REPLACEMENT OF PRECIPITATOR INTERNALS
BIG BEND UNIT 1

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Abstract

Big Bend 1 is a 420 MW coal-fired unit commissioned in 1970 and equipped with a Joy Western weighted-wire precipitator. In 1976, a second Joy Western precipitator was installed in parallel to meet the new environmental regulations. Since 1976, the performance of the electrostatic precipitators (ESPs) had deteriorated to the point where they could no longer meet the required particulate removal performance. The options considered were to rebuild the ESP internals in kind with weighted wire and nine inch plate spacing or utilize newer technology incorporating rigid electrodes and twelve inch plate spacing. The evaluation of the options included the following factors:

- Maintenance cost differential
- Impact on unit electrical distribution system
- Investment cost differential (material and labor)
- Particulate removal efficiency differential
- Operational flexibility

The evaluation led to selection of the 12-inch plate spacing design. This paper describes the rebuild project and includes recent data that confirm the correct decision was made.

Introduction

Unit 1 at Tampa Electric Company's (TECO) Big Bend Station is a 420 megawatt unit which was commissioned in 1970 with a Joy Western weighted-wire precipitator for particulate control. In 1976, a second Joy Western weighted-wire precipitator was installed in parallel to meet new environmental regulations. However, since that time, the electrostatic precipitators (ESP's) had deteriorated to the point where they could not consistently meet their particulate emission compliance limits. To ensure proper particulate control, it became necessary to replace the internals of both precipitators. The options considered included both rebuilding internals using the existing weighted-wire design with collecting plates on nine (9) inch centers and using new technology by rebuilding the internals with rigid discharge electrodes and collecting plates on twelve (12) inch centers. Numerous factors were considered in the evaluation of these options including:

1. The maintenance costs for the two systems.

2. The cost benefit of the wider plate spacing (including installation and material cost).

3. The potential for loss in precipitator performance using the new technology without increasing the overall size of each precipitator (to regain the original design specific collecting area).

4. The effect of the 12-inch plate spacing design on power requirements (Would it be necessary to increase the size of the main transformer and its feed?).

5. The impact to operations on fuel flexibility.

The evaluation incorporated TECO's ESP experience, ESP manufacturer's recommendations, and the results from several EPRI ESP studies.

Background

Tampa Electric Company's (TECO's) Big Bend Unit 1 was commissioned in October 1970. This unit has a Riley Stoker pulverized coal-fired boiler, with a Western Precipitation electrostatic precipitator. Table 1 provides selected precipitator parameters and information on the fuels the boiler was expected to burn. The precipitator's guaranteed collection efficiency was 99%, however this guarantee was never met. Actually, the precipitator efficiency was measured to be in the 98.3% to 98.6% range during numerous performance tests. In June 1976, a second Western Precipitation electrostatic precipitator was installed in parallel to meet new environmental regulations. Table 2 provides data for the second precipitator information and for a range of potential fuels. With the addition of the second precipitator, the guaranteed collection efficiency was increased to 99.8%. The test results typically produced efficiency in the 99.3% range. Again, the guaranteed efficiency was not met. The continued poor performance of precipitators resulted in high stack opacity readings which, in turn, caused periodic load restrictions. In October 1986, Tampa Electric Company commissioned Stone & Webster Engineering Corporation (SWEC) to perform a precipitator improvement study. As a result, a three-phase, three-year upgrade plan was recommended. This plan included:

- Installation of plate straighteners in fields 3 to 7 of west (new) precipitator.
- Replacement of the outlet two rows (fields 1 and 2) of plates, electrodes and associated equipment (west precipitator).
- Installation of new automatic voltage controls for both the east (old) and west (new) precipitators.
- Installation of new collecting plates and discharge electrode rappers and controls for both the east and west precipitators.
- Installation of new nuclear hopper level detectors for both the east and west precipitators.
- Biasing gas flow between the east and west precipitators. (40% to the east and 60% to the west.)

The installation of plate straighteners was completed in 1987. However, within a year of their installation, some of the plate straighteners became dislodged from their proper positions, and this movement would eventually lead to a ground of the associated field.

Following the completion of all the recommended SWEC improvements in 1990, additional efficiency tests were again conducted. The changes did improve the overall performance, but the efficiency only increased to 99.4%.

Finally, in 1991 during a routine outage inspection, more plate straighteners were found in the hoppers of the new precipitator. In addition, it was discovered that approximately 15 plates in the old precipitator had begun tearing at the bottom of the plate panels. At that point, it became necessary to develop a different approach to restore the integrity and performance of the two precipitators.

Options

As indicated earlier, the two principal options were concerned with the plate spacing and discharge electrode design. They were:

Option 1

Replace the internals of the two precipitators with the existing weighted wire design with collecting plates on nine (9) inch centers.

Option 2

Replace the internals of the two precipitators with new rigid electrode design with the collecting plates on twelve (12) inch centers.

