SCR System Operating Experience at AES Somerset

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Abstract

The AES Somerset Station in New York added a selective catalytic reduction (SCR) system to Unit 1 over the winter of 1998/1999 to further reduce NO_x emissions from this plant. This was the first large U.S. coal-fired SCR retrofit and was placed in service in 1999. As of October 2002, the Somerset SCR system has operated during four ozone seasons.

Somerset Unit 1 (formerly Kintigh) is a 675MW radiant boiler firing eastern bituminous medium-sulfur coals. This unit began operation in 1984 with an electrostatic precipitator and wet flue gas desulfurization system. Dual register burners were installed for combustion NO_x control. The new SCR is designed for 90% NO_x reduction with an ammonia slip of 3 ppm after 24,000 operating hours.

This paper describes the Somerset SCR and provides an update to the operating experiences along with the alterations and improvements that have been incorporated into system operation and hardware. The paper includes the major lessons learned in the areas of ammonia vaporization, NO_x monitoring, and other operating issues. Outage inspection findings in the reactor, flues, and ammonia injection grid areas are noted, and catalyst performance activity results are provided.

Introduction

AES Corporation, Arlington, Virginia, is a global power producer that owns and operates power plants around the world. In August of 1998 AES was the successful bidder for the generating assets of New York State Electric & Gas which consisted of 11 units and 1440 MW. Upon transfer of ownership these units became 100% merchant plants, thus making successful operation contingent on the ability to produce power at the lowest possible cost.

The Somerset Station was the largest and newest of these assets with a rated capacity of 675 MW. Somerset is a single unit firing pulverized coal with a B&W Radiant type boiler designed to generate 4,485,000 lb/hr of superheated steam at 2950 psig and 1005F. The turbine-generator was provided by GE. Originally commissioned in 1984, Somerset was built to New Source Performance Standards which included dual register low NO_x burners for combustion NO_x control. Particulate control for Somerset utilized an electrostatic precipitator to reduce emissions to 0.03 lb/million Btu and 20% opacity. SO_2 control was achieved by a wet flue gas desulfurization (FGD) system to reduce emissions to 0.6 lb/million Btu.

Since the Somerset plant was a high emitter of NO_x, one of the first activities AES undertook as new owner was to address the NO_x issue. AES reviewed all available NO_x reduction technologies and selected the SCR as the most effective method of meeting the plant's long term needs. In late September of 1998 B&W was awarded the contract for the design, manufacture, installation, and startup of the SCR system. AES specified that the SCR must be in operation for the 1999 ozone season, so project activities commenced immediately.

SCR Description

The SCR system at Somerset was installed in the high dust location between the boiler economizer outlet and the air heater inlet. System components in the flue gas stream consist of the reactor, dual connecting flues both inlet and outlet to convey hot flue gas, SCR bypass flues for isolation during the non-ozone season, economizer bypass flues to maximize gas temperature, dampers for isolation and control, ammonia injection grids (AIG), flue expansion joints, and catalyst. This SCR reactor is a four catalyst layer or stage reactor with the three upper layers installed initially (a 3 + 1 design). Each catalyst layer contains 144 modules arranged in a 12 x 12 array. This results in a 80 ft wide x 40 ft deep reactor cross section. The reactor is 45 ft in height. Figure 1 provides a side view of the Somerset project and the SCR equipment arrangement.

Design and Performance

The Somerset SCR design and performance conditions as originally specified are given in Table 1. The 675 MW unit rating results in a flue gas flow of 6.5 million lb/hr and the 0.55 lb/million Btu normal boiler NO_x emission converts to 410 ppm on an actual dry basis. The 90% design NO_x reduction results in an emission value that is significantly less than typical boiler emission regulations. At the time of project award, AES selected 3 ppm ammonia slip as the design value at the end of the 24,000 hour design catalyst performance life. It should be noted that the specified eastern bituminous coals contain a relatively low arsenic content and the ash contains some amount of calcium, so the arsenic was anticipated to have minimal effects on the normal catalyst deterioration rate when designed for these coals. A low value for the time of 0.75% SO_2 oxidation across the catalyst was specified to minimize the effects of the SCR addition on SO_3 concentration. The outcome of these design and performance conditions resulted in the selection of 897 m^3 of 6 mm plate-type catalyst from Babcock Hitachi to meet the NO_x emissions.

