On the Choice of ESP Design for a Multitude of World Low Sulphur Coals

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Abstract.

Electrostatic Precipitators (ESP's) are the main particulate collectors for most new power stations firing coal. ESP's are able to achieve present emission regulations and are often preferred by users due to robustness, low operating cost and high availability. Many new boilers will burn low sulphur coal. Present legislation requires limits on sulphur emissions and with the burning of low sulphur coal it is then often possible to avoid desulphurisation equipment.

The owner of the plant wants to have the flexibility to buy any coal on the world market for various reasons. Coals with sulphur content less than 1% and relatively low ash content are readily available and are exported from countries like Australia, South Africa, Indonesia, China and Latin America. The ash properties from such coals vary widely and the impact on the ESP size can be dramatic. Coal and coal ash analyses in combination with boiler conditions, humidity, gas temperature etc. are considered when selecting the size and design. The specification for the ESP often comprises a wide selection of coals that might be fired several years later. What is a realistic size of the ESP taking the specific coals or the ranges into account?

The paper discusses the influence from various parameters on the ESP size and suggests different strategies to be applied in order arrive at cost-efficient solutions. It is important that the boiler vendor has close contact with the ESP vendor to optimise the whole plant. Furthermore, the plant owner should have a proper knowledge of limitations and possibilities when buying the ESP.

Introduction.

The electrostatic precipitator (ESP) is generally accepted as a reliable and efficient particulate control device with low operating cost, low maintenance and high availability. It has also been proved to be able to achieve the required emission levels for most major applications. Over the years, environmental legislation has demanded increasingly lower particulate emissions. Today's emission standards are in the range of 20 – 50 mg/m^3 NTP for new plants but guarantees of 10 mg/m^3 NTP or even lower are not unusual.

The use of ESP's after coal fired boilers is by far the most common application. The properties of the ash vary widely between the coals and the determination of the size of an ESP to give the necessary treatment time for the flue gas can be a challenge. Common sizing methods typically consider a nominal ash size distribution for all pulverised coal-fired applications and a single (average) coal and coal ash composition for a given coal. In fact, a wide range of size distributions results from the combustion of different coals and likewise of the same coal in different boilers[1]. Individual ash particles have compositions significantly different from the bulk ash composition as determined by standard ASTM analysis. The wide range in fly ash properties (particle size and shape, composition, resistivity, cohesivity etc.) together with flue gas composition (e.g. SO_3 concentration, moisture content) and temperature determine the final ESP size for a given performance level.

The design and size of an ESP for a specific task must to a great extent be based on experience from installations with similar coals and boiler conditions. Achieved migration velocities, an important parameter when sizing a new ESP, have to be extrapolated frequently to lower emission levels and other coals. Vendors have developed or acquired such models in a more or less sophisticated way. This kind of knowledge is often considered as proprietary information by the vendors and is then not easily available for users. This paper will discuss in general terms about ESP sizing based on coal and coal ash analyses and will not discuss various sizing models or various design features of ESP's from different vendors.

A new power plant can for example use coal from one adjacent coalmine. The size of an ESP will then reflect that coal. Variations in coal properties are likely to show up but it is basically the same coal all the time and the sizing is relatively straight forward – see also the discussion below. Another case is when the power station depends on a variety of coals. The vendor or the user must then decide which of the coals will dictate the size of the ESP. Large power plants in many countries in Europe and Asia are using so-called export coals. These coals are characterised by having relatively low sulphur, S, and a low ash content. By using a low S coal, a flue gas de-sulphurisation (FGD) plant can in many cases be avoided.

The purpose of this paper is to illustrate the complexity when sizing an ESP. Knowledge about the limitations for coals will help both the user and the designer in finding optimal solutions. The paper also exemplifies why it is important to know the system "boiler-ESP" for the proper selection of an ESP size. The coal and system parameters being discussed can be applied for both new plants and upgrading of old plants.

Coal and coal ash analyses.

Analyses for a specific coal.

Table 1 shows a typical example of an export coal. The coal might have a name, e.g. Ulan, Hunter Valley or Clermont. Some of these coals appear frequently in specifications and are known to major ESP vendors. Other coals may be new and experimental or test data does not exist. Proximate as well as ultimate analyses on as received basis, air dry basis or dry and ash free basis are sometimes given. Note for example that the value for the S content varies with the type of analysis. The vendor might be able to make his owns estimations on gas composition, inlet load etc. based on the data in the table.

