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USING PEPSE FOR JUSTIFYING A PRECIPITATOR BYPASS DUCT

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ABSTRACT

The Nebraska Public Power District's Gerald Gentleman Station has replaced their electrostatic precipitators with baghouses. Part of the process was deciding if there was a need to bypass the precipitators. PEPSE was used to evaluate the potential performance improvement from bypassing the precipitators. The PEPSE evaluation included the analysis of air infiltration and thermal losses through the existing precipitators and their affect on boiler efficiency.

Introduction

Gerald Gentleman Station is Nebraska Public Power District's (NPPD's) largest generating station. The station consists of two nominal 650 Mw coal fired units.

Gentleman Station burns coal from the Powder River Basin (PRB) in northeast Wyoming. At the time Gentleman Station was designed, the industry consensus was that hot-side electrostatic precipitators should be used to remove ash from the flue gas for units burning PRB coal. As utilities gained operating experience burning PRB coal, it became apparent there were problems with combining PRB coal and hot-side precipitators. Hot-side precipitators did not work well with the ash composition and resistivity of PRB coal. In the eighties, utilities began to replace their hot-side precipitators with cold-side precipitators to bring their units to compliance with opacity regulations. As the technology improved, some utilities converted to baghouses. NPPD evaluated replacing the Gentleman Station precipitators in the eighties, but could not justify the expense. The units stayed in compliance by persistently maintaining the precipitators, regular precipitator cleanings, and conditioning the flue gas by adding soda ash to the coal.

In the nineties, the performance of the Gentleman Station precipitators began to deteriorate. Fields in the precipitators were regularly shorting from broken wires, warped plates, and other problems. Precipitator cleaning outages became more frequent and the station began to derate to stay in compliance. The units also had trouble staying compliant when changing loads. With the demand for electricity increasing and the industry becoming more competitive, these limitations were a problem for NPPD. Based upon these inputs, it was decided to replace the precipitators with reverse gas baghouses. Also included in the project were new induced draft fans and loose packed air heater baskets.

The Precipitator Bypass Challenge

One of the more difficult decisions involved determining if the precipitators should be bypassed. Since Gentleman Station was originally designed with hot-side precipitators, the precipitators were between the boilers and the air heaters. Options considered were:

1. Build a bypass duct around the precipitators for each unit. This was the ideal option, but it would increase the cost of the project close to thirty percent and require additional outage time for installation.
2. Continue to run the precipitators. Continuing to run the precipitators would mean continued operation and maintenance for the precipitators and their ash systems. The precipitator

power consumption, combined with the larger induced draft fans required for increased system pressure drop, could result in reduced station output.

3. Pass the gas through the de-energized precipitators and continue to run the precipitator ash systems. This option still required the operating and maintaining a second ash system per unit.
4. Pass the gas through the de-energized precipitators and not run the precipitator ash systems. This option would require putting a floor in the bottom of the precipitators to prevent ash from falling into hoppers below.

Two common problems with options 2, 3, and 4 were the pressure and temperature drops across the precipitators. With larger induced draft fans already required for the pressure drop through the baghouses, other system pressure drops needed to be kept at a minimum. Both units had a temperature drop of 80° F to 100° F through the precipitators.

The temperature drop was the combined loss of air infiltration and convective heat loss. The air infiltration was from induced air from the precipitator rapper systems, leaks around numerous doors in the precipitators, and tears in the ducts and expansion joints. (Air infiltration increases the induced draft fan horsepower and decreases the air heater efficiency.) The convective heat loss was from poor and aging insulation. (This part of the temperature drop decreases the amount of available energy to the air heaters.) Since the precipitator temperature drop was from two sources, calculating a heat rate loss by hand would have been difficult. The heat rate losses can be calculated relatively quickly if a working computer model is in place.

Testing and Modeling

To acquire accurate data for determining the efficiency losses from the precipitator temperature drop, the units were tested. The operating conditions for the tests were set by precipitator performance and system demand requirements. A third-party testing company was hired to measure flue gas conditions. Station personnel gathered coal and ash samples. The station distributed control systems (DCS) were used to acquire the remaining data. The measured temperature drop between the economizer and the air heater inlets was 94° F for Unit 1 and 104° F for Unit 2. The precipitator air infiltration for Unit 1 was 9.08% and 10.86% for Unit 2.

After the test data was gathered and organized, PEPSE was used to evaluate the data. PEPSE boiler models for both units were already in place. During the development of the models, a general heat exchanger had been included to represent the precipitator convective heat losses. An ambient air source had also been included for the precipitator air infiltration. Figure 1 shows the economizer to air heater arrangement for Unit 1. The precipitator heat loss was also included in the boiler efficiency calculations.

After data entry, the PEPSE models were tuned to the operating conditions of the boilers. The air heater and precipitator leakage rates were calculated separately and entered with the data. The leakage rates could have been calculated by using PEPSE controls. The reason for not using the PEPSE controls was the modeling phase needed to be completed quickly and controls sometimes cause convergence problems. The convective heat loss for the precipitator was calculated by a control that adjusted the heat loss to the measured gas inlet temperature of the air heaters.

