Advanced Methods of Mpgrading Electrostatic Precipitators

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Abstract: many electrostatic precipitators (esp) around the world have been operating for several decades. more stringent emission requirements and more challenging conditions due to fuel switching and other process changes result in a need for improved dust collecting efficiency. often, it is sufficient to improve the performance of the existing esp system by utilizing appropriate upgrading technologies. another reason to invest in esp upgrade technology is to reduce operating costs.
For the existing ESP upgrade applications, some technologies may be better suited than others for reasons of layout and cost, process integration, age and design of that plant and the emission levels to be achieved. The most appropriate solution can be selected after detailed inspection and assessment of the present electrical, mechanical and gas distribution status as well as process conditions. Initially the ESP needs to be restored to mechanical and electrical operating conditions. The Upgrade solutions include full range of options for; Control System Upgrade, Extension of Field, Flue gas Conditioning.

The paper will first present environmental drivers facing ESP operators. Secondly, The various ESP technological upgrades will be reviewed, including a discussion on the advantages and disadvantages of the selected upgrade methodology.

Keywords: esp, electrostatic precipitator, emission, pollution, upgrade, control system, high voltage power supply

1 ENVIRONMENTAL DRIVERS

Environmental legislation arises in response to local concerns over increasing concentrations of pollution. The concentrations of these pollutants can be reduced either by applying a simple Emission Limit Value (ELV) to all major sources (*the environmental quality approach*) or by requiring that all sources fit suitable control and/or maintain equipment to reduce emissions (*the technology-driven approach*). In reality, much of today's legislation seen around the world is a combination of these two approaches.

Although it is well recognized that pollution is often not a localized problem and that gaseous air pollutants can cross great distances, each country may choose to adopt approaches including ELV, technology selection of Best Available Technology (BAT) & Best Available Control Technology (BACT) or trading schemes, whichever is most suitable. Legislation therefore varies from country to country depending on factors such as the economy, fuel supply, fuel dependency and specific pollution problems.

Companies and even plants are today facing global environmental initiatives. The World Bank standard requires specific and most international projects to meet prevailing world standards for subsequent investment purposes. The United Nations initiatives UN ECE (Convention on Long-Range Trans boundary Air Pollution) and UN FCCC (Kyoto Protocol) have been developed and expanded over the years to specify individual protocols to reduce specific pollutants.

1.1 Regional Environmental Regulations

The European Union (EU) and the USA alternately seek leadership in driving standards for particular pollutants. Type of pollutant, level and timing of compliance frequently varies. China and the rest of the world generally follow the environmental lead of the EU and the USA, usually with a time delay related to economic development. Conclusion of the air pollution regulation is available in Table 1 end of this paper.

1.2 European Environmental Regulations

The EU currently has four directives, which are very relevant to emissions from fossil-based power generation:

(1) The National Emissions Ceilings Directive (NECD), which caps total emissions of SO_x, NO_x, VOC and ammonia from all sources in each country;

(2) The Large Combustion Plant Directive (LCPD), which requires that countries either adopt the suggested emission limits for large units or take appropriate action to ensure an equivalent reduction in emissions;

(3) The Integrated Pollution Prevention and Control (IPPC), which requires in the permitting process that new sources aim to reduce emissions of multiple pollutants simultaneously;

(4) The Greenhouse Gas Allowances Trading Directive (GHGAT), which caps total emissions of CO_2 from more than 12 000 installations.

Most European countries have or are in the process of implementing the IPPC, the NEC and LCPD (LCPD). For the LCPD, most countries have accepted the ELVs as specified with only a few opting for the alternative national plan approach (Belgium (Flanders region), Czech Republic, Finland, Greece, Ireland, the Netherlands and the UK).

1.3 United States Environmental Regulations

Legislation for air pollution control in the USA appears far more complex than that in Europe because of differences in existing legislation, industrial structures and administrative organization (Federal and States legislations).

The USA currently has three principal directives that build upon the Clean Air Act legislation, which are relevant to emissions from fossil-based power generation:

(1) The Clean Air Interstate Rule (CAIR), a rule that will achieve the largest reduction in air pollution in more than a decade. CAIR will permanently cap emissions of sulphur dioxide (SO2) and nitrogen oxides (NO_x) in the eastern United States;

(2) The Clean Air Mercury Rule (CAMR), the first federally mandated requirements that coal-fired electric utilities reduce their emissions of mercury;

(3) The Regional Haze Rule, which calls States and Federal agencies, to develop and implement air quality protection plans to reduce the pollution that causes visibility impairment.