Table 1. Typical coal analyses.

COUNTRY			**AUSTRALIA**
COAL			**XXX**
HHV (Air Dry base)		**kJ/kg**	**28050**
HHV (Air Dry base)		**kcal/kg**	**6700**
Surfave Mois. (As Received base)		**%**	**5,26**
Total Mois. (As Received base)		**%**	**10,00**
Proximate Analyses (air dry base)	**Inherent Mois.**	**%**	**5,00**
	Fixed Carbon	**%**	**42,00**
	Volatile Matter	**%**	**39,00**
	Ash	**%**	**14,00**
	Total	**%**	**100,00**
	Sulphur	**%**	**0,43**
	Nitrogen (DAF)	**%**	**1,50**
	Fuel Ratio		**1,08**
Ultimate Analyses (dry ash free)	**Carbon**	**%**	**81,06**
	Hydrogen	**%**	**6,35**
	Oxygen	**%**	**10,59**
	Nitrogen	**%**	**1,50**
	Sulphur	**%**	**0,50**
	Total	**%**	**100,00**

HHV (As Received base)		**kJ/kg**	**28574**
HHV (As Received base)		**kcal/kg**	**6347**
Ultimate Analyses (as received base)	**Carbon**	**%**	**62,21**
	Hydrogen	**%**	**4,87**
	Oxygen	**%**	**8,13**
	Nitrogen	**%**	**1,15**
	Sulphur	**%**	**0,38**
	Ash	**%**	**13,26**
	Moisture	**%**	**10,00**
	Total	**%**	**100,00**
Ash Fusibility	**I.D.T.**	**degr. C**	**1300**
	H.T.	**degr. C**	**1600**
	F.L.T.	**degr. C**	**1600**

Table 2 shows the corresponding coal ash analysis. All elements are expressed as oxides. It should be observed that this is not the same as a fly ash analysis. The fly ash content is often assumed to be in the range 80 – 95 % of the total coal ash for a pulverised coal (PC) fired boiler. The rest is bottom ash. As said before the real mineral composition of the particles are different from the analyses in table 2[2].

Table 2. Coal ash analysis.

Coal Ash Analysis	**SiO2**	**%**	**62,80**
	Al2O3	**%**	**28,90**
	Fe2O3	**%**	**1,60**
	CaO	**%**	**1,90**
	MgO	**%**	**0,01**
	TiO2	**%**	**1,80**
	Na2O	**%**	**0,60**
	K2O	**%**	**0,60**
	P2O5	**%**	**0,30**
	Mn3O4	**%**	**0,01**
	SO3	**%**	**0,45**
	Others	**%**	**1,03**
	Total	**%**	**100,00**

For a specific coal it is common to give the various oxides as a single number and not as a range. A discussion about this follows in a subsequent section.

Analyses for a multitude of coals.

Table 3 shows a simplified version of coals given in a specification. The vendor is often asked to guarantee an emission level for all the coals. In the example there are coals from Australia, China, Indonesia and South Africa. Coals from Poland, Russia, Colombia and USA (Powder River Basin coal) are also seen depending on where the power station is located.

Table 3. Typical specified export coals for a power plant.

Country		Australia	Australia	Australia	China	China	Indonesia	Indonesia	South Af	South Af
Coal		A	B	C	D	E	F	G	H	I
Ash	%	13,26	11,54	14,00	6,44	12,93	6,53	2,00	11,90	13,27
Sulphur	%	0,38	0,39	0,50	0,31	0,89	0,65	0,10	0,69	0,62
SiO2	%	62,80	75,11	69,50	62,84	41,90	53,82	35,00	49,10	50,50
Al2O3	%	28,90	18,35	24,50	23,93	44,90	28,15	17,00	29,46	37,70
Fe2O3	%	1,60	2,79	1,10	5,07	4,00	8,97	18,00	3,52	2,80
CaO	%	1,90	0,60	0,60	1,45	3,00	2,10	12,00	9,36	2,50
MgO	%	0,01	0,60	0,40	0,62	0,40	1,97	5,00	2,11	0,50
TiO2	%	1,80	1,10	1,30	0,74	1,60	1,29	1,50	1,38	2,10
Na2O	%	0,60	0,31	0,10	0,65	0,30	1,44	0,20	0,36	0,06
K2O	%	0,60	0,75	2,20	1,21	0,15	1,10	0,60	0,46	0,50
P2O5	%	0,30	0,15	0,20	0,60	0,75	0,98	0,20	0,51	1,80
Mn3O4	%	0,01			0,09	0,10		0,30	0,08	0,01
SO3	%	0,45	0,24	0,10	0,48	2,00	0,09	8,00	2,03	1,00
Others	%	1,03			2,32	0,90	0,09	2,20	1,63	0,53
Total	%	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

