Particulate and Opacity Control - Program 76

Program Overview

Program Description

Fossil-based power generators must meet ever-tightening opacity and particulate emission limits at minimum cost, despite aging equipment, varying fuel properties (coals, biofuels), and added loadings (often of difficult-to-collect ash). Power generators need cost-effective particulate control upgrades for plants, which are facing stricter emission limits, using changing fuels, or injecting carbon or alkali sorbents for mercury or SO_x capture. If their plants are burning medium- to high-sulfur coal, they need robust, reliable, low-cost, low-plant-impact measures to avoid blue plumes and sulfuric acid fallout.

The Electric Power Research Institute's (EPRI's) Particulate and Opacity Control program (Program 76) seeks or develops and evaluates emerging technologies that economically satisfy particulate emission and opacity limits under a variety of operating conditions, including changes in ash loadings, fuel sulfur content, and the imposition of stricter limits.

Research Value

EPRI increases the number of demonstrated technologies that can achieve members' particulate and opacity performance goals at least cost, while minimizing the impact of these controls on power plant operations. Members of this program can use the results of this R&D to achieve:

- Savings of $10–$30/kW by avoiding more expensive electrostatic precipitator (ESP) upgrades; higher savings if an ESP "fix" avoids replacement by a baghouse
- Savings in replacement power costs due to opacity-driven derates
- Extended bag life and lower pressure drop through better fabrics
- Continued ash sales and avoidance of ESP upgrades if operational modifications can avoid or reduce alkali injection rate for SO_3 reduction

Approach

Projects conceive or find and demonstrate countermeasures for impacts on ESP or baghouse performance of changed particulate properties, loss of startup/shutdown and upset exemptions, and ESP deterioration.

- R&D involving ESP upgrades for undersized units and difficult fly ash seeks and demonstrates advanced power supplies, flow modifications, and novel ESP technologies that counter the effects of high resistivity, sodium depletion in hot-side ESPs, rapping losses, and, potentially, changed ash properties due to biofiring (cofiring or 100% biofuel firing), increased unburned carbon, injected carbon (for mercury control), and alkali injection for SO_x control. Activities range from fly ash characterization studies to field tests of emerging technologies (e.g., PMscreen and new electrode designs).
- Research for optimized baghouse performance for all fly ash develops methods to extend bag life, reduce pressure drop, avoid "cleaning puffs," and detect leaks, all irrespective of fly ash properties.
- Robust, least-cost acid emission reductions R&D tests fuel, combustion, or boiler operation modifications to reduce SO_3 formation in the boiler; assesses and develops countermeasures to alkali sorbent feeding problems encountered in early sorbent injection installations; provides updates on industry experience with SO_3 controls; and maintains Tech Watch for novel mitigation measures.

Accomplishments

EPRI provides power companies with solutions to solid and aerosol particulate emissions that do not attract the attention of equipment suppliers due to small return on investment or high risk. EPRI conducts unbiased, third-party tests of new commercial offerings to demonstrate their performance and to assist their developers in improving the product. Recent examples include:

- Monitoring to optimize ESP performance and ash evacuation
- Modifications to EPRI's ESP performance prediction model (ESPM) to include fly ash containing activated or unburned carbon
- 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 one site using Indigo Agglomerator™ and at one site using skewed flow
- Lower-pressure-drop baghouse fabrics that retain high particulate collection

Current Year Activities

The program R&D for 2010 will focus on completing work to develop and demonstrate the benefits of advanced power supplies, developing and testing fabrics and baghouse operations to reduce pressure drop increase and particulate emissions during baghouse cleaning, demonstrating a low-cost particulate-polishing system, and enhancing the reliability and reducing the cost of SO_3 control. Specific efforts will include:

- Demonstration of EPRIswitch with solid-state polarity reversal to reduce or avoid hot-side ESP deterioration due to sodium depletion
- Demonstration of EPRIswitch + ROPE's (Rapid Onset Pulse Energization) ability to maintain cold-side ESP performance following addition of alkali injection for SO_x control
- Demonstration at large scale of PMscreen as a low-cost polishing device (e.g., to counter particulate increases due to sorbent injection air pollution controls)
- Search for and testing of new fabrics to simultaneously reduce pressure drop and emissions during cleaning while resisting degradation due to sorbent injection
- Determination of fly ash properties with cofiring or 100% firing of biofuels and the impact of these properties on ash collection by both ESPs and baghouses
- 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 injected alkali, and methods to avoid any 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