The CAIR has been the keystone of the federal law that regulates air emissions until US Supreme Court recently agreed complaint of some States and the future of the CAIR is now open.

As in Europe, individual states within the USA also have the power to set appropriate local legislation, as long as it is as strict as or stricter than the national legislation. However, only 24 states have authority by law to establish limits more stringent than the federal standards.

Table 1 Air pollution regulation

	1970	1980	1990	2000
US	**Clean Air Act:** New Source Perfomance Standards (PM, NO_x, SO_x) 1967 **Clean Air Act:** National Ambient Air Quality Standards & State Imple-mentation Plans 1970		**Clean Air Act:** Complete rewrite of the old Clean Air Act 1990 **SO2 cap and trade system** 1995	**Clean Air Intersta-te Rule (CAIR):** SO_2, NO_x cap & trade system 2005 **Clean Air Mercury Rule (CAMR):** mercury cap & trade system 2005
European Union	Various different national regulations: rather stringent in Scandinavia, Germany, less stringent in Southern and Eastern European countries First: British Clean Air Act 1956	**LCPD**: 1st regul-ation on emission limits (SO_x, No_x, PM) 1988	**IPPC**: Permitting on the basis of best available techn-ologies (BAT) 1996	**LCPD revision**: More stringent emission limit values (SO_x, Nox, PM) 2001 **NECD**: National Emissions Ceilings 2010 for total country emission 2001
Japan	**Air Pollution Control Law:** Emission standards for industrial facilities (SO_x) 1968 **Air Pollution Control Law:** „Total emission" control for SO_x 1974	**Air Pollution Control Law:** „Total emission" control for NO_x 1981	**Air Pollution Control Law:** Latest amendment 1996	
China			**Emission standard of air pollutants for thermal power plants** 1996	**Emission Standard of Ai Pollutants for Boilers** 2001 **Emission standard of air pollutants for thermal power plants** 2003

1.4 Chinese Environmental Regulations

A new legislation authorizing a change from emission regulations based on concentration (common for sources other than coal-fired units) to regulations based on the mass of pollutant emissions has been recently passed. The new regime is entitled "total emissions control". It will allow local environmental authorities to limit the total air pollutant emissions in a given area by issuing permits and collecting fees.

1.5 Interdependence or Divergence of Environmental Regulations

Although many countries have been successful in reducing emissions of pollutants, the history of the development of emissions legislation demonstrates that these reductions were achieved either by the tightening of emission reduction targets over time or by the introduction of new environmental regulations. A trend, from single pollutant control towards multipollutant control is also currently been observed. The implementation of multipollutant emissions legislation shall reverse the trend of growing quantity of environmental regulations observed in the past.

Emission information has also become more and more public on most pollutants. Additionally, improvements with emission monitoring equipment and the increasing availability of continuous emission monitoring equipment have improved data on actual emissions. In some cases, it has improved the understanding of the nature and the origin of the pollutant in question and lead to more appropriate control methods.

The link between air pollution and health has also been more evidently established. These detrimental effects on human health have led, and in some countries, are leading, to increased pressure to tighten emission limits.

Such observations have led to the development of cooperation between countries to control transboundary pollution. International protocols and agreements, such as those produced by UN ECE or the UN FCCC are of course largely voluntary. However, once a country has signed up for a protocol and the protocol is ratified by the required number of member countries, the targets for pollution control become binding. A first step of interdependence of environmental regulations has been set.

1.6 Technological Drivers for Existing Plants

The total world installed capacity is approaching 4500

GW [1]. The conventional steam plants are still the predominant technology with about 50% of the total, followed by the hydro and gas turbines with around 20%.

1.7 Future Energy Demand

The consumption of electricity worldwide has been growing at a relatively steady rate for the past half century and is expected to continue for the next 20 years with little change. The growth varies from region to region with China and the developing countries having the highest projected growth.

The GDP growth is the main driver of energy demand. The use of primary energy per person has been closely linked with the GDP per person. The population growth has been about 1.0% per year and the GDP growth has been about 3.0%, with the USA at 3.0%, Europe at 2.2% and developing Asia at 6.0%. The future growth in world GDP is expected to be around 3.0% [2]. The main reasons for this forecast are the rising fuel price and some form of more stringent environmental regulations e.g. carbon dioxide tax, which are driving energy conservation.