It is well known that some of the constituents are more important than others for the ESP performance. Thus low S, high Si and Al and sometimes high Ca content generates a fly ash that has a high resistivity. Back-corona conditions may result in an ESP and even with today's sophisticated control algorithms in order to overcome these conditions a larger ESP has to be provided to meet the guaranteed emission. Fe, Na and K are known to be beneficial for performance and high values of these compounds result in a smaller ESP.

As can be seen from Table 3 the differences in the ash analyses are quite substantial even for coals from within a country. The Australian coals often have an ash content of 10 – 15 % and low S content. Coal C has Si + Al oxides of 94 % (extremes up to 97 % have been seen) and a very low Na content. The two coals from China are not alike. Coal E has Al-oxide of almost 45 % and this type of coal is known in the literature[3] to produce difficult to collect fly ash. Many of the Indonesian coals have low ash content. Coal G has only 2 % ash and 0,1 % S and is somewhat high in Ca. The South African coals can be fairly high in Ca-oxide, coal H has greater than 9 % and can be low in Na-oxide, coal I has 0,06 %. It is evident that large variations exist and sizing of an ESP may be hazardous.

ESP sizing considering the coal and coal ash analyses.

Which coal composition is the most difficult one and should the ESP size be based on that one? How to choose the specific collecting area (SCA) with a minimum of risk? The proposed size of an ESP for a given task must comprise a safety margin. When investigating performance test data from operational plants there is always a spread in data even if conditions seem to be the same. If average emissions or migration velocities are used for the new ESP size, the likelihood of a performance failure in a test is 50 %. This is not acceptable and therefore a safety margin has to be applied on the size. The philosophy for and estimation of the safety margin may vary between various vendors. One strategy could be to size according to experimental data but apply a lower emission (this is then the expected emission). Another strategy could be to reduce the migration velocity a certain percentage implying that the vast majority of experimental data show higher migration velocities than the one for the new plant. 100 % safety can in principle not be achieved economically.

Sometimes the specification for an ESP plant calls for a minimum collecting area. The vendor must then decide if the given area is appropriate for the guaranteed emission or if some extra area has to be added. The vendor has to have proper knowledge about applicable migration velocities for the various coals in order to make the correct choice. The same applies when there is no specified area then the vendor must decide the necessary area based on “worst” conditions. Items to be considered in the choice of the ESP size are:

- Is there a proper knowledge about every specified coal? If not, should a larger safety margin be applied for the “unknown” coals?
- Does input data, such as inlet ash concentration, gas flow and moisture content look realistic or are extra safety margins already applied in the specification?
- Should a standard safety margin be applied for the worst coal? What is the likelihood of firing the worst coal at the plant?

Table 3 shows an example of individual coals. The analysis for the actual coal fired at the plant will certainly deviate from the specified one. If so, is the guarantee still valid? From a customer’s viewpoint it should be valid. However, from experience the vendors have learnt that a specific coal having a special brand name, e.g. Ulan coal from one coal supplier, can vary within wide ranges. A vendor might choose to propose in the contract to have maximum values of e.g. Si, Al and Ca and to have minimum values for e.g. Na, K, Fe and S. The limits are often set to the same values as given in the specification. Instead of limits, correction curves are commonly given for critical parameters. For example a correction curve of the performance for Na for coal B may cover a range from 0,1 to 0,5 %. Should then correction curves be proposed for every individual coal or could they cover all coals? Furthermore, what guarantee is valid if a coal, which is not defined in the specification/contract is fired? One way for the customer to overcome this problem is to give ranges in the specification. If the coals in table 3 are given as ranges it will look like in table 4.

