76 Particulate and Opacity Control

Program Overview

Program Description

This program seeks and develops emerging particulate control technologies that economically satisfy particulate emission and opacity limits under a variety of operating conditions, including changes in ash loadings and the imposition of stricter limits. Projects conceive or find and demonstrate countermeasures for impacts on electrostatic precipitator (ESP) or baghouse performance of high unburned carbon, injected powdered activated carbon for mercury control or alkali for sulfur dioxide/sulfur trioxide (SO_2/SO_3) control, loss of startup/shutdown and upset exemptions, and ESP deterioration.

Industry Needs and Issues Addressed

- Ability to meet ever-tightening opacity and particulate emission limits with aging equipment, varying coal properties, and added loadings (often of difficult-to-collect ash) at minimum cost
- Cost-effective particulate control upgrades for plants injecting carbon or alkali sorbents for mercury or SO_x capture
- Procedures to meet opacity/particulate emission limits during start-up/shut-down/transients
- Low-cost, low boiler plant impact measures to avoid blue plumes and sulfuric acid fallout

Impact

- Savings of $10–$30/kW by avoiding more expensive upgrades; possibly higher if ESP “fix” avoids baghouse
- Unquantifiable but very large savings in replacement power costs due to opacity-driven de-rates
- Extended bag life and lower pressure drop through better fabrics
- Savings of hundreds of thousands up to millions of dollars if combustion modifications can avoid or reduce alkali injection rate for SO_3 reduction

Key Accomplishments

- ESP performance monitoring and ash evacuation optimization system
- Evidence of ultra-low particulate emissions capabilities of current generation of new ESPs
- Extended time between off-line cleaning on hot-side ESP using EPRIswitch
- Particulate removal efficiencies greater than 99.9% with a moderate-size ESP plus ElectroCore™
- Significant opacity reductions at two sites using Indigo Agglomerator or skewed flow
- Novel, lower-pressure-drop baghouse fabrics

Current Year Objectives

- Demonstration of EPRIswitch with solid-state polarity reversal to reduce or avoid hot-side ESP deterioration due to sodium depletion
- Demonstration of advanced power supply to maintain cold-side ESP performance following addition of alkali injection for SO_x control
- Demonstration of ability of computational fluid dynamics (CFD)-designed hopper baffles to reduce ESP performance degradation with high unburned carbon or injected activated carbon
- ESPM upgrade that can predict particulate emissions with alkali, and methods to avoid such emission increases
- Application of fundamentally based SO_3 formation and depletion model in pilot or full-scale tests of boiler operational changes to reduce SO_3
- Large pilot or full-scale demonstration of at least one emerging ESP performance upgrade technology

Industry Involvement

- Estimated 2009 funding: $1.9M

Program Technical Lead

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Summary of Projects

Project Number	Project Title	Value
P76.001	ESP Power Supplies for Reduced Cost Operation	Complete demonstration of high-frequency, solid-state power supply with very-high-speed polarity reversal to address hot-side ESP degradation due to sodium depletion, rapping re-entrainment losses, and possible collection of high-resistivity ash without flue gas conditioning.
P76.002	Particulate Control Operation With Advanced Gaseous Pollutant Controls	Methods to predict ESP performance and mitigate or avoid degradation when injecting alkali for SO_x control or experiencing higher carbon (unburned or injected) due to NO_x or mercury controls. Deployment of online ESP Q&A program for troubleshooting ESP problems. Possible field test of wet ESP in new power plant.
P76.003	Evaluations of Emerging Technologies	Large pilot and field tests of new technologies that offer the promise of highly effective particulate capture at much reduced costs, such as screen-based technologies, novel electrodes.
P76.004	Development and Demonstration of Acid Removal Processes	Validation of fundamentally based SO_3 predictive model. Tests of combustion or boiler operation modifications to reduce SO_3. Update on industry experience with SO_3 controls and Tech Watch for novel mitigation measures.