Estimated 2010 Program Funding

$1.8M

Program Manager

George Offen, 650-855-8942, goffen@epri.com

Summary of Projects

Project Number	Project Title	Description
P76.001	ESP Upgrades for Small Units and/or Difficult Fly Ash	This project will develop low-cost upgrades to ESPs that meet the new challenges of collecting difficult ash, avoiding emission increases despite higher inlet loadings, or complying with increasingly stringent emission limits. Updates to ESPM, EPRI's performance prediction tool, will support these technology developments.
P76.002	Optimized Baghouse Performance for All Fly Ash	Through surveys of high-performing baghouse installations and promoting/supporting the development of advanced fabrics, this project will document best practices and develop bag materials that produce lower emissions 24/7, longer bag lives, and lower O&M costs.
P76.003	Robust, Least-cost Acid Emission Reduction	This project identifies and demonstrates lower-cost and more-reliable SO_3/sulfuric acid mitigation strategies, reducing back-end corrosion and eliminating blue plumes.

P76.001 ESP Upgrades for Small Units and/or Difficult Fly Ash (069166)

Key Research Question

Many ESPs are too small to meet current or anticipated stringent emission/opacity limits, are being used to collect a higher-resistivity dust than the design fly ash (e.g., following a switch to Powder River Basin [PRB] coal or after implementation of calcium-based sorbents for SOx reduction), or are hot-side ESPs that continue to experience performance issues. Owners of these units seek very-low-cost upgrades to overcome these performance limitations. Several advanced power supplies have the potential to meet this need, but need to be proven for a number of applications. Other technologies, such as low-cost polishing devices, may be competitive and provide better performance and merit further development and demonstration.

Other ESPs have difficulty meeting their emission/opacity limits due to the high carbon content in the ash as a result of low-NOx burners or activated carbon injection for mercury capture. Earlier work by EPRI identified hopper re-entrainment of carbon particles as the primary cause of the elevated emissions, and computational fluid dynamic (CFD) models suggested that the problem could be mitigated with hopper baffles. These findings need to be demonstrated and optimized on full-scale ESPs.

Power companies constantly face questions about the impact of fuel changes on ESP performance and the benefits of proposed upgrades. More recently, biofuels (cofired or 100% fired) have become a fuel of interest to meet climate change challenges and contribute to meeting Renewable Portfolio Standards (RPSs). To answer these questions on ESP performance, environmental control engineers need a comprehensive, reliable, and accurate computer model. EPRI's ESPM model is such a tool, and is effective, but needs updating as more is learned about ESP performance with difficult-to-collect ash.

Approach

EPRI will complete demonstrations of EPRIswitch, alone or in conjunction with Southern Company's ROPE technology, at one to three plants burning PRB or injecting calcium sorbents for SO_x control, as well as at one additional hot-side ESP suffering performance degradation due to sodium depletion. Demonstration of PMscreen as a low-cost polishing device will continue, subject to interest by host sites and other collaborative partners.

In addition, EPRI will revisit the cool pipe precharger concept, with or without rigid discharge electrodes, for high-resistivity dust applications; the first step will be an engineering economic assessment for today's needs and economics. If this analysis indicates that the concept could be a competitive option, or at least a viable

fallback option in the event advanced power supplies don't reach their potential, EPRI will seek collaborative demonstration partners.

For ESPs experiencing carbon re-entrainment, EPRI will use CFD models to design hopper baffles for one to two units, fabricate/install them, and conduct performance testing to demonstrate the value of this approach. Other potential ESP upgrade options that EPRI will consider over the next few years are:

- ElectroCore™ (ready for full-scale demonstration)
- Conversion of the last field of a conventional ESP to wet operation
- Electrostatically enhanced fabric filters
- New dielectric-coated discharge electrode purported to provide a very uniform corona
- University concept for a new type of centrifugal collector
- Multi-stage collector

EPRI will also seek to test the performance of wet ESPs located post-flue gas desulfurization (FGD) in newly operational plants. (Field tests will require supplemental funding for any equipment and detailed sampling.) As a start to determine ESP or baghouse performance when firing/cofiring biofuels, EPRI will measure fly ash properties at sites burning (or testing) these fuels and relate those properties to particulate control performance parameters. To give power company engineers a reliable ESP performance predictor for today's issues, EPRI will obtain the necessary data on fly ash properties, ESP electrical parameters, and resulting emissions/opacity during the above tests and use the results to improve/fine-tune the algorithms in ESPM.

