Improvement of Heat Rate in Fossil Fired Plants by Management of Precipitator Power

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ABSTRACT:

Electrostatic precipitators that collect fly ash from fossil fired steam generators can use several megawatts of unit power. Although precipitator performance is governed by power input under classical conditions, there are times when precipitator power can be managed for significant energy savings without compromising performance standards. Reductions of between twenty and fifty percent of precipitator power can often be achieved. This reduction in precipitator power improves plant heat rate.

This paper discusses precipitator performance and power relationships and describes cases where precipitator power management has increased plant power available for sale.

INTRODUCTION:

The purpose of this paper is to introduce electrostatic precipitator power and performance relationships. The paper presents possibilities for energy savings through precipitator power management. Examples are included.

An electrostatic precipitator is basically an enlargement of the duct between the steam generator and the stack. Its electrodes create ducts parallel to gas flow. Electrode rows are equidistant and alternate between high voltage discharge and grounded collecting electrodes. The discharge electrodes create particle charging current. The voltage difference between electrodes creates a high intensity electrical field that moves the charged dust particles to the collecting electrodes where they form a layer of dust. The dust layer is disturbed by rapping the electrodes, and falls by gravity into hoppers located below the electrodes.

Precipitators use energy to move the dust laden gas. (Pressure drop through the precipitator is usually less than 1" wg.). They require energy to rap the electrodes and to remove the ash from the hoppers. Many precipitators use resistance heaters and small air blowers to keep support insulators warm and clean. The power required to charge and separate the dust from the gas represents the largest use of energy by the precipitator. This charging and collecting precipitator power is supplied by transformer rectifier sets and provides the greatest opportunity for precipitator power savings.

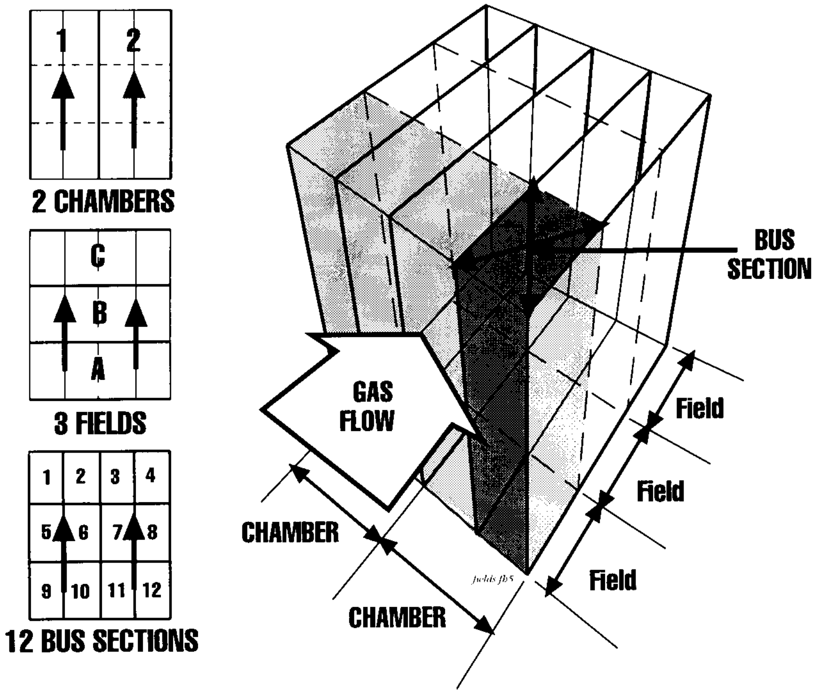
WHAT MAKES A PRECIPITATOR WORK

Precipitator efficiency depends on process conditions, the precipitator design, and the proper operation of controls, rappers, hopper evacuation and other subsystems. The process creates hot, dust-laden gas. The character of the gas, including its chemistry, moisture and temperature and the character of the dust, including its size, density, chemistry, and resistivity, determine the efficiency of a specific precipitator. The design of the specific precipitator will also determine its efficiency for specific process conditions.

Specific collection area (SCA) is the precipitator dimension used to describe its size relative to its process. SCA, expressed in units of precipitator collection area per volume of gas treated, must be normalized for plate spacing. Average and specific gas velocity through the precipitator, treatment time, and power input per gas volume are also precipitator dimensions which relate to process conditions.