However fossil fuels will still dominate the future of the power generation sector with the natural gas share increasing and coal remaining the main source of primary energy [3, 4]. Obviously the forecast may somewhat be influenced by the relative price evolution of these fuels, as well as by the future new environmental pressures.

1.8 Aging of the Installed Fleet

In addition to the capacity installations, which are necessary to satisfy the growth in economy and the replacement of the lost capacity due to retirements (for example plants operating under the 20000 h clause of the EU LCPD), there is no doubt that there is a large retrofit/ rehabilitation market for a variety of reasons. Firstly, the number of plants approaching 40 years of age (a nominal life time) in the next decade will be large. Secondly the imposition of tougher conventional emissions requirements, plus CO_2 reduction will force change. It is estimated, based on experience, that roughly 20% of plants in the 40 year age-bracket will be rehabilitated and this represents approximately 20 GW/year [5].

1.9 Fuel Flexibility

As indicated previously, a new force reshaping the power sector is energy market liberalization and globalisation. Deregulation of generation is forcing power generators to focus their attention closely on the impact of any change on cost of generating power. Since fuel is one of the largest cost elements of producing electricity, power generators will be looking for attractive fuel opportunities while meeting very strict environmental regulations. The regional availability of fossil fuels sources will create very different buying patterns in fuel. In countries like China, India, USA, Australia, Japan, Germany, and Eastern European countries, the use coal will remain dominant. Similarly, countries with gas, will grow where gas is available.

2 MANAGING REQUIREMENTS FOR PARTICULATE EMISSION

Power and industrial companies evolve in an increasingly competitive and deregulated market. They require products and services that enable them to produce power and industrial goods in a knowledgeable and most profitable manner. Availability, operating flexibility and environmental compliance are key assets that owners and shareholders want to have from air pollution control system to add value.

Although the above mentioned requirements might be perceived as often conflicting, there is a full scope of products and services available. operators can select solutions from inspections, upgrades, monitoring and control, optimisation to complete operation contracts with emissions and operating time guarantees of air pollution control equipment.

For the existing ESP upgrade applications, some technologies may be better suited than others for reasons of layout and cost, process integration, age and design of that plant and the emission levels to be achieved. The most appropriate solution can be selected after detailed inspection and assessment of the present electrical, mechanical and gas distribution status as well as process conditions. Initially the ESP needs to be restored and maintained to mechanical and electrical operating conditions. The Upgrade solutions include full range of options for; Control System Upgrade, Extension of Field, Flue gas Conditioning. Last two years trend towards plant upgrades has been significantly increasing and Alstom has globally executed more than hundred ESP upgrades in coal, oil and bio fired power plants as well as iron & steel, cement, pulp & paper industry and waste to energy plants.

2.1 Inspection, Assessment and Maintenance

The basis of operation and maintenance is awareness of the operating situation of the air pollution control equipment concerned. Mechanical and electrical inspections determine the actual condition of the equipment. In order to maintain the optimum efficiency regular inspections for the flue gas line equipments are recommended:

(1) Annual review of the operation and control system settings;

(2) Mechanical inspections part of annual planned maintenance shut down;

(3) A complete electrical inspection every two to three years;

(4) Fans and other accessories annual mechanical inspection and operational measurements every three to five years.

Assessments of the flue gas line are recommended at least between 5-8 years to confirm its proper operation. The need for the assessment may also become evident:

(1) Prior to obtaining new environmental permits and related investment plans;

(2) When increasing the power output or changing fuel,

process and production.

Analysis needs to be made for the best type and the best time to repair or replace parts to minimize service interruption, either during a short or a major outage. Process of continual inspections in numerous locations benefits also to make performance comparisons, detect trends and suggest to act in advance of a failure and requirements.

Not only to decrease emissions after the new ESP installation but also improve economy of the regular major maintenance Alstom is continuously developing and testing new ESP design. One example is e.g. a new technique to reduce the rapping losses from ESP called Off-Flow Rapping System (OFRS) (Fig. 1).