Project Descriptions

P76.001 ESP Power Supplies for Reduced Cost Operation (100610)

Issue

Many ESPs are marginal or face more stringent emission/opacity limits, often because they are hot-side ESPs or are collecting a high-resistivity dust (e.g., Powder River Basin [PRB] or low-sulfur bituminous). Owners of these units seek very-low-cost upgrades to overcome these performance limitations. Power supplies with high frequency energization, intermittency, and polarity reversal are expected to improve particulate collection efficiency at much lower cost than any other option. EPRI conceived and developed EPRIswitch to provide these capabilities, taking advantage of new solid-state electronics. EPRIswitch performed well at one hot-side ESP in 2007, and is being tested further at that site and one other in 2008, but this power supply and related technologies developed by others need additional demonstrations.

Description

EPRI will complete demonstration of EPRIswitch at two or three sites, such as plants burning PRB or low-sulfur bituminous coal that currently need SO_3 conditioning, or that inject a calcium sorbent for SO_2 control. Southern Company's ROPE technology will be tested at a high-resistivity ash site. Guidelines will be prepared for the use of advanced power supplies, describing where each is useful and how to apply it. Commercial availability of EPRIswitch will also be ensured.

Value

- Save $15–$25/kW if EPRIswitch or other advanced power supplies avoids the need for an additional ESP field (assuming space were available) or $40–$80/kW if it avoids a polishing baghouse.
- Enable the use of sorbent injection for SO_2 control in small or low-capacity-factor plants by avoiding the additional cost of a baghouse.

How to Apply Results

Power plant owners and operators will be able to procure EPRIswitch and tune it to their needs to meet their particulate/opacity emission limits at much lower cost than other options. They also will be able to decide on related advanced power supplies based on the generic discussions in the EPRIswitch reports.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
EPRIswitch and Other Advanced Power Supplies for Difficult ESP Applications – Initial Field Test Results: Test report on EPRIswitch and ROPE applications on single fields at sites with hot-side ESP and injecting calcium-based sorbents for SO_3 and, potentially, SO_2 control. Possible preliminary test results from full-ESP retrofit of one or both technologies at host site(s).	12/31/2009	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
EPRIswitch and Other Advanced Power Supplies for Difficult ESP Applications: Demonstration of full-scale applications of advanced power supplies at two or three at sites with hard-to-collect ash.	2010	Technical Report

P76.002 Particulate Control Operation With Advanced Gaseous Pollutant Controls (103628)

Issue

Fly ash containing calcium-based sorbents or elevated carbon content is more difficult for an ESP to collect than ordinary fly ash. (The added alkali would be for SO_2 or SO_3 control; the increased carbon would be unburned due to combustion staging for NO_x control or injected for mercury capture.) The root causes of these problems have been studied extensively over the past few years, leading to hypotheses for the degradation effects and suggested countermeasures. These countermeasures need to be tested in the field. At the same time, power companies need reliable models to predict ESP performance under a range of potentially different future conditions. The current inability to predict ESP performance with confidence under adverse particulate conditions (e.g., when using NO_x, SO_x, or mercury controls) either eliminates some control options or leads to overly-conservative and costly equipment upgrades. New plants will have very stringent emission limits, most likely with no exemptions for start-up/shut-down or transients. This requires new approaches to operating boiler and particulate controls during transients.

Description

EPRI will complete its field tests of ESP inlet fly ash properties and corresponding ESP electrical properties for these difficult ashes. Using these data, EPRI will (a) upgrade its ESP performance prediction model, ESPM, to handle these conditions, and (b) seek countermeasures, such as hopper baffles or the applications of advanced power supplies (see Project 76.001) or emerging technologies such as the sieving ESP or EPRI's PMscreen (see Project 76.003). EPRI also will seek to test the performance of wet ESPs located post-FGD in newly operational plants. (Field tests will require supplemental funding for any equipment and detailed sampling.)

A parallel effort will prepare guidelines for maintaining compliance during start-up/shut-down and transients, based largely on best practices found in the industry and EPRI's understanding of the factors that cause opacity/emission increases during transients.

Value

- Save $10–$25/kW if ESP degradation due to sorbent or carbon only can be solved by a one- to two-field enlargement of the ESP.
- Save $40–$80/kW if the plant otherwise would need to add a polishing baghouse (COmpact Hybrid Particulate Collector [COHPAC]).
- Understand the cost of switching to gas to maintain compliance during start-up.
- Flexibility to swing load according to demand instead of being constrained by possible transient emissions.