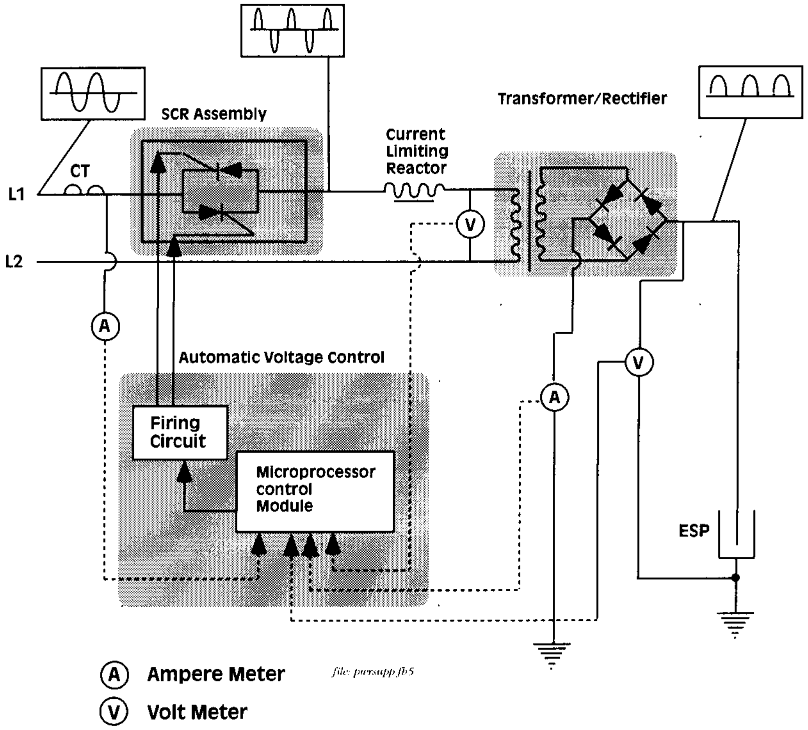
Absolute dimensions include the installed power and current per square foot of collection area, aspect ratio (treatment length divided by height), number and size of chambers, fields, bus sections and transformer-rectifier numbers and sizes. Rapping density is a relative dimension which does not relate to process. There are many other dimensions which describe precipitators. However, under reasonable process conditions, the size (SCA), gas velocity, aspect ratio, and power input have the largest effect on precipitator efficiency.

Figure 1: General Layout of Precipitator Fields, Sections, etc.



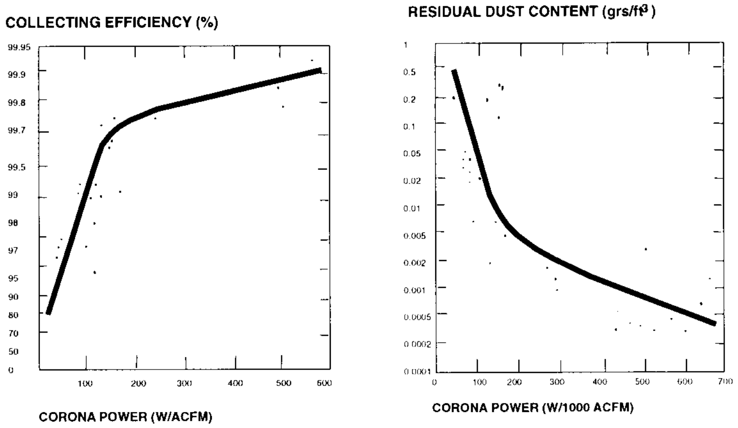
Precipitator power is supplied by transformer rectifier sets which take 400V to 600V primary power and transform it to 45KV to 100KV. The output is converted to pulsating direct current in the rectifier section. The power is controlled by back-to-back SCR switching fired at the direction of a logic circuit.

Figure 2: Power Supply and Control Circuit



The precipitator efficiency is related to power input as shown below under conditions of low to moderate dust resistivity.