Table 4. Ranges for the coals in table 3.

		Range, %
Ash	**%**	**2,00 - 14,0**
Sulphur	**%**	**0,1 - 0,89**
SiO2	**%**	**35,0 - 75,11**
Al2O3	**%**	**17,00 - 44,9**
Fe2O3	**%**	**1,1 - 18,0**
CaO	**%**	**0,6 - 12,0**
Na2O	**%**	**0,06 - 1,44**
K2O	**%**	**0,15 - 2,20**
SO3	**%**	**0,10 - 8,00**

The designer of the ESP gets a new problem. What is the worst combination and is that a realistic coal? Does it exist? By choosing high values for Si+Al and low for S, Na, K and Fe, and still a sum giving 100 %, the designer might have picked a non-existing coal. Should the standard safety margin be applied for such a coal?

The examples generated from tables 3 and 4 demonstrate uncertainties both for the user and for the supplier of an ESP plant. Suggestions on how to reduce the problem are discussed later in the paper.

Necessary SCA's.

A recent specification for an ESP in Asia included 45 different coals. Coal and coal ash analyses were given together with gas flows, gas temperatures, moisture content and inlet loads for each individual coal. The corresponding SCA's were calculated in order to guarantee the same emission (mg/Nm^3) for all coals. The result can be seen in Fig. 1 – relative SCA in descending order for the various coals. This example is based on ALSTOM's sizing formulas to illustrate the large variation in SCA's. The SCA values are not adjusted for number of fields, aspect ratio etc. Thus, minor deviations will occur if 45 separate ESP's were to be sized. However, it does not change the principle discussions in the paper.

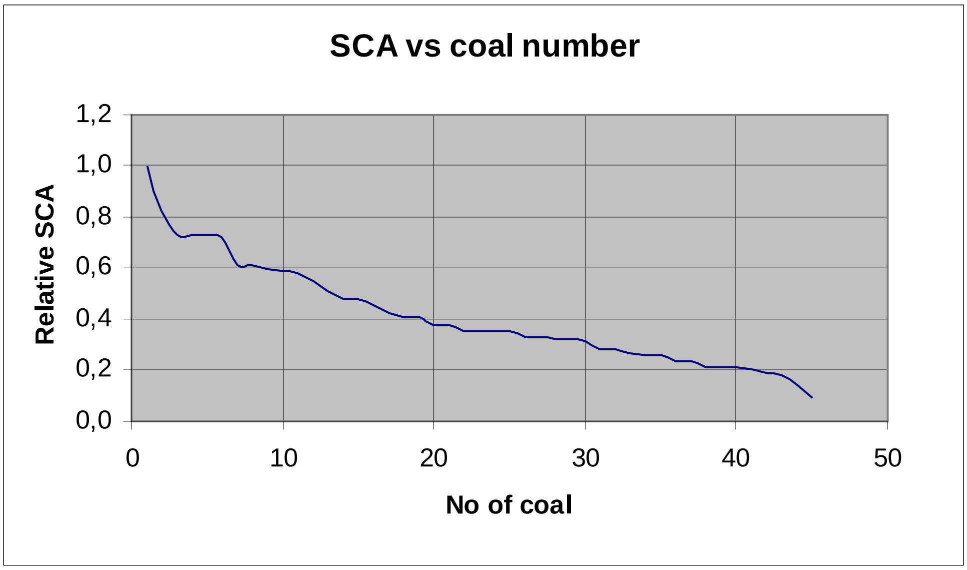

Fig.1. Relative SCA values for 45 coals in order to achieve a guaranteed emission (mg/Nm^3).

There is a difference of 10 times between the easiest and the most difficult coal. Some of the easy coals – resulting in low SCA's – are Indonesian coals with a very low ash content resulting in low inlet burdens. The corresponding collecting efficiencies for these coals are, therefore, comparatively low. If the ESP is sized for the worst coal the actual emission will be far below the guaranteed value for most of the coals. It will look as if the ESP is oversized. The user will feel that he invested too much.

Factors influencing the ESP size.