How to Apply Results

Plant engineers can use the project findings, periodically presented at advisor meetings and documented in reports, to properly characterize their ESP noncompliance problem, identify the best countermeasure, procure the solution, and operate it. In support, they can use ESPM to predict particulate emissions and opacity changes under different conditions and the potential effectiveness of proposed countermeasures.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Guidelines for Operating ESPs with Advanced Gaseous Pollutant Controls and Very Stringent Emission Limits – Initial Field Test Results: Detailed properties of fly ash containing elevated carbon or alkali content due to NOx, SOx, or mercury controls, as needed to predict ESP performance. Possible fly ash property data when co-firing wood waste or biomass. Initial field tests of potential countermeasures (operating procedures and equipment upgrades) to enable new or existing ESPs to achieve particulate permit levels despite these difficult flyash properties.	12/31/2009	Technical Update
Current Status of Fabric Filters: Operating Experience and New Designs: Update of 2005 utility boiler baghouse survey on operating experience, with focus on applications with ash/sorbent mixtures and/or new fabrics. Include uses as primary particulate controls or polishing/TOXECON® applications; pending availability of new fabrics. May include results of slipstream tests of new fabrics.	11/30/2009	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Guidelines for Maintaining ESP Performance During Transients: Information about fuel systems (e.g., oil gun maintenance and operation, improved flame diagnostics), ESP operating procedures, flow management to avoid dropout, and, possibly, equipment upgrades to avoid exceeding particulate/opacity emission limits during start-up, shut-down, or rapid transients between loads. Data on cost implications. Field test data to support recommendations.	2010	Technical Report
Guidelines for Operating ESPs with Advanced Gaseous Pollutant Controls and Very Stringent Emission Limits: Operating procedures and equipment upgrades to enable new or existing ESPs to achieve particulate permit levels despite high calcium sorbent or carbon content in the fly ash.	2011	Technical Report
ESPM 5.0: Upgraded ESP performance prediction model with validated algorithms for calculating particulate emissions and opacity for ash containing elevated carbon or alkali content. Includes predictions of countermeasure effectiveness.	2010	Software

P76.003 Evaluations of Emerging Technologies (103629)

Issue

Competition, increasingly stringent emission limits, and gaseous pollutant controls that produce harder-to-collect fly ash can prevent an ESP from meeting its particulate/opacity limits, especially if it is small- or normal-sized. Power companies need alternatives to the expensive solutions available today, such as enlarging the ESP or adding a baghouse in series following the ESP. Many power companies also have ESPs that marginally meet their emission/opacity limits, and need only a slight improvement to achieve compliance. As these often are older or lower-capacity-factor units, their owners cannot justify significant capital expenses to upgrade them.

Description

EPRI staff will continue to network with their extensive contacts in the industry for early notice of potentially cost-effective novel technologies, while also monitoring the literature and attending conferences. EPRI will evaluate technologies for which information can be obtained, first through engineering assessments and then, if the assessments show promise, through tests at the appropriate scale (lab, slipstream pilot, or full-scale). Tests will be completed on any technologies currently under investigation, such as the sieving ESP and EPRI's patented PMscreen. Other potential options are ElectroCore™ (ready for full-scale demonstration), conversion of the last field of a conventional ESP to wet operation, electrostatically enhanced fabric filters, a new dielectric-coated, discharge electrode purported to provide a very uniform corona, a university concept for a new type of centrifugal collector, and the multi-stage collector.

Value

- Save $10–$25/kW if the required performance would require a one- to two-field enlargement of the ESP.
- Save $40–$80/kW if the plant would need to add a polishing baghouse (COHPAC).