Figure 3: Power Versus Efficiency



ENERGY SAVINGS UNDER CLASSICAL CONDITIONS

Precipitator sizing and design has generally become more conservative over the past twenty-five years. This trend results from: 1. Actual and anticipated tightening of particulate emission standards, 2. Better information on existing precipitator performance experience, 3. The desire for more flexibility in process fuels, and, 4. Reaction to difficulties in dealing with the operating sensitivities of marginally sized precipitators. SO3 conditioning of cold side precipitators has also improved the performance of many units.

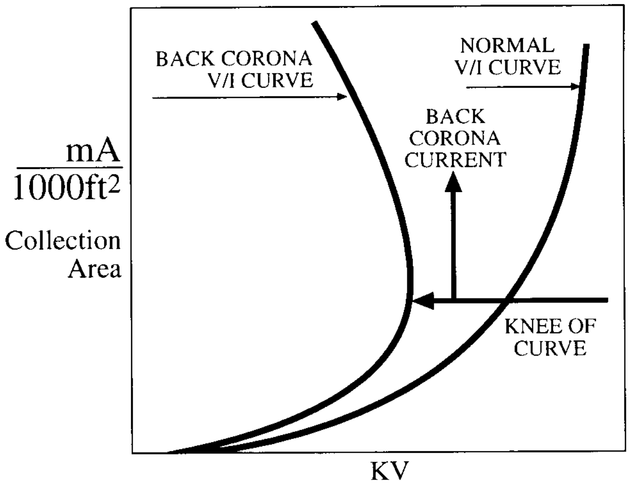
Many coal fired generators are operated with frequent and deep load swings. When the steam generator load is reduced, the precipitator effectively grows in size relative to the process and becomes more efficient. (Hot side precipitator efficiency can be reduced at lower loads due to higher ash resistivity at lower gas temperatures).

Precipitators which are conservatively sized and those where reduction of process load creates excess precipitator capacity are candidates for energy savings. Master control computer programs use unit generating load and opacity to modulate precipitator power. This approach automaticall matches collection needs and creates significant energy savings during times of excess precipitator capacity. The four case histories that follow are examples of this approach.

HIGH DUST RESISTIVITY CASES

When ash resistivity is high enough to create back corona, higher precipitator power can actually reduce efficiency. In cases where back corona exists, intermittent energization or back corona detection and power reduction algorithms can be used to reduce precipitator power and improve performance. Voltage current curves can be generated to determine the existence of back corona. None of the precipitators discussed have significant back corona.

Figure 4: V/I Curves With and Without Back Corona



CASE HISTORIES

Case 1

The first example of precipitator energy savings was a test performed for a large North American utility. The plant has four identical coal fired units described below:

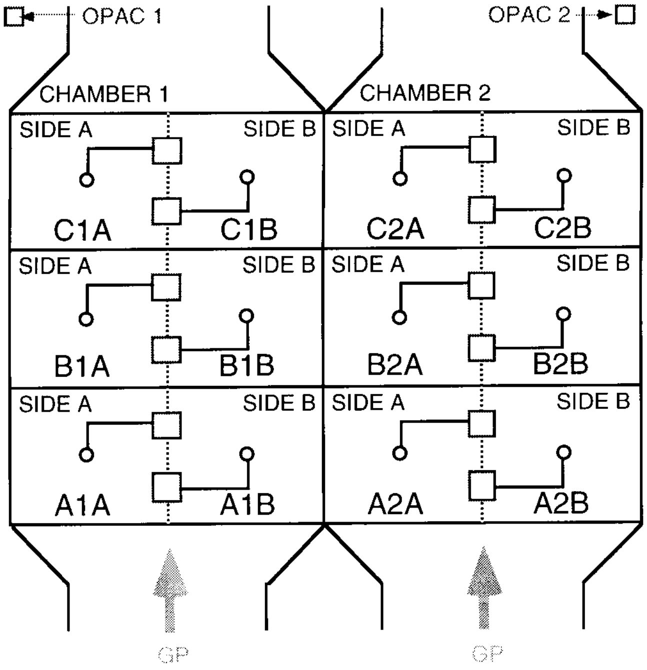
Boiler:

Manufacturer	Combustion Engineering
Configuration	Double cell-tangentially fired
MW Rating	540 gross
Fuel	1.5 to 1.8% S coal, 8% ash 12,900 BTU/lb.