Reagent Storage, Supply, and Injection Systems

Anhydrous ammonia was selected as the reagent for the SCR NO_x reduction. On-site storage consists of two 45,000 gallon bullet shaped storage tanks sized to meet a 14 day storage requirement. Ammonia can be shipped to the site by either tank

Figure 1 Somerset SCR project.

Table 1
Somerset SCR Design and Performance

Unit Size	675 MW
Inlet NO_x	0.55 lb/million Btu
Outlet NO_x	0.055 lb/million Btu
NO_x Reduction	90%
Ammonia Slip	3 ppm
Catalyst Life	24,000 hours
Sulfur in Coal	2.5 – 3.0 %
CaO in Ash	3 – 6 %
Arsenic in Coal	< 10 ppm
Flue Gas Temperature	650 F
SO_2 to SO_3 Conversion	0.75 %
Catalyst Volume	897 m^3 – 6 mm

truck or rail car. Additional equipment in the storage area includes two unloading compressors along with three 50% electric vaporizers. A normal compliment of ambient ammonia detectors, alarms, vents, fogging deluge system, instrumentation, controls, circuit breakers, and platforms were also supplied to complete the system. The process design of the ammonia vapor supply system uses the vaporizers to maintain a constant vapor pressure in the tanks. Liquid ammonia is drawn off the bottom of either tank and passes through a vaporizer where the liquid evaporates and returns to the top of the tank.

Pressurized ammonia vapor from the top of the tank is transported 1500 feet to the flow control valve skids located within the SCR perimeter. After metering and flow control, the vapor from each control system is injected into a dilution air mixer for transport to the manifold valve station and ammonia injection grid (AIG). The source of the dilution air is from the discharge of the primary air fan that provides ambient temperature air. Since there are two flues from the boiler outlet to the SCR reactor there are independent ammonia injection grids in each flue. The AIG is a zone flow control design that includes 21 injection zones in each flue in a 7 x 3 array. Each zone has multiple injection nozzles to distribute the ammonia evenly across the gas path. Thus, the ammonia is carried from the storage tank to the flow control skid, to the mixer, to the manifold valve station for distribution, and ultimately to the injection grid. Essentially the dilution air provides a constant flow medium for injecting the required ammonia for the reaction with the NO_x. Figure 2 shows the Somerset AIG.

Startup and Early Operation

The SCR tie-in outage, six week duration, occurred in May and June 1999 following construction. Installation of the SCR equipment and all auxiliaries took place from December 14, 1998 to June 1999. Due to delays in finalizing the operating permit issues, the first injection of ammonia occurred in July 1999. The remaining startup and optimization activities for the SCR system were carried out over the next thirty days.

The short design, engineering, procurement, and installation time frame for this project did not allow in-depth reviews of all interrelated sub-systems. The initial operation of the SCR demonstrated that while all equipment functioned as designed, there were some items that were not optimized for the actual operation.

Following is a discussion of three areas that required some alteration to provide a more functional system.

In the ammonia storage area, early operation indicated that ammonia vaporization could not keep up with ammonia flow