Selection

Evaluation of the factors identified in the introduction produced the following conclusions:

- Maintenance Costs - The maintenance cost using option 2 was estimated to be approximately 50% less than the costs for the first option. This cost differential is due primarily to the elimination of manpower needed to remove grounds during outage times (resulting from broken wire). Rigid discharge electrodes have a very low rate of failure.
- Impact to the electrical distribution system - There would be no significant increase in electrical distribution requirements between options 1 or 2. This effect results from two characteristics of the wide plate spacing technology. In a typical installation, the power supply voltage increases at a rate that is roughly proportional to the plate spacing. However, the total current decreases at a rate that is inversely proportional to the plate spacing. The net result is no change in total power requirement as the plate spacing is increased (assuming fly ash properties do not change).
- Investment Cost Differential - The estimated cost of the project using option 1 was $5,200,000 and using option 2 the estimated cost was $4,000,000. Therefore, option 2's investment cost would be $1,200,000 less. This included material and installation costs.
- Particulate Removal Efficiency - With the help of EPRI's precipitator programs, it was determined that overall efficiency would change even though the overall SCA would be reduced by 25% using option 2. The evidence for this conclusion came from both pilot and full-scale studies that demonstrated that increasing the plate spacing (in a casing with a fixed size) would not reduce collection efficiency. In fact, these studies showed that ESP performance became less sensitive to small degrees of misalignment and actually resulted in improved performance in some installations.
- Operational Flexibility - Finally, by using option 2, there would be more flexibility in the fuels that could be burned.

Based on this analysis, it was decided to rebuild the ESP with a 12-inch plate spacing.

Performance After Construction

Big Bend 1 returned to service May 7, 1992 after a six (6) week major outage. It was obvious from the first day that the performance of the precipitators was improved. The stack opacity was running approximately 5%-10% less than it had before the rebuild. Six (6) months after the unit returned to service a performance test was run on the unit. The average efficiency was 99.55% with an overall particulate rate of 0.02298 pounds per million BTU of heat input to the boiler. (See Table 3 for summary of data.)

Conclusion

Since start-up, the Big Bend Unit No. 1 electrostatic precipitators have operated successfully, as noted above. The performance improvement is largely attributed to improved internal alignment. Furthermore, since the ESPs were rebuilt, there have been no discharge electrode failures. Based upon the excellent performance to date, it is anticipated that these units will continue to operate well in the future.

TABLE 1	
OLD PRECIPITATOR PERFORMANCE DATA	
Boiler output, lb steam per hr	2,830,000
Quantity flue gas at collector inlet, lb per hr	3,710,000
Flue gas temp, F	292
Corresponding flue gas flow, cfm	1,140,000
Draft loss, in. of water	Less than .5
Guaranteed collection efficiency, per cent	99.0
Inlet grain loading used as design basis grains/ft.3	4.7
Gas velocity, fps	6.4
Influence time, sec	3.75
Power input to line, kw Normal	452
Power input to precipitator, kw	407
Number of sections per side of precipitator	4
Active length of sections, ft.-in.	24-0
Number of ducts	132

COAL FOR OLD PRECIPITATOR (EAST)			
	(A) WESTERN KENTUCKY		(B) EASTERN KENTUCKY
Source	As Received, Per Cent	Dry, Per Cent	As Received, Per Cent
Moisture	10.79	--	7.5
Volatile	33.10	37.1	37.5
Fixed Carbon	44.25	49.6	48.6
Ash	11.86	13.3	6.4
Sulfur (Separate)	4.02	4.5	2.9
Btu Per Lb	11,126	12,470	13,670
Fusion Temp, F	2,050		2,230

TABLE 2	
NEW PRECIPITATOR PERFORMANCE DATA	
Design basis flue gas flow, acfm (to new precipitator)	900,000
Draft loss, furnished equipment inlet to furnished equipment outlet, in. of water	< 0.5
Inlet grain loading used as design basis, grains per actual cu. ft.	9.185
Average velocity based on actual cross sectional area open to flow, fps	4.76
Manufacturer's design value of particulate migration velocity, fps	0.345
Influence time, sec	6.3
Maximum precipitator outlet particulate loading, grains per actual cu. ft.	.02
Expected overall collection efficiency based on design inlet grain loading, percent	>99.8
Total maximum power input (including all fans, vibrators, rappers and control devices), kw, kva (Contractor's loads only)	1576 kva, 1435 kw
Useful corona power absorbed by precipitator electrodes, kw	1016
Power factor of operating precipitator, percent	90
Length of plate in contact with gas, ft.	36

COAL FOR OLD & NEW PRECIPITATORS (EAST & WEST)						
	Fixed Carbon	**Volatile Matter**	**Ash**	**Moisture**	**Sulfur**	**Btu/Lb as Fired**
Present Fuels						
A	40.01	34.79	13.20	12.00	3.82	10,810
B	42.78	34.84	10.38	12.00	2.98	11,220
C	46.79	32.76	11.45	9.00	2.84	11,837
D	40.57	37.37	12.06	10.00	3.73	11,432
Future Fuels						
E	38.15	33.56	17.54	10.75	4.24	10,180
F	37.98	33.37	17.28	11.37	4.56	9,971
G	42.02	32.68	11.30	14.00	3.18	10,580
H	38.37	30.97	17.66	13.00	4.09	9,683

TABLE 3			
FINAL PERFORMANCE TEST SUMMARY			
The efficiency of the total control system averaged 99.55 percent with an overall particulate emission rate of 0.02298 pounds per million BTU (lbs/MMBTU) of heat input to the boiler.			
Run Number	**Total System**	**New ESP (West)**	**Old ESP (East)**
1	99.60%	99.46%	99.79%
2	99.56%	99.64%	99.58%
3	99.46%	99.34%	99.66%
Average	99.55%	99.50%	99.69%
Particulate concentration averages at the individual sampling locations:			
Location	**gr/SCF**	**lbs/Hr**	**lbs/MMBTU**
Air Heater Outlet	2.9640	26302	4.8374
New ESP Inlet Duct	2.4109	11207	4.1134
New ESP Outlet Duct	0.01212	53.25	0.02045
Stack Inlet	0.01340	99.38	0.02298