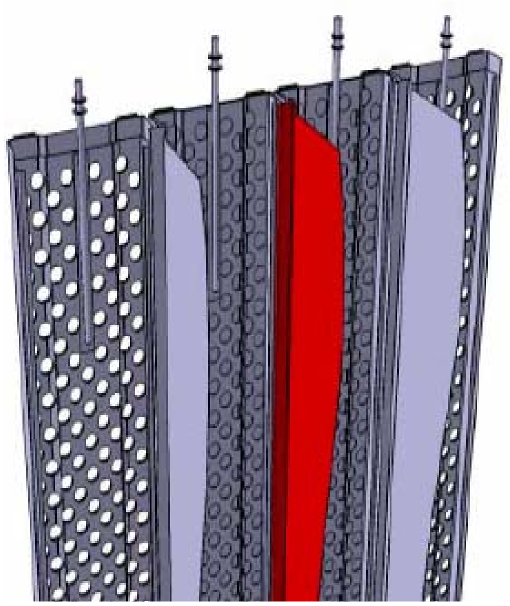

Fig. 1 ESP with the associated screens in the closed position

2.2 Latest Methods of ESP Upgrades

For an electrostatic precipitator (ESP) in good flow, mechanical and electrical conditions there are several opportunities to improve particulate collection efficiency. As illustrated for different requirements in Table 2 there are a series of upgrading techniques ranging from Transformer/ Rectifier (T/R) control, high voltage power supply Switched Integrated Rectifiers (SIR), flue gas conditioning, more efficient ESP design to field extension. The most suitable technique is chosen based on the actual conditions, outage opportunity and economical aspects. The cost for the upgrading techniques differs significantly. [7, 8]

2.3 Control System and Energising

Alstom has developed the new generation of high voltage power supplies SIRs. The exchange of conventional T/R's to SIRs will usually result in a significant performance improvement as illustrated for different applications in Fig. 2. This is due to a higher power input possible at operations that are limited by voltage or sparks.

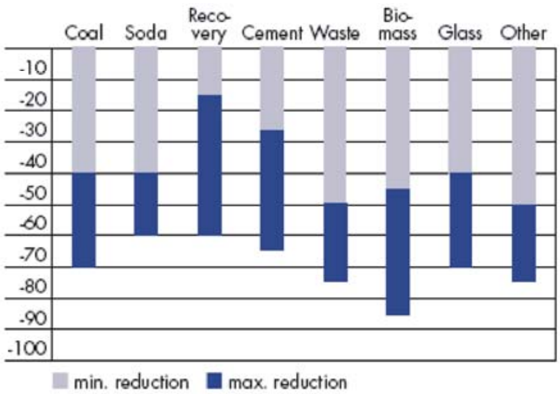

Fig. 2 Emission level decrease in % with SIRs compared to conventional T/Rs

Table 2 Methods of ESP Upgrades [7]

Operating Condition	Measure	Alstom Solution
High resistivity dust with back-corona	Dealing with high resistivity	- Controllers with advanced charging and intelligent rapping control - Improved discharge electrode design
High resistivity dust with back-corona	Reduce resistivity	- Flue gas conditioning
High dust re-entrainment	Reduce rapping losses	- Optimised rapping procedures - Modified gas distribution - Improved dust cake agglomeration with flue gas conditioning - Increase ESP size
High dust re-entrainment	Handling high flue gas velocity	- Reduce effect of corona suppression - Improved dust cake agglomeration - Increase ESP size to achieve better collection efficiency
Lower dust emission requirements	Insufficient collecting efficiency with other upgrade methods	- Increase ESP size - Change the particle size distribution with agglomeration technologies

2.4 Case Study: Coal-fired Power Plant Particulate Emission Reduction in Portugal

The South Africa coal fired boiler (2×315 MW electrical) ESP 4 T/R was upgraded with four SIR sets. The challenge to meet new environmental permit was mainly high space charge combined with high resistivity fly ash.

Before project the dust emissions level was around 35 mg/Nm^3 After the upgrade and extensive tuning the dust emissions level dropped down to 25 mg/Nm^3.

2.5 Optimisation

Increasingly operators are interested in advanced control system and optimisation software solutions. Optimisation software as part of an overall air pollution control plan has been shown to not only improve environmental compliance, but also to exhibit a number of financial benefits for users, such as a decrease in overall operating costs, an increase in equipment life time and the even ability to manage valuable air pollution trading credits.

Based on process experience in particulate control Alstom developed the Electrostatic Precipitator Optimising of Charges (EPOQ) control algorithm. The control algorithm is a self-adapting expert software, with one aim only to minimize emissions as pictured in Fig. 3.