Precipitator

Manufacturer	Joy Canada
Chambers	2
Fields	3
TR sets	12
SCA	177 square feet per 1000 ACFM - 10” spacing A ; 9” B&C
Average gas velocity	8.73 ft/sec
Gas treatment time	4.12 sec
Gas conditioning	none
Opacity limit	20% (Precipitator followed by scrubber)

Figure 5:
General Arrangement of Case 1 Precipitator



Baseline power levels were measured by the central optimization software. The precipitator power was monitored for eight days with power controlled by individual voltage controls at the highest levels they could achieve.

The average PkW represents the arithmetic mean of the data points. The baseline numerical value was 543.3 kW.

After the baseline data was recorded, a relatively simple, limited step optimization program was installed to optimize the power levels of each chamber of the precipitator. During this test period, the steam generator continued to cycle, but the optimization software managed the individual controls to eliminate wasted power. During this period, there was no noticeable change in opacity, which was well under 10% for both test conditions.

The average PkW during the optimization period was 440.6 kW which represents a 23% power savings.

Case 2

The second example of precipitator energy savings is an installation of updated controls and an optimization system installed on all three generating units at Pacific Power David Johnston Generating Station in Glenrock, Wyoming.

Boiler:	**Unit 1**	**Unit 2**	**Unit 3**
Manufacturer	Babcock/Wilcox	Babcock/Wilcox	Babcock/Wilcox
Configuration	Wall Fired	Wall Fired	Wall Fired
MW Rating	110	110	250
Fuel (all three units)	1.1% S coal, 9 to 10% ash 7500 to 8000 BTU/lb.		

Precipitator:	**Unit 1**	**Unit 2**	**Unit 3**
Manufacturer	Lodge Cottrell	Lodge Cottrell	Lodge Cottrell
Chambers	1	1	1
Fields	5	5	5
TR sets	15	15	30
SCA	706	706	629
Average gas velocity			
Gas treatment time			
Gas conditioning	none	none	none
Opacity limit	40% EPA, internal limit: 20% all three units		

Each of the TR sets uses about 42.4kW. Therefore, Unit 1 and 2 each consume about 636 kWH. Unit 3 consumes 1,272 kWH at full power.

Each of the three units was operated with and without the energy saving optimization program in service. Two test periods were evaluated for each precipitator. The first test lasted approximately one month, comparing times with optimization operating with times when it was disabled. The second test was one week with optimization running, compared with one week without optimization.

The Unit 1, one month test resulted in about 38% reduction in precipitator energy with optimization operating. An additional one week test with optimization operating reduced precipitator power by 44% over the week with optimization disabled.

The Unit 2 testing was done during a time when four TR sets were out of service due to component failure. This made it difficult to optimize energy reduction. However, the energy savings with optimization was still 18% during the one month and one week comparison periods.

The Unit 3 long term test provided about 10% energy reduction with the optimization program in service compared to the time the software was shut off. During the shorter test comparison, the savings was 15.7%

Pacificorp reported in a recent company newsletter that they anticipated the new controls and optimization system would pay for itself in energy savings in three years. Based on actual experience, the payback will be half that time.

Case 3

The third case of energy savings was a test installation on a southwest US lignite burning plant.

Boiler:

Manufacturer	Combustion Engineering
Configuration	Double cell-tangentially fired
MW Rating	805 gross
Fuel	1.25% S coal, 12% ash 6600 BTU/lb.

Precipitator

Manufacturer	Research Cottrell
Chambers	2 boxes, 4 chambers each
Fields	5
TR sets	40
SCA	364 square feet per 1000 ACFM - 9" spacing
Average gas velocity	5.5 ft/sec
Gas treatment time	8.2 sec
Gas conditioning	none used during testing
Opacity limit	20%

This plant did a test of one chamber of one of the two piggy-back precipitators. New, microprocessor controls were installed on each of the five fields of the chamber. A portable opacity monitor was installed and connected along with a unit load signal to the optimization computer. The controls and software were installed on line by the plant personnel.

The installation was tested for a two month period and information was gathered. The program for optimization had thirty discrete steps which advanced or reversed the reduction of precipitator power based on feedback from the load and opacity signals.
The system reduced the precipitator power in the test chamber from about 280 KW to about 115 KW. At 115 KW, the unit ran for extended periods without significant increase in opacity. This represents a 59% reduction in precipitator power use for the test chamber. Based on the test results, the utility plans to install the system on the complete precipitator.

