OPTIMIZATION OF EXISTING ESP'S REPRESENTED BY AN EXAMPLE

1 Preamble

This paper describes the process of optimizing an existing electrostatic precipitator unit fitted to a coal-fired boiler. Specially, there was a unit selected whose remaining service life had been extended by 15 years, and whose electrostatic precipitators (ESP) came from different manufacturers. Furthermore different types of coal had been used during the boiler's service life, making repeatedly changing the demands on the electrostatic precipitator unit.

2 Description of the unit

2.1 History

The boiler unit with an output of 300 MW was built in 1965, and was designed to burn low grade Ruhr coal