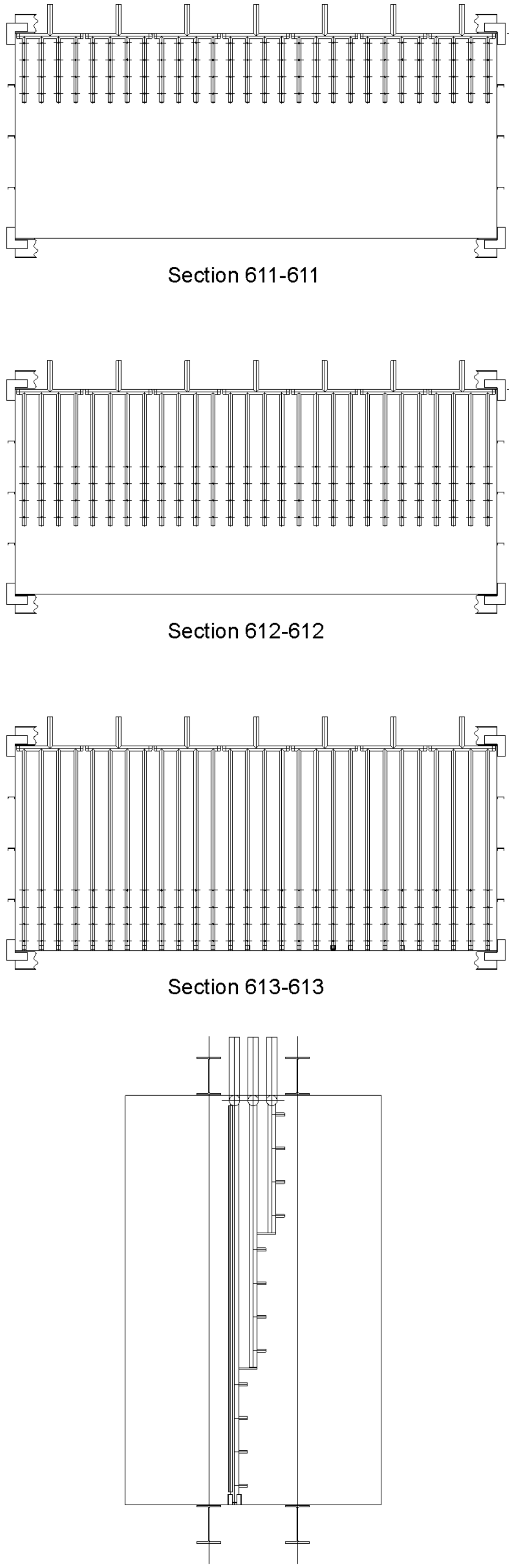

Figure 2 Somerset ammonia injection grid.

demand. After some difficulties with the vaporizer electrical components the resolution was to revise the piping from the vaporizer discharge back to the tank to allow this subsystem to function over the full operating range. As back-up, a liquid ammonia feed pump was added to the piping between the tank and the vaporizers; however, this pump has never been needed to achieve the required ammonia flow rates. Thus, after the piping revisions, the vaporization system functions as originally designed. This includes some non-ozone season operation when ambient temperatures are much cooler than ozone season conditions.

The initial design of the NO_x monitoring system included extractive-type NO_x analyzer equipment along with a multiple point flue gas sampling system. Four NO_x analyzers were provided with one in each SCR inlet flue and one in each outlet flue for the typical feed forward and outlet NO_x trim for ammonia flow control. The gas sampling system used the pressure drop across the air heaters to generate an average sample from multiple points across each individual flue from which to draw the actual sample for gas analysis.

The gas sampling system worked well enough although some minor piping changes were required to avoid ash fallout. However, the system that extracted gas from the average sample for analysis and the analyzer system itself had major operating difficulties. After considerable work in trying to get a more functional system with the original equipment, and after some component replacements, the decision was made to replace the system.

The selected replacement equipment was an in-situ opto-electronic type analyzer system. Four in-situ instruments were installed at strategic positions to provide the same ammonia flow control functions as originally intended. This replacement NO_x analyzer system has proved to be much more reliable and accurate. The lesson learned is that reliability of the selected NO_x monitoring system is the over-riding design requirement.

The third significant area of equipment reliability difficulty was the large dampers located in the horizontal flow connecting flues at the SCR outlet. During startup activities the dampers indicated an internal binding with closing difficulties which did not provide the operability or tight seal that was required by design. The cause of the binding was a deflection in the outer damper frame during unit operation. This deflection was caused by the interface with the flues and the induced draft negative pressures placed on the damper frames. The solution was to reinforce the damper frame and readjust seals. Therefore, the overall lesson learned was to provide more engineering interface between the damper supplier and flue designer to confirm the structural design.