Impact

By having EPRI develop and demonstrate low-cost ESP upgrades or solutions to issues caused by difficult ash, power companies can:

- Save $15–$25/kW if EPRIswitch or other advanced power supplies avoid the need for an additional ESP field, or $40–$80/kW if they avoid 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 and tune EPRIswitch, with ROPE if needed, 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. Similarly, the reports on hopper baffles for ESPs collecting high-carbon fly ash will provide guidance on the design and expected effectiveness of this approach, and those on PMscreen will give engineers the information they need to decide on the adequacy of this polishing device for their situation. Predicting the benefits of any of these approaches can be done by running ESPM, a model that has been modified over the years to increase its ease of use and robustness.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Low-cost ESP Retrofit Devices for Small ESPs, Increased PM Loading, High-carbon Ash, or Biofuels: Evaluation of cool pipe precharger, large pilot test results on PMscreen. Pending host/TC interest, possible early field test results on cool pipe precharger or hopper baffles to reduce re-entrainment of high-carbon content ash. Measurement of fly ash properties when firing/cofiring biofuels and relationship to ESP or baghouse performance metrics.	12/31/10	Technical Update

Product Title & Description	Planned Completion Date	Product Type
ESPM 5.0: Update to include 2009 and early 2010 measurements of ash properties with alkali injection (especially calcium-based in quantities for SO_2 reduction) and feedback from use of ESPM with high-carbon ash.	12/31/10	Software
EPRIswitch and Other Advanced Power Supplies for Difficult ESP Applications: Demonstration of full-scale applications of advanced power supplies at two or three sites with hard-to-collect ash. May be high-resistivity ash (PRB or calcium injection), high-carbon ash, or added loading due to sorbent injection. Possible use with biofuel firing/cofiring, if needed.	12/31/10	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Low-cost ESP Retrofit Devices for Small ESPs, Increased PM Loading, High-carbon Ash, or biofuels: Update of 2010 report with field test results on 2010 technologies or new ones.	12/31/11	Technical Update
EPRIswitch and Other Advanced Power Supplies for Difficult ESP Applications: Final report in series with field test results of EPRIswitch, with or without ROPE, on one to three installations with high-resistivity ash (PRB or sorbent injection for SO_x mitigation) and on one to two hot-side ESPs with sodium depletion issues.	12/31/12	Technical Report
Low-cost ESP Retrofit Devices for Small ESPs, Increased PM Loading, High-carbon Ash, or biofuels: Final report in series with field test results on original set or new technologies introduced in 2010-12.	12/31/13	Technical Report

P76.002 Optimized Baghouse Performance for All Fly Ash (069167)

Key Research Question

Power companies increasingly are turning to baghouses (*aka* fabric filters) to realize multiple benefits: very low total particulate emissions independent of fuel properties; substantial reduction of trace metals through the capture of fine particulate; high capture rates of mercury on unburned or activated carbon; and the potential to also capture sulfuric acid, other acid gases (especially hydrochloric acid [HCl] and hydrofluoric acid [HF]), and any organic gases present in the flue gas. However, baghouses can experience high pressure drop after only a few months or years of operation, and this imposes an energy penalty on the power plant. Conversely, low-pressure-drop systems are prone to emission spikes, or puffs, during bag-cleaning periods. Additionally, bags can fail within 1-3 years of installation, which adds an undesirable cost to the system and runs the risk and expense of forced outages. Research is needed on new bag materials that are stronger, resistant to flue gas species (especially sulfuric acid, chlorine, and bromine), porous enough to avoid undue pressure buildup, and still highly efficient during both normal capture operation and cleaning cycles.

Approach

EPRI will continue to monitor R&D activities by bag material suppliers in search of new fabrics that address one or more of the above challenges. EPRI will also try to conceive, as well as search for, novel ideas that it can suggest to the material suppliers, and then test the samples that suppliers produce. A survey will be conducted to gather the field experiences of the numerous new baghouse installations, and that data will be combined with information from older installations in a guideline on best practices for the operation and maintenance of baghouses.

Topics to be considered for this guideline include:

- Methods to reduce emissions during cleaning (potentially including changes to the air flow patterns in the baghouse based on CFD modeling)
- Procedures to protect bag material during start-up/shutdown
- Instruments to detect leaks
- Decision criteria on when to replace bags
- Critical features to include in modeling studies
- Special considerations when firing or cofiring biomass
- Future opportunities applying novel concepts.