There are a number of process factors that are often overlooked when determining the ESP size. Some of the factors besides the coal and coal ash properties are briefly discussed in the following chapters. Factors specific for the ESP design such as number of fields, discharge electrodes, rapping, controls etc. will not be discussed in this paper.

Boiler – ESP system.

It has been demonstrated earlier[1,2] that the boiler conditions can have a major impact on the ESP performance. In summary:

- A high flame temperature increases the formation of ultrafine particles – particles having a diameter of around 0.1-0.3 µm. These particles can have a detrimental effect on the ESP performance and the ESP size might have to be increased. First, the total surface area of all fly ash particles becomes larger at the higher temperatures and the generated SO_3 in the boiler may not be sufficient to create enough improvement of the surface conductivity of the ash. Secondly, a high amount of particle surface area may lead to corona suppression due to the space charge effect. Thirdly, the smaller particles need longer treatment time in the ESP to be collected.

- The majority of number of particles from a PC boiler are in the ultrafine range[4] and need to be precipitated to achieve today's low emission levels.
- The formation of SO_3 in the boiler is depending on the temperature, the time for the gas at high temperatures and the oxygen content.
- Unburnt, or loss on ignition (LOI) varies depending on the design of the burners and the boiler. Unburnt particles in terms of large conductive particles can easily bounce (being collected but re-entrain) through the ESP. A low gas velocity through the ESP improves the collection of the LOI. Boilers with so called low NOx burners may generate more LOI than old standard burners and may need special consideration while designing an ESP.

A few examples of how boiler conditions changed the ESP performance illustrate the system dependency. At one plant the emission was too high when a new South African coal was fired. The new low S coal generated a high resistivity fly ash, which resulted in heavy back-corona in the ESP. Tuning of the controls in the ESP plant did give some improvements. However, a substantial reduction of the particulate emission took place after the tilt of the burners was adjusted so that more treatment time was used for the flame. The flame temperature was reduced and the back-corona almost disappeared.

Another example is from Japan where low S coal from Australia was fired in two different plants. One boiler was rated 700 MWe while the other one was 200 MWe. The small boiler was more aggressively sized and in order to generate the guaranteed power output the temperatures in the flame zone were higher than in the large boiler. The ESP after the small boiler just achieved the guarantee and showed difficult operating conditions including high resistivity fly ash. The ESP after the large boiler was operating without problems. The SCA values and guaranteed emissions of the two ESP's were comparable. It can also be noted that the small boiler normally generated a LOI of 1-2 %. By accident, on one occasion, the LOI increased to greater than 15 % and the ESP performed well with an emission significantly below guaranteed emission level. The gas velocity in the ESP by design was low and most of the LOI was fine soot particles reducing the particulate resistivity.

A warning also has to be raised for hydrocarbons emanating from the boiler operation. Hydrocarbons may come from oil burners that give incomplete combustion. Evaporated hydrocarbon compounds will condense and cover particles entering the ESP. Small amounts, < 0.5 % of the ash, can drastically increase the resistivity and as a consequence increase the emission.

Changes of the boiler load can also change the composition of the fly ash to the ESP. Oxygen content, treatment time and flame temperatures will change. Furthermore, the ratio between bottom ash to fly ash will also change as the gas velocity in the boiler varies. Thus, it does not follow that the same migration velocity be applied for varying boiler loads. This may be important when giving guarantees at different boiler loads.

Gas temperature.

It is well known that reduced gas temperatures below the resistivity peak, normally around 150 ºC, increase the migration velocity[1]. Experience from pilot and full-scale plants verifies this. However, there is another effect, which is often overlooked. The air preheaters generate a temperature profile that is uneven across the gas duct and the ESP inlet providing no mixing is done. A temperature deviation of 615 to 20 ºC from the average is not unusual. Thus, if the average gas temperature is e.g. 140 ºC, there can be cool areas down to 120 ºC and hot areas up to 160 ºC. This temperature variation implies that there will be different ash resistivities across the ESP and it may be possible to have back-corona in one area but not over the whole ESP.

A reverse temperature dependency may, however, be seen in such a case. The gas with the lowest temperature from the air preheater may have lost its SO_3 content due to condensation on the cold surfaces in the preheater. A lower gas temperature may therefore show a higher resistivity.

In the case of such a temperature range it may be justified to mix the gases in the ductwork before the ESP in order to achieve improved temperature and SO_3 distribution.