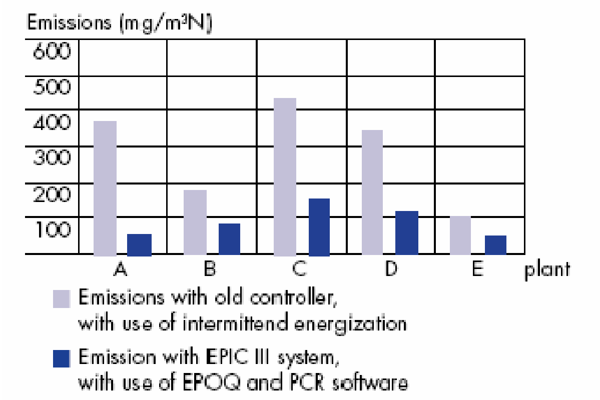

Fig. 3 Emission levels with the use of EPOQ algorithm versus the use of intermitted energization

2.6 Case Study: North American Power Plant Optimise ESPs to Gain Full Production Capacity

At the 6×125 and 4×150 MW electrical coal fired plant needed to move from US eastern bituminous to low sulphur coal blend. The new sectionalizing, installation of the SIRs & EPOQ software and remote monitoring system enables fuel switch to less expensive with full electricity production.

2.7 ESP internals, Extension of ESP field or Size

Pre-assembly gives many advantages and time needed for a ESP maintenance and upgrade. This method is applicable in cases where the old casing walls are used and may be extended in height or extend also the old precipitator with an additional field. The pre-assembly makes the erection of precipitators easier and in some cases even possible because of the tight time schedule during a shutdown.

2.8 Case Study: Production Bottle Necks Elimination be Extending Two Lime Sludge Kiln ESPs with Additional Filed in Finland

Pulp mill production increase caused dust inlet increase from 45 up to 65 g/Nm^3 and led to production limits to meet mill environmental permits. The upgrade was completed during production outage just of ten days with just a 24 hour window to erect the ESP fields. The additional challenge was interpreting the weather forecast and monitoring the wind speeds in order to safely manage the heavy lifts (Fig. 4).

Fig. 4 Heavy lift of the second ESP field

The result of upgrade was plant particulate emissions reduction from 110 down to 30 mg/Nm^3 and finally full pulp production capacity.

2.9 Monitoring and Control

Control and monitoring systems offer today opportunity for continuous process supervision. Regular monitoring and fine-tuning of the air pollution control equipment guarantee the lowest possible emissions and energy consumption. Analysis of operating data allows maintenance measures to be implemented in a planned and optimal manner. The system also produces a rapid advance warning if the operating conditions should deviate from the norm and thus require further, unscheduled work to be carried out.

2.10 Long-Term Service Agreement for Particulate Compliance

To further innovate in the service area, and relying on a unique broad expertise, Alstom offers a new and advantageous concept that solves many operating problems. This long-term service agreement is backed by a complete performance guarantee for operating economy and emission levels. The agreement is based on a longer period of time (for example 10 years) to give the customer complete control over the cost of their air pollution control equipment, without any surprises caused by extended downtime or faults in the design of the power plant.

3 CONCLUSIONS

Today’s power generators and industrial producers need to operate their plants more cost-effectively and complying with more stringent environmental regulations while meeting the increasing demand for electricity. Challenges such as emissions compliance have caused operators to look for ways to help existing plants do – what once seemed impossible – to simultaneously produce more power and products, increase profitability and become more environmentally friendly.

REFERENCES

1,2. WEC stat.
3. Annual Energy Outlook 2007 with Projections to 2030.
4. Report #: DOE/EIA-0383, Washington (DC) (2007).
5. International Energy Agency (IEA) World Energy Outlook 2006, Paris (2006).
6. Alstom internal communication, Paris (2007).
7. Upgrade technologies for Electrostatic Precipitators. Lena Lillieblad et al. ICESP X - June 2006.
8. Long-term economical aspects of energising electrostatic precipitators with high-frequency switched power supplies. M. Kirsten et al, Power Gen Europe conference, June 26-28, Madrid (2007).
9. Trends in Air Pollutant Emissions in Europe and Asia. J. Cofala, et al., IIAS.
10. Air Emission trends in Russia and Asia (1990-2030). Zbigniew Klimont, International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.