How to Apply Results

Corporate or plant environmental engineers responsible for equipping and operating the ESP for compliance with particulate/opacity limits can use EPRI's test results and interpretations of new technologies to choose the most cost-effective option. Engineers can use EPRI's guidance on the capabilities, operation requirements, and other characteristics of a technology to procure and operate it.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Technical Evaluation of Emerging Technologies: Test data and EPRI evaluations on each technology assessed and tested. Focus will be on particulate collection effectiveness, reliability, any impacts or limitations, and cost (including retrofit difficulty). The primary reports are expected to be on scale-up installations of the Sieving ESP, assuming the improvements considered in 2008 are successful, and EPRI's patented PMscreen (pending availability of host sites and associated supplemental funding for the hardware). Other reports may be published if EPRI finds additional novel, promising technologies in 2008.	12/31/2009	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Technical Evaluation of Emerging Technologies: Similar to 2009 deliverable for the technology or technologies under consideration in late 2008–2009. This effort may be extended beyond 2010 at member direction.	2011	Technical Report

P76.004 Development and Demonstration of Acid Removal Processes (101447)

Issue

Power companies are concerned about visible blue plumes caused by sulfuric acid mist, new limits on SO_3 and sulfuric acid emissions, and boiler impacts due to high SO_3 and sulfuric acid concentrations in the colder section of the air preheater and downstream components. Plants that need to reduce SO_3 emissions can currently only capture SO_3 that has been formed—for example, by injecting alkali sorbents or adding a wet ESP. Both approaches are expensive, and sorbent injection can have negative side impacts. Power plants seek lower-cost approaches to mitigate the initial formation of SO_3 through combustion or sootblower modifications or the use of novel technologies.

Description

Through additional field measurements of SO_3 concentrations, temperatures, and fly ash/deposit conditions along the combustion gas path, EPRI will complete its effort to develop mechanistic and quantitative information to understand the SO_3 formation processes in the boiler. This knowledge will guide the designs of mitigation strategies, such as combustion modifications to reduce homogeneous oxidation in the furnace, justification for deep coal cleaning to remove iron, and adjustment of sootblower timing to minimize catalytic formation of SO_3 on boiler tubes. EPRI will work with members to select and test the most promising SO_3 minimization strategies at host power plants. The project will continue to track supplier developments and new offerings, evaluating those that seem promising to the extent the supplier and host plants agree.

Value

- Minimize back-end corrosion.
- Reduce the potential for de-rates to avoid opacity violations, which could cost hundreds of thousands of dollars per incident in replacement power.
- Save $1–$2 million/yr for a 500-MW plant if it can avoid alkali injection, or a fraction thereof if it can only reduce amount injected
- Reduce the risks of legal actions due to nearby touchdowns of a sulfuric acid plume.

How to Apply Results

Engineers can use the reports presenting the model runs on mitigation options to identify the most favorable SO_3 reduction strategies for their plant and coal. They can then run the model (or have it run for them) to predict the effectiveness of these strategies under a number of different scenarios. Members also can join the Sulfur Oxides Control Interest Group (SOXIG), a supplemental project that provides a forum for technology exchanges among practitioners.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Options for SO3 Mitigation Based on Formation Mechanisms: Access to two computer models of SO_3 formation/depletion mechanisms in coal-fired boilers that have been validated against measurements. Guidelines for using the models to identify and assess fuel changes and boiler operational modifications that can reduce SO_3/sulfuric acid emissions. Power companies will be able to contract with the modelers for analyses of their units; they can direct the modelers to consider various options and assess the resulting recommendations based on the experiences documented in the guidelines. Members also can request assistance from EPRI in these studies.	6/30/2009	Assembled Package
SO3 Mitigation: Current Utility Operating Experience: Update of March 2006 report (#1010754), providing survey and analysis of experience (by then up to five years in some cases) gained by power companies operating SO_3 control. Will include descriptions of any new technologies introduced since the March 2006 report, with available field experience and EPRI's assessments of the technologies.	12/31/2009	Technical Update
Alkali Injection Ahead of SO2 Control for Enhanced SO3 Capture: White paper on power company experience injecting alkali just ahead of the FGD for SO_3 control without affecting ESP performance or ash use, while realizing double duty from the alkali.	6/30/2009	Technical Resource

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
New Approaches to SO3 Mitigation in Coal-fired Boilers: Summary of additional installations and technology offerings since the 2009 report. If field experience indicates that some of the SO_3 formation mechanisms now are better understood, EPRI will provide the new data to the modeling community for updating their models.	2011	Technical Report