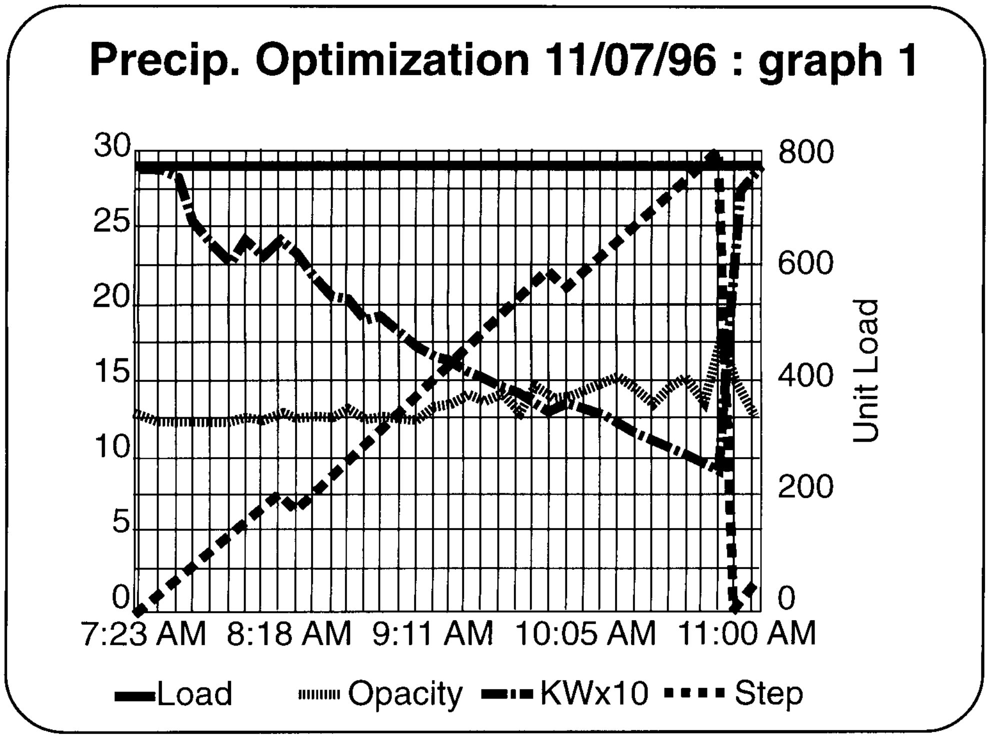


Figure 6: Precipitator Optimization Graph (Case 3)

This graph shows the program steps advancing, precipitator power reducing, while the load and opacity remain stable. At about 11:00 am, the system went to step 1 (full precipitator power) due to an opacity increase.