Subsequent Operation

The SCR system at Somerset has now operated for four ozone seasons plus some amount of time throughout the rest of the year to reduce NO_x and achieve New York NO_x emission requirements. Experiences in key areas of operation after SCR addition are provided in the following descriptions.

NO_x Reduction

The SCR system has demonstrated that it can and will achieve the 90% design NO_x reduction; however, typical operating NO_x reduction at the higher loads is closer to 85% which allows a more comfortable operating condition while achieving a low NO_x emission. During the design of the SCR system for Somerset it was decided to provide the largest economizer bypass flues

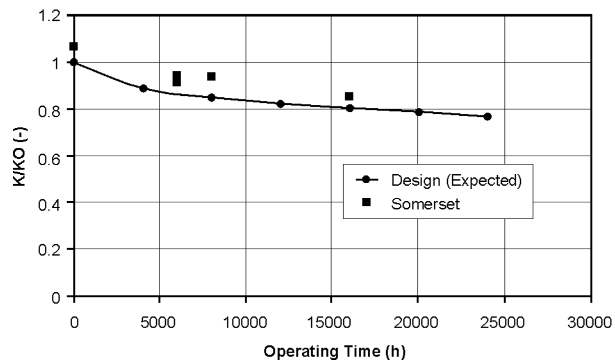

Figure 3 Somerset catalyst deactivation curve.

that could be installed with no major changes to the boiler and structural steel or movement of existing equipment. This limits the available gas flow that can be bypassed around the economizer and since the normal economizer outlet gas temperature is about 650F, it limits the available operating load range with the SCR in service. Thus, when the boiler is cycled to reduced load at off peak load periods, the ammonia injection is halted to prevent sulfate deposits on the catalyst. This mode of operation reduces the long-term NO_x reduction.

Ammonia Slip

Ammonia slip is monitored by measuring ammonia in the flyash, which is landfilled. Over the four ozone seasons of operation there has been the occasional increase in ammonia detected in the ash and some minor adjustments to the AIG distribution valves have been required to re-optimize the system. On infrequent occasions an ammonia odor has been detected from the ash when it is wetted and mixed with FGD sludge and lime as part of the landfill stabilization process. Based on the ash measurements, the ammonia slip values have remained low throughout the SCR operation.

Another method which would indicate ammonia slip levels is air heater pressure drop increase or more frequent air heater washing. At Somerset there has been no noticeable increase in air heater pressure drop and the frequency of air heater washing has been maintained at the same interval as before the SCR addition.

Catalyst

Catalyst performance and activity are typically monitored by observing the NO_x reduction and ammonia slip as well as the analysis of sample coupons and full length elements of catalyst. The preceding paragraphs have given an indication of the NO_x reduction and ammonia slip performance. Figure 3 provides the results of the multiple laboratory test measurements of catalyst activity from Somerset and how these measurements relate to design over the period of operation. The deactivation curve indicates that the catalyst activity level has remained above the expected activity. Laboratory tests have also indicated that although some increase of arsenic on the catalyst has been detected, poisoning from the arsenic has not been excessive.

Outage Inspections

After the initial SCR tie-in outage in 1999, the outages at Somerset have been infrequent and for only short periods of two days to one week. These outages have allowed internal inspection of the SCR system to monitor the operating effects on the SCR components. Inspection areas of most interest include the reactor and catalyst, the connecting flues, the AIG, the dampers, and the expansion joints.

Reactor and Catalyst

Steam sootblowers were provided above each layer of catalyst, and these blowers in combination with the uniform gas flow throughout the reactor have been quite effective in keeping ash accumulations to a minimum. The horizontal ledges of the structural components have accumulated ash until reaching an equilibrium, the flow straighteners have remained completely clear of ash, and the catalyst has also remained clean. Figure 4 provides a typical view of the reactor and the top layer of catalyst after operation. Minor ash accumulation has been noted on one of the two baffles located in the inlet hood but this has not been detrimental in any way. Some minor repair areas to the catalyst dust shields have been noted.