Selective Catalytic Reduction.

The installation of deNOx plants – e.g. by using selective catalytic reduction systems – can drastically change the conditions for the ESP. The SCR catalyst in the deNOx plant will convert amounts of SO_2 to SO_3 that will lower the resistivity of the fly ash. NH_3 is added to the flue gas before the denitrification plants and there is a few ppm of NH_3 slip in the flue gas leaving the deNOx plant. SO_3 and NH_3 will form ammonium (bi-) sulphate that is easily collected in the ESP together with the fly ash. This sulphate will reduce the resistivity and increase the cohesivity of the fly ash and re-entrainment can be substantially reduced.

An example from a European plant where selective catalytic reduction was installed changed the emission for South African coal dramatically. Instead of using conditioning agents and relatively low temperatures the conditioning could be taken away and the temperature was raised by 30 ºC, a temperature that earlier generated severe back-corona.

The above given examples demonstrate the importance of knowing the whole plant system. The operating conditions and the particulate for a given coal may appear quite differently from one plant to the other. Close contact between the end user, the boiler supplier and ESP designer is of the utmost importance in order to reduce the risk for an inadequately small or oversized ESP both of which have commercial ramifications.

Discussion.

Multitudes of coals.

When a multitude of coals is specified, how to size the ESP? Fig. 1 is used as a base for the discussion.

Deletion of coals.

If the worst coal is deleted the ESP size could be reduced to about 80 % of the original collection area. This is a significant saving for the customer/user in terms of investment, operational and maintenance cost. A further reduction to below 75 % of the original collection area can be done if two coals are deleted. Two coals out of 45 are less than 5 % of the specified coals.

Today's competitive bidding for new plants and the urgency of getting orders may lead the ESP vendor to take a calculated risk with a smaller ESP size. The vendor may consider that the risk of the worst coals being fired during the performance test is limited. Should the particulate emission be too high during such a test it may be considered that the risk of getting a difficult coal a second time is so low that the risk is worth taking. The vendor may also take into account any built-in safety margin. The same safety margin for the difficult coals may not be applied thereby reducing the costs for the ESP plant.

Commissioning and start-up of the plant should be done as thoroughly as possible to achieve optimum performance of the ESP. For example, careful gas distribution adjustments, air load tests and settings of the high voltage control equipment when achieving steady-state conditions from the boiler must be done even if the expected coal generates fly ash that is easily precipitated. There is an obvious risk that emission will appear to be much below the guaranteed value for such a coal even without proper optimisation and that the supplier and user are satisfied with the result. The consequence of such action is that the emission might then at a later stage exceed guaranteed values when a more difficult coal is fired.

The exchange of information between ESP suppliers and the boiler manufacturer or the user of the ESP at an early stage of the bidding procedure would be a recommended and preferred procedure to avoid misunderstandings. Cost savings can be substantial if the most difficult coals can be disregarded. The number of coals to be deleted may vary from case to case. The user may ask the supplier to give expected emissions for all coals in order to judge if all obligations are fulfilled should an easy coal be fired compared to the "guarantee" coal.

Blending of coals.

Are there alternatives other than deleting coals to reduce the ESP size and cost? One possibility is to blend coals, the difficult ones could be mixed with easier coals and the resulting emissions will be reduced accordingly. This assumes that the user has good records of incoming coals, where they are located in the coal-yard and a proper mixing procedure so that controlled blending can be assured. This method is used today in several plants importing coals.

Conditioning.

Another approach is to use conditioning agents, e.g. SO_3 or NH_3 or a combination thereof. The conditioning system is then only required to operate for certain coals. The user often knows well in advance what kind of coals he is going to fire and can plan accordingly. An SO_3 system normally needs 4 – 6 hours starting up time while the NH_3 system can be switched on and off frequently without problems. A prerequisite for both blending and conditioning is that the user understands the objective and “buys in” to the approach. As time goes by the user will gain experience from operation and know when and how to use these options for different coal supplies and boiler operating conditions.

General coal limitations covering most of export coals.