For Unit 1, the model indicated a 55° F temperature drop from the 9.08% air infiltration. The results showed that 38° F of the precipitator temperature drop was from the convective heat loss. Unit 1's boiler efficiency was 81.60%.

For Unit 2 temperature drop from convective heat loss was 44° F. The 10.86% precipitator air infiltration was causing a 60° F decrease in temperature. The unit boiler efficiency was 82.71%.

After the tuning phase, several predictive cases were run. The first set of predictive runs was made with a 0% precipitator air infiltration using the convective heat losses from the tests. Just zeroing the air infiltration improved the Unit 1 boiler efficiency to 82.33%. After evaluating the changes in the temperatures around the air heater, it was decided to shut off the steam to the steam coil air preheaters. This change improved the boiler efficiency to 82.47%. After that, flue flow was adjusted to match the steam conditions of the tests. This adjustment increased the boiler efficiency to 82.65%.

Zeroing the precipitator air infiltration on Unit 2 improved boiler efficiency to 83.29%. Reducing the steam flow to the steam coil air preheaters increased the boiler efficiency to 83.47%. Adjusting the fuel increased the boiler efficiency to 83.58%.

A similar set of predictive calculations was run with a 10° F convective heat loss. A 10° F convective heat loss was used since it was considered the lowest feasible reduction that could be achieved. Reducing the convective heat loss increased the original boiler efficiency from 81.60% to 82.15% for Unit 1. When the steam coil air preheater flow was shut off, the boiler efficiency increased to 82.29%. Adjusting the fuel increased the boiler efficiency to 82.32%.

For Unit 2, the boiler efficiency increased from the original 82.71% to 83.16%, with a 10° F convective heat loss. Closing the steam coil air preheater steam flow increased the efficiency to 83.35%. The boiler efficiency increased to 83.39% when the fuel was adjusted.

The third set of predictive calculations was run with 0% air infiltration and a 10° F convective heat loss. Unit 1's boiler efficiency increased from the original 81.60% to 82.96%. The boiler efficiency increased to 83.10% when the steam-to-steam coil air preheater was closed. After the fuel was adjusted, the boiler efficiency increased to 83.18%. The increase in boiler efficiency from 81.60% to 83.18% would decrease Unit 1's 10,460 BTU/Kwh operating heat rate by 199 BTU/Kwh.

For Unit 2, the boiler efficiency increased to 83.81% from the original 82.71%, with a 10° F convective heat loss and 0% air infiltration. The boiler efficiency was 84.00% when the steam-to-steam coil air heaters was shut off. The boiler efficiency increased to 84.11% when fuel was adjusted. For Unit 2, the increase in boiler efficiency from 82.71% to 84.11% would reduce its 10,400 BTU/Kwh operating heat rate by 173 BTU/Kwh.

The savings that would be provided by the bypass ducts was calculated by combining the change in heat rate with the increased fan horsepower and cost of maintaining and operating an extra ash system per unit. The calculated savings were compared to the cost of the bypass ducts, including outage time for different duct routes. The most economical route for Unit 1 was to remove some of the inside precipitator boxes so the duct could be routed straight to the air heaters. This option provided a 4.6 year discounted payback. For Unit 2, it was possible to run a duct straight from the economizer to the air heaters without removing any existing structures. This option provided a 4.7 year discounted payback. The heat rate savings determined by PEPSE was over fifty percent of the total savings. Using this information, NPPD's management and Board of Directors approved the addition of the bypass ducts to the baghouse project.

Results and Conclusions

Reverse gas baghouses for both units were purchased from Wheelabrator Air Pollution Control, Inc. New axial flow induced draft fans for both units were purchased from TLT Babcock, Inc. Construction started for both units in 1999. The Unit 1 bypass and baghouse were placed in service in December 2000. The Unit 2 baghouse was placed in service in May 2001. Due to concerns that construction delays might extend into the summer season, the bypass duct for Unit 2 was not tied into the system in May 2001. The duct is in place and it is anticipated that it will be put in service during the next major Unit 2 outage in the spring of 2003.

Since January 1, 2001, Unit 1 has operated at a net capacity factor above 95% and without an opacity violation. Opacity has been averaging less than 1%. Post-installation test results show a temperature drop across the bypass duct of 18° F. Air infiltration figures for the bypass duct are not available, however, the system leakage from the economizer to the stack is approximately 10%. The boiler efficiency has been running around 83.3%. The increase in boiler efficiency is close to that predicted with the PRPSE model. Performance information for Unit 2 is not available at the time of this writing.

As with any large project, the Gentleman Station baghouse conversion was a team effort. PEPSE was a small but valuable part of this effort. As competition changes the industry, NPPD will continue to search for inventive methods to improve efficiency and control costs. Maintaining working PEPSE models has proven to be an important part in developing and evaluating large projects.

REFERENCES

PEPSE COMPUTER CODE, SCIENTECH, 440 West Broadway, Idaho Falls, ID Version 63, 1998

Figure 1: Unit 1 Precipitator Arrangement