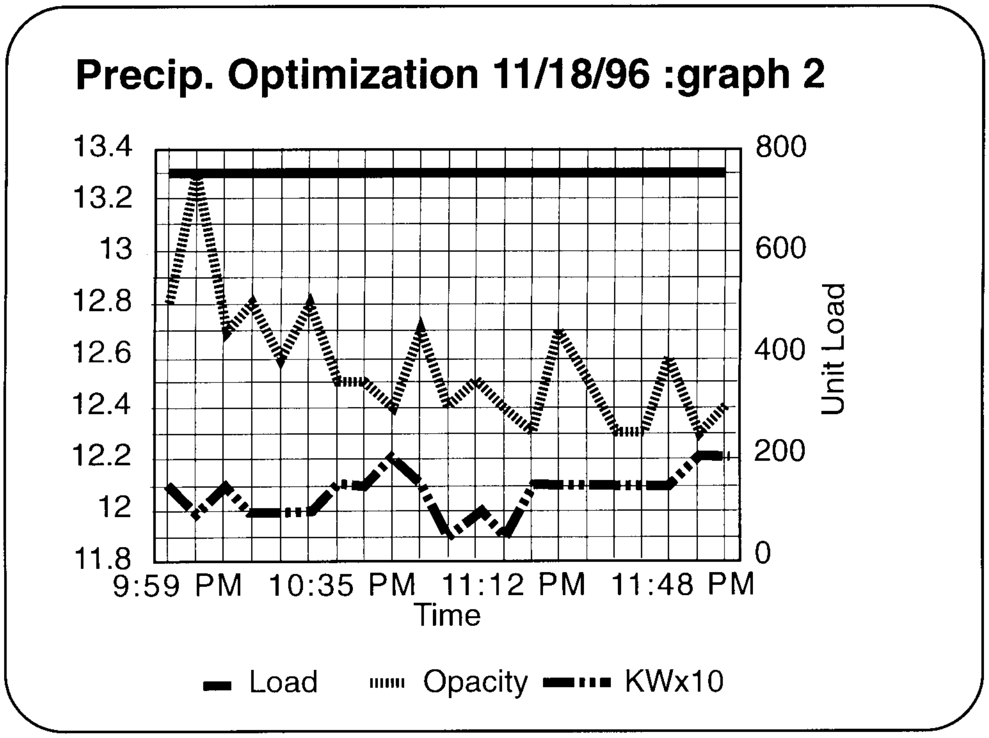


Figure 7: Precipitator Optimization Graph (Case 3)

This graph shows a steady load and precipitator power changes in response to opacity changes.

Case 4

The forth example of precipitator energy savings is an installation of updated controls and an optimization system installed on three identical generating units at a Midwestern public utility.

Boiler:	**Unit 1**	**Unit 3**	**Unit 4**
Manufacturer	Babcock & Wilcox	Babcock & Wilcox	Babcock & Wilcox
Configuration	wall fired wet bottom (all three units)		
MW Rating	217	217	217
Fuel (all three units)	.75-3.0% S coal, 5 to 13% ash 12,000 to 13,000 BTU/lb.		

Precipitator	**Unit 1**	**Unit 3**	**Unit 4**
Manufacturer	Flakt	Flakt	Flakt
Chambers	1	1	1
Fields	5	5	5
TR sets	20	20	20
SCA	335	335	335
Average gas velocity	5 ft/sec	5 ft/sec	5 ft/sec
Gas treatment time	11 sec	11sec	11 sec
Gas conditioning	none	none	none
Opacity limit	20%	20%	20%

All precipitator controls at this plant are being upgraded and a new computer system is being added. At the time of the testing, three of the units had been converted to the new system.

The test was done by turning the energy savings module of the optimization system on for a period of 25 minutes to two hours, followed by a similar period where the module was turned off, followed by a third time period when the module was reactivated. The data logging module of the optimization was used in all cases to record precipitator operating parameters as well as unit opacity and generating load. The load was stable between 190 mW and 207 mW for the period. Opacities varied less than 0.5% for each of the units during the testing. The opacity for Unit 1 was 4% to 4.9%, Unit 3 was 6% to 6.2%, and Unit 4 was 10% during the tests.

The results of the tests based on measurement of primary kW were a savings of 41% for Unit 3 using the energy savings module, a savings of 57% for Unit 1, and a savings of 69% for unit 4.

The plant Performance Superintendent indicated that the total investment in new controls and the optimization system will be offset by less than 18 months of energy savings.

DISCUSSION OF RESULTS

All of the testing in the four case studies was done by different personnel using custom programming of the energy management modules. Tests were done under different process conditions. Some tests were done remotely with optimization program changes made by modem. All tests resulted in significant savings in precipitator power with no change in opacity.

The results of the four cases make a strong argument for the installation of updated controls with the capability of managing the energy used by the precipitator. The cases represent a broad range of precipitator sizes and fuel. Even in the case of an undersized precipitator as in case 1 (SCA 177), the fact that the unit cycles, provides opportunity to save considerable precipitator power (23% in this case). Larger precipitators, as in Case 4, can realize more than 50% energy savings.

Precipitator relative size and design, fuel characteristics, and generating unit output determine the actual savings available.

CONCLUSIONS

Payback of the hardware and installation costs of updated precipitator controls and optimization systems are between six months and 2.5 years depending on the design and operation of the boiler and precipitator and the value assigned to saved power.

High performance precipitators serving coal fired steam generators will have installed power potential of about 1% of the gross mW output of the generator. The actual power used might typically be one-third to two-thirds of the installed power. The savings potential is significant and relatively easy to measure using available microprocessor controls and Windows-based software.

ACKNOWLEDGMENTS

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