requirements
- Alarm requirements
- Operator interface requirements

This standard is applicable to both steam boiler power plants and combustion turbine power plants. In some sections a requirement only applies to one type of plant and should be disregarded for applications on the other type of plant.

4.1 Process measurement requirements

4.1.1 Instrument installation for SCR controls

Process sensing devices should be installed as close as practical to the source of the measurement with consideration being given to excessive vibration, temperature, and access for periodic maintenance. Separate isolation valves and impulse lines should be run to each pressure-sensing device used for control. No copper or copper-based alloy shall be used for any ammonia-wetted fittings, tubing, or instrumentation.

For measurements in flue-gas ducts, multiple sensors may be required to get a representative measurement.

4.1.2 Measurement conditioning

Filtering techniques used to condition process measurements shall not adversely affect stability or reduce control system response.

4.1.3 Process measurements

4.1.3.1 Ammonia storage and delivery subsystem

- Ammonia storage tank level
One local measurement is required, and one remote measurement separate from and independent of the local measurement is also required. This is used to compute the quantity (in percent of tank capacity) of ammonia liquid in the tank.
- Ammonia storage tank pressure
Two redundant measurements are required. The sensor should measure both pressure and vacuum.
- Ammonia storage tank temperature
- Fogging system supply pressure
- Safety shower activation sensor
- Supply header suction pressure
- Supply header discharge pressure
- Forwarding pump suction strainer differential pressure

4.1.3.2 Dilution air and ammonia flow control subsystem

- Inlet NO_x concentration or calculated index for inlet NO_x concentration
- Outlet NO_x concentration
- Flue-gas flow rate or calculated index for flue-gas flow rate
- Ammonia-mass flow rate
- Dilution air-mass flow rate (for anhydrous systems)
- Dilution air temperature (for anhydrous systems)
- Dilution air pressure (for anhydrous systems)

- Heater (air/gas) flow
- Heater (air/gas) temperature
- Heater (air/gas) pressure
- Ammonia filter differential pressure
- Ammonia flow-control valve discharge pressure
- Ammonia vaporizer sump temperature
- Ammonia and diluent mixture temperature
- SCR flue-gas inlet temperature

4.1.3.3 Startup and shutdown subsystem

- Economizer outlet temperature
- SCR flue-gas inlet temperature
- SCR flue-gas outlet temperature
- Catalyst (or reactor steel) temperature

4.1.3.4 Flue-gas bypass and isolation subsystem

- Inlet and outlet damper seal air differential pressure (if seal air is provided)
- Dehumidifier heater inlet temperature (if required). (Depending on duct size and arrangement, a grid of temperature sensors may be required to obtain a representative measurement.)
- Dehumidifier heater outlet temperature
- Warming medium temperature (e.g., air or flue gas)
- SCR outlet temperature. (Depending on duct size and arrangement, a grid of temperature sensors may be required to obtain a representative measurement. The lowest of these readings should be used.)

4.1.3.5 Catalyst cleaning subsystem

- Overall SCR differential pressure
- Each catalyst layer differential pressure
- Sootblowing medium (steam or air) supply pressure
- Sootblowing medium (steam only) supply temperature
- Sonic air-horn supply pressure
- Sootblowing steam-header drain temperature

4.1.3.6 Ammonia leak-detection systems

- Ambient ammonia concentration

4.2 Control and logic requirements

Automatic tracking shall be provided for bumpless control-mode transfer for all modulating control systems described in 4.2.1 through 4.2.5 below.

4.2.1 Ammonia storage and delivery subsystem

4.2.1.1 Truck or train unloading

The train or truck unloading control system shall include a manually initiated emergency automatic shutdown function. In addition, an automatically initiated shutdown shall occur when a high-ambient ammonia concentration (50-100 ppm) is detected. For anhydrous ammonia systems, the unloading system shall be automatically shutdown if the storage tank level is high or the storage tank pressure is high. An interlock to ensure the physical connection of transfer hoses before ammonia is unloaded shall be provided.

4.2.1.2 Anhydrous ammonia system

A schematic of the anhydrous ammonia system is presented in Figure 4-1, where the ammonia storage and the ammonia flow control unit skid (AFCU skid) are labeled. In the ammonia storage section, concentrated ammonia (NH_3) is stored as a liquid in a pressurized NH_3 storage tank. An external heater is used to maintain a specified minimum saturation temperature and pressure in the tank. A measured flow rate of saturated ammonia gas is then extracted from storage to the AFCU skid where dilution air is added. The air and ammonia mixture metered by an ammonia flow control unit is then piped to the ammonia injection grid.

An alternate arrangement in which liquid ammonia is drawn from the bottom of the storage tank and transferred to a stand-alone vaporizer system is shown in Figure 4-2. Ammonia vapors generated by this vaporizer are diluted with ambient air and transferred to the ammonia injection grid.

The anhydrous ammonia system typically provides to the lowest equipment and operating costs. This system presents safety concerns, as high-concentration ammonia has to be shipped to, and stored at, the site. It can only be used at locations that can be continuously restricted to professional access for handling.

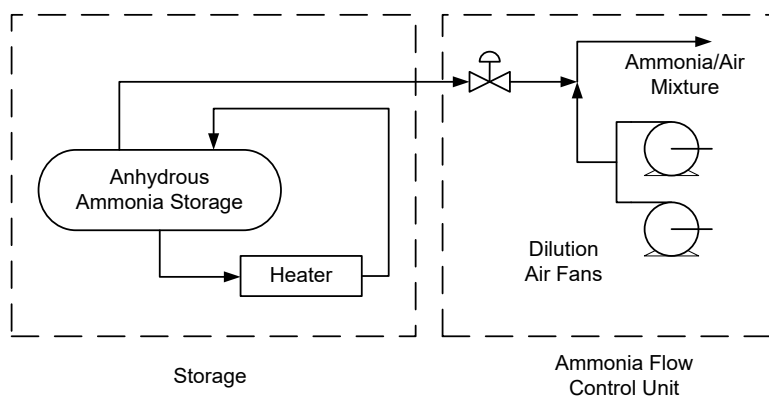


Figure 4-1
Anhydrous system for low-ammonia flow requirements