Impact

Success in addressing the issues identified for baghouses will lead to:

- Increased intervals between bag replacement for challenged baghouses from the current 2-3 years to potentially 4-5 years, at a typical amortized savings of $0.5M/yr for a 500-MW plant (plus reduced downtime). These savings depend on success in developing and demonstrating more durable and acid-resistant fabrics; implementing procedures that avoid acid attack on the bags during transients; and demonstrating reliable leak detection monitoring systems so bag replacement is done only when needed.
- Maintaining pressure drop across the baghouse below 5-6 in. H_2O, versus allowing it to increase to, e.g., 10 in. H_20, saving >$200,000/yr for a 500-MW plant.
- More compact designs of baghouses, with higher air-to-cloth ratios and online cleaning, saving 10-20% in capital costs.

How to Apply Results

Plant engineers can use the survey findings, periodically presented at advisory meetings and documented in the planned Guideline, to improve the performance of their existing baghouses, reduce operations and maintenance (O&M) costs, and avoid potential derates due to opacity excursions. Engineering/procurement staff can use the results to specify the most cost-effective baghouses for their needs, accounting for capital vs. O&M cost tradeoffs. Corporate environmental engineers can gain an understanding of future possibilities by following the progress of the R&D in novel fabrics; they then can use this understanding to recommend optimal particulate control strategies.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Current Practices in Power Plant Pulse-jet Fabric Filters: Field experience of new installations, and guidance on best O&M practices for pulse-jet fabric filters to maintain very low emissions and achieve long bag life.	12/31/10	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Pulse-jet Fabric Filter Design and O&M Guidelines: Update of 2010 report, with more definitive information.	12/31/11	Technical Report
Pulse-jet Fabric Filter Design and O&M Guidelines Update: Update of 2011 report with long-term experience on new installations and in capturing MACT-limited pollutants (e.g., SO_3, acid gases).	12/31/13	Technical Report

P76.003 Robust, Least-cost Acid Emission Reduction (101447)

Key Research Question

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 currently can 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, coal cleaning, or the use of novel technologies. At plants using sorbent injection, operators also seek guidance on sorbent specification, handling, transport, and injection to maximize sorbent utilization and greatly reduce current maintenance.

Approach

EPRI plans to complete its development of mechanistic and quantitative information to understand the SO_3 formation processes in the boiler in 2009. In 2010, this knowledge will guide the designs of mitigation strategies such as combustion modifications to reduce homogeneous oxidation in the furnace, 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.

In parallel, EPRI will work with the collaborative partners supporting the 2009 field tests on sorbent injection systems to select and demonstrate at full-scale the most promising solutions to deposition and plugging in sorbent transport lines and injection nozzles. The project will continue to track supplier developments and new offerings, evaluating (to the extent the supplier and host plants agree) those that seem promising.

Impact

By finding and demonstrating cost-effective methods to reduce SO_3 concentrations in the post-air preheater region of a coal-fired boiler, this RD&D effort will:

- Minimize back-end corrosion.
- Reduce the potential for derates to avoid opacity violations, which could cost hundreds of thousands of dollars per event 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 the 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 then can run the model (or have it run for them) to predict the effectiveness of these strategies under a number of different scenarios. Members can also join the Sulfur Oxides Control Interest Group (SOXIG), a supplemental project that provides a forum for technology exchanges among practitioners.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Reliable, Low-maintenance Alkali Sorbent Injection Systems for SO3 Reduction: Initial test results of full-scale demonstrations of procedures and equipment identified in the 2009 Plant Yates tests as promising approaches to reliable transport and injection of alkali sorbents (especially hydrated lime) and optimized mixing of the injected sorbent with the flue gas.	12/31/10	Technical Report
Opportunities to Reduce SO3 Formation in Coal-fired Boilers: Field test data on attempt to reduce SO_3 concentrations at the economizer outlet via combustion modifications, coal cleaning, intelligent sootblowing targeted for this purpose, or other approaches suggested by the mechanistic modeling studies.	12/31/10	Technical Update

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 2010 reports. 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.	09/30/11	Technical Report
New Approaches to SO3 Mitigation in Coal-fired Boilers: Update of 2011 report with additional field test results from R&D programs and experience at commercial installations of SO_3 reduction systems (typically alkali injection).	12/31/12	Technical Update
Guidelines on SO3 Mitigation in Coal-fired Boilers: Guidelines for reducing SO_3 flue gas concentrations along the flue gas path and at the stack (for given SCR behavior), including strategies to reduce SO_3 formation and best practices to control it once formed.	12/31/13	Technical Report