A more practical solution may be that some general limits are set up in the specification. For example the ESP performance should be guaranteed for all coals (coal ashes) having

- Ash content < 15 %
- S > 0.5 %
- Fe_2O_3 > 3%
- SiO_2 + AlO3 < 92 %
- Na_2O > 0.2 %

Users have practised this model. They have then investigated the market for coals and found that more than 80 % of all export coals are covered within these limits and this was considered appropriate. It is then an easy task for the purchaser of coal to buy according to these rules. The various coals will give slightly different gas flows but that difference is rather marginal compared to coal variations. The specification may comprise highest gas flow and instead of ash content it may define a maximum ash load.

Coal and coal ash analyses.

The difficulty with individual coal and coal ash analyses are that ranges are not specified for the various parameters. There are some options for the user when writing the specification.

- The specification can give ranges for certain parameters. It is common to give for example the highest and lowest S content. The vendor should state the limits for other parameters in his proposal should they be needed. The advantage for the user is that the rules for complying with the guarantee are defined. However, if the vendor sets strict limits giving values similar to the specified coal composition then the user is often outside the given range and no guarantee applies. This method will make it difficult to compare bids from different vendors.
- The vendor is asked to state any limits for individual parameters and must provide correction curves giving a firm guarantee when a parameter deviates from the specified limits It is still difficult to compare bids from different vendors.
- The specification could state that if any limits apply then a deviation of e.g. x % above or below the design value must be accepted before any correction curves are allowed. The figure x must however be selected as an appropriate value depending on the parameter. For example, for Na a variance of 20 % below the specified value must be allowed for while the variance for Si+Al would be an increase of 2 % (this lower variance % would apply when the sum of the oxides is in the 90 % range). This method could be a better approach in order to be able to compare bids from various vendors.

All examples of limits, ranges and corrections imply that the user or the person who makes the evaluation has a good knowledge of coals and the effect of these on ESP performance. It is advised that when evaluating bids examples of coal deviations should be tested and compared. These methods are applicable when one or several coals are specified. However, the complexity increases with the number of coals. One option could be that either the user specify a design coal and ask for specific information about this or that the vendor defines the worst coal and give the corresponding limits. The method described earlier with general limits on certain parameters seems however to be an attractive way to define guarantee limits. Such general limits could be complemented with correction curves for coals outside the range.

Boiler conditions.

It is imperative that information about the boiler and boiler conditions are given in order to design a good functioning ESP plant. Examples of important items are

- Type of boiler. A boiler firing pulverised coal produces much finer ash than e.g. a fluidised bed boiler.
- If deNOx plant, a selective catalytic (SCR) or non catalytic (SNCR) will be installed upstream the ESP
- Load variations and ramp rate of the boiler. Starting up procedure with support fuel, e.g. oil or gas.
- If additional fuel, such as biomass, is to be fired at various boiler loads.
- If low NOx burners are installed.

Summary.

The sizing of ESP's based on one or several coal and coal ash compositions is a complex task. A proper knowledge both among vendors and users is a prerequisite for the lowest investment cost while still maintaining good flexibility especially when there is a choice to purchase various coals. Export coals available often have low sulphur and low ash content. Some of them generate high resistivity ashes demanding large ESP's in order to achieve today's low emissions standards.

When several coals are specified it could pay off to discuss with the user the ranking of the coals and necessary sizes. As a result some coals may be deleted and substantial cost savings can result. Should the user still want to use the more difficult coals he may choose to blend them or to install conditioning systems to be used when these coals are available for firing. A simplified way of defining the guarantee is to set general limits for the coals and making sure that these limits comply with available export coals.

A better understanding of the effect on the ESP performance of the various parameters should also lead to acceptable limitations – sometimes combined with correction curves – and making it easier for the user to compare proposals from different vendors. A specified coal should cover a deviation on some critical parameters in order to give the customer flexibility and to maintain guaranteed emissions when the fired coal varies somewhat from the specified one.

Also the system for the boiler-ESP plant has an impact on the size of the ESP. Boiler type and firing conditions influences the particle size. For low S coals the amount of submicron particles is of paramount interest. Too little SO_3 in the flue gas can result in high resistivity conditions in the ESP. Selective catalytic reduction of NOx can result in an enhancement of the ESP performance. Other factors that have to be considered are hydrocarbons in particle form in the ESP (resulting in high resistivities) and unburnt particles. Both of these items may need modification of the ESP design to ensure low emissions.

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