Connecting Flues

There was some concern for ash fallout in the horizontal flues leading to the SCR and at the SCR outlets to the air heater inlets. This portion of the SCR system was modeled extensively as part of the physical flow modeling activity during the engineering phase of the project, and baffles were strategically placed to provide uniform flow patterns throughout the system. Outage inspections have shown that the flues are swept clean as designed and as shown in Figure 5.

AIG

As described earlier, the AIG is a zone flow design with a series of vertical pipes and nozzles (see Figure 2). With the use of ambient air from the primary air fans as the dilution medium, there have been questions on this specific design regarding internal particulate formation. Although there was some initial, internal accumulation of material at the lower end of the grid piping caused by debris, subsequent inspections have indicated minimal deposits on the flow nozzles. Figures 6 and 7 provide views from AIG inspections in 2001 and 2002 which demonstrate no nozzle pluggage and only occasional and minor external accumulation.

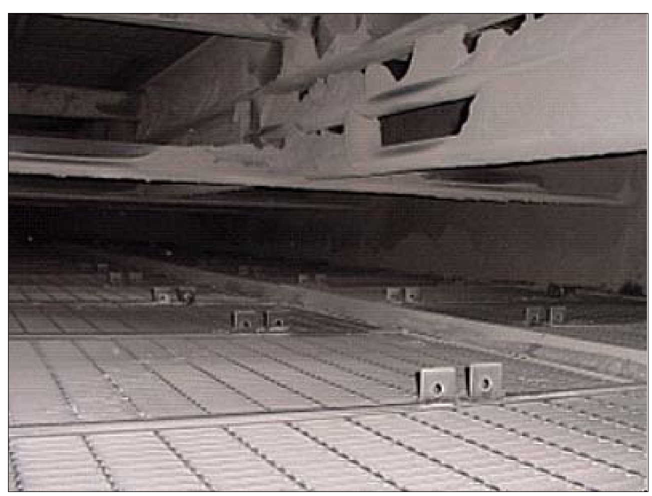

Figure 4 Reactor and catalyst inspection.

Dampers

With the very large flues, 650-700F flue gas temperatures, and the need for on-line damper operation, inspections of the internal components are always recommended. Other than the original SCR outlet damper binding referenced earlier, only minor maintenance of the dampers, seals and drive systems has been required. Figure 8 shows one of the SCR bypass dampers and indicates complete closure and seal.

Figure 5 Horizontal flue inspection.

Figure 6 Somerset AIG inspection December 2001.

Expansion Joints

A retrofit SCR installation is a rather stringent application for the required fabric-type expansion joints due to the large size, the flue gas temperature, the ash conditions, and the thermal movement/expansion of the boiler and the connecting flues. With the boiler expanding down, the SCR expanding up, and the flues expanding in multiple directions, it is sometimes difficult to predict the actual direction of expansion that will occur after field installation and opera-

Figure 7 Somerset AIG inspection April 2002.

Figure 8 SCR bypass damper.

Figure 9 Economizer bypass expansion joint.

tion. Figure 9 indicates one of the economizer bypass flue expansion joints where the breech opening was less than design allowing the fabric folds to overheat and fail. Expansion joints in all other locations were found in good condition.

Summary

The retrofit at Somerset has demonstrated that an SCR can be installed and operated successfully on a large coal-fired unit over an extended period of operation. After some initial equipment issues that required some alterations or replacements to make improvements, the SCR system has performed with high reliability. Operation of the SCR has resulted in minimal effects to downstream equipment even with the increase in SO_3 content and with the presence of ammonia slip. Outage inspections and testing have shown that the equipment can be selected to perform as designed and that the catalyst can meet the design life requirements.

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