PLENARY SESSION 2

STATUS AND FUTURE OF ESP AND FF

ESPs IN THE 21ST CENTURY: EXTINCTION OR EVOLUTION

R. L. Andrews
C. A. Altin
R. Salib
Ebasco Services Incorporated

Abstract

The final implementation of the 1990 Clean Air Act Amendments in the year 2000 will place substantial stress on the existing utility electrostatic precipitator population to meet particulate emission requirements for units which may be fuel switched to clean coals for SO_2 reduction, possible air toxics limitations, and greater enforcement of performance standards during unit start-up, shutdowns, and upsets.

This paper reviews the options available to utilities for control system upgrades including:

- Supplemental SCA and conventional mechanical and electrical rehabilitations
- Unconventional conversion of precipitators to fabric filter operation or the addition of supplemental fabric filters (COHPAC)
- Chemical approach of single and dual flue-gas conditioning

The role of pilot testing and the usefulness of data acquisition and diagnostics for evaluating current equipment performance levels are also explored.

Introduction

Electrostatic precipitators have been the workhorse particulate control technology for coal-fired domestic utility applications for the last three decades. The ESPs certainly represent the most mature of all particulate control technologies available to us today. ESPs have:

- the largest established application base with close to 1000 units in operation in the utility industry

- an extensive performance data base collected to demonstrate compliance with emission regulations and supplier warranties

- well modeled fundamentals developed through not only industry efforts and extensive EPA-EPRI programs

It is also apparent that ESP technology is under more stress now for improved emission performance than it has been in the past decade. The purpose of this paper is to focus exclusively on this unique technology and freely speculate on where we expect it to be in the next century.

Considered in the context of a growth or evolution to meet changing requirements, the two principal issues to be addressed are:

- Where must future ESP technology move to respond best to the requirements of improved performance?

- Does this technology have the capacity for substantial change necessary for survival?

The subject of ESP progress by enhancement, upgrading and life extension is of longstanding interest to Ebasco. We will refer to our previous paper in this area: "Electrostatic Precipitator Upgrading: A Technology Overview" which Gary Greico presented to the ASME Joint Power Generation Conference in 1984. That paper presented a technology status summary of the ensemble of upgrade strategies available for ESPs nine years ago. That paper is of interest here since one of the necessary considerations for extrapolating technology progress over the next decade is to revisit the progress which has actually been achieved in the last decade.

Performance Improvement Stresses

We have said that ESP technology is under stress for improving emissions performance. This stress principally originates from the new 1990 Clean Air Act Amendments but there are also some non-CAAA considerations which are important. For the CAAA factors, a principal source of concern is for Phase I SO_2 Acid Rain compliance and its indirect effect on particulate control. Although about two dozen units achieved SO_2 control by Flue Gas Desulfurization (FGD) system retrofits, dozens more took the approach of fuel switching to lower sulfur coal. A comparable mix might be expected for the next Phase II, reduction in the year 2000. Although these low sulfur coals are generally lower in ash than the original design coals, this is frequently more than offset by decreased ESP performance associated with higher fly ash resistivity.

For units with retrofit FGD systems after an existing ESP, a growing emphasis on producing chemical gypsum for commercial wallboard manufacture may require improved particulate collection to prevent excessive fly ash, i.e., inerts or off-colors from appearing in the final gypsum product.

A more direct effect of the CAAA is the pending requirement for EPA to establish emission limits for certain air toxics which are emitted from coal-fired units in the form of fine particulates containing heavy metals. Although it is not apparent that the final air toxic requirements will represent an extremely difficult performance requirement for ESPs, it is certainly an area which could be a "sleeper" with dramatic impacts.

Another area of concern is short term opacity excursions due to upsets or transients in ESP operation. Many State Implementation Plans (SIPs) approved by EPA had fairly strict requirements on the magnitude and frequency of such periods of high opacity. Federal policy does not change these requirements, but rather requires greater enforcement of SIPs in some states that have taken historically a more discretionary approach.

There are also two areas of stress on ESPs which do not originate in CAAA but rather during the individual state process of air quality permitting and new generation planning. Under the Best Available Control Technology (BACT) assessment, fabric filters are usually perceived as having better performance than ESPs even though total particulate emission standards are met and there are no specific requirements for fine particulates. This general perception of poorer ESP performance for fine particulates may be the single most important factor for confidence in the longevity of the technology.

A much more subtle stress results from the consideration of externalities on the implied social cost of residual emissions which are still within the regulatory standards. Although externalities are typically applied in the comparison of demand side vs. supply side options for new generation, logic implies that the comparisons may eventually be applied to pollution control technologies themselves. Since some states have very high externalities ($/ton) for residual particulate emissions, it may put future pressure on utilities to actually achieve emission reductions beyond standards as a better approach to implied cost/benefit optimums.

Enhancement Technologies

Prior to considering the relevancy of various performance improvement approaches, it is necessary to discuss the application base. For new ESP installations, the principal applications are supplemental ESPs in parallel with existing ESPs for improved performance. ESPs for new coal fired units are limited, at least for the domestic market, because of the limited number of new coal-fired generating units expected for the balance of this decade. The majority of projects will be modifications to existing ESPs either to restore them to their original performance capability or to enhance them to a new level of lower emissions.

The basis for the extension of ESPs as a viable technology is therefore closely related to its ability to respond to the need to maintain the large existing application base in step with required performance. It is therefore instructive to focus on the enhancement technologies available primarily for existing ESPs.

Approaches to enhancement generally fall into three concept categories:

- The first is ideal electrostatic particulate collection as described by Deutsch-Anderson type models where the objective of enhancement is to increase the particle migration velocity or to modify the ESP to achieve the highest migration velocity capability of the physical design.

- The second category of enhancements is to address the non-ideal or non-Deutsch contribution to emissions by improvements in such factors as flow distribution, air infiltration and reentrainment.

- The third category is reliability or maintaining the long term performance capability of a given ESP design.

In turn, these concept categories can alternately be arranged into more conventional functional approach groups such as:

- Process related
- Mechanically related
- Electrically related
- Controls related

Under process related enhancement approaches, there are two forms of gas conditioning, sulfur trioxide (SO_3) for ash resistivity reduction and ammonia (NH_3) conditioning. The primary effect of ammonia conditioning is to reduce reentrainment by increasing particle cohesion, produce favorable space charge effects and possible interactions with SO_3. A minor process approach, certainly in comparison to potential impact of gas conditioning, is temperature control to avoid corrosion when operating below the gas acid dewpoint.

Under mechanically related enhancement approaches, there are gas uniformity correction of both flow and temperature, overall improvements in rapping by increased intensity, improved sectionalization or increase in numbers of rappers, and general improvements in the transmission of rapping energy to the electrodes. Additional mechanical approaches are electrode alignment, casing integrity to minimize air infiltration, and electrode strength and alignment reliability.

Under electrically related enhancements there are increased ratings of T/R sets if operation is ratings limited; increased sectionalization of discharge sections by increasing the number of T/R sets; and general improvements in electrical waveform by current limiting reactor resizing. Under controls related enhancements, there is conversion to modern microprocessor controls yielding better spark mode response and automatic avoidance of back ionization. Modern equipment also offers the potential for control, coupling of energization and rapping for cleaning improvements through reduced power rapping under certain conditions. Modern controls also offer the capability for improved diagnostics of operating behavior and faults.

In addition to the established approaches to enhancement, there is a category which we referred to ten years ago as Limited Experience techniques. These included pulse energization, precharging and sonic cleaning supplement to rapping. In general, the limited experience approaches of ten years ago, although sometimes mentioned as part of a "Super ESP" design, still retain the status of only limited demonstration.

With this rapid trip through the major approaches to performance enhancement, what general progress has been made in the last ten years? With the exception of the almost universal acceptance of gas conditioning as an attractive "silver bullet" approach to resistivity problems, the ensemble of available upgrade techniques is pretty much the same now as it was then.

Evaluation Approach

Given the basic set of major approaches to enhancement, the evaluation of options can generally proceed in a straight forward manner. The first step is to define the emission requirements to be achieved. In view of the previous discussion on the "stresses" for improvement, some of which are only vaguely defined, establishing the emission requirements may be the most difficult task. Depending on the nature of the effort, emission requirements are often omitted with performance developed as a function of cost for ranked enhancements.

The second step in evaluation is to characterize the existing operation through diagnostics. This generally can be accomplished with conventional OEM physical inspections, data review, and evaluation of the system response to fine tuning procedures such as thorough manual cleaning.

The third step is selection of relevant enhancement options with development of the principal characteristics such as:

- Performance Enhancement Expectations
- Technology Status Confidence
- Capital and Operating Costs
- Outage Requirements
- Space Requirements
- Other Impacts (such as electrical auxiliary and operational procedures changes)

In the event that the desired performance improvements cannot be achieved within the physical constraints of the existing ESP, then supplemental alternatives are defined and evaluated. The ESP versions of these alternatives would include additional SCA by series field addition or separate parallel ESPs. In addition the alternatives could follow the fabric filter route with parallel filters, internal conversion of the ESP to fabric filter compartments or series addition of a high air/cloth ratio filter (COPAC). In general, consideration of the fabric filter alternatives and hybrids is almost mandatory if opacity and fine particulates are the emission issue.

The product of the evaluation provides ranked results for the major considerations of:

- Performance Expectations
- Confidence in Status
- Costing

and will in general support the decision making process. In the event that the existing data is insufficient to justify a decision or enhancement approach, then an expanded evaluation will have to be conducted. Expanded evaluations can involve the following types of efforts:

- Data acquisition/diagnostics to a more elaborate extent than normally conducted

- Flow modeling and the appropriate field testing to support flow/temperature distribution design assessment

- Pilot testing

- Full scale demonstrations

Although small scale pilot ESP testing was done on occasion in the 1970s for applications involving new or unusual composition coal supplies or for gas conditioning effect verification, the approach was not used much in the 1980s. In general, a more valuable technique is full scale demonstration on a unit which is relevant to a whole class of similar installations. The full scale approach certainly avoids troublesome scale up interpretations and can be extended to relevant life cycle testing of components.

Conclusions

Looking to the short term future, we have prepared a short wish list of R&D needs. In the research area we feel that opportunities for advancement exist in the areas of:

- Software for optimization of ESP operation via central computer control.

- More comprehensive theoretical modeling of performance including extending existing models to 3-dimensional electrode geometry and more realistic AC waveforms.

- More comprehensive economic analyses of the external cost of residual emissions in comparison to performance enhancement cost.

- More comprehensive field analyses of transient process behavior to establish the best approaches to opacity excursions.

The perceived opportunity for the first two areas follows from the fact that the general capability for low cost computational power has increased dramatically in the last five years and has not yet been extended into ESP operational control and diagnostics to the degree it might be beneficial.

The second two R&D items represent areas where further information is required to better focus on concepts of approaches which may only be vague at this time.

In the area of development, we note that an important issue is - who does the development? Over the last decade, EPRI has basically risen to fill the void in this area as the ESP suppliers cut back on development due to the lack of continuing large scale capital projects. Considering that EPRI has done its best on large scale demonstration projects, perhaps the most useful development project would be a demonstration of the "best-of-the-best" operation of a fine tuned ESP which employs many or all of the enhancements described in this paper. This would provide a definitive example of the envelope of performance especially with emissions data that supports or refutes the perception that fabric filters are a much better control approach for fine particulates.

For the basic question of this paper - Is the future of ESPs in the 21st century evolution or extinction? - We offer the following speculations:

- Electrostatic precipitation technology has not been characterized by a rapid progression of changes. As is true of many mature technologies, evolution may mean stasis or emphasis on applying the older, well understood enhancements to the substantial application base of existing ESPs. This is certainly the economically justified approach to life extending these assets already in place.

- For new coal-fired units in foreign countries, our perception is that there is generally a preference to stay with the established technologies. This market may become the largest source of continuing capital flow for longevity of ESP technology but it will not necessarily stress the technology for ever increasing emissions performance improvements.

- For new units or supplemental ESPs in the United States, ESP technology faces a difficult time. This is based primarily on the general perception that fabric filtration may have more potential to evolve designs with even better performance than currently demonstrated. Continuing effective competition by ESP technology would require continuing demonstration of low capital costs and reliability even if modest improvements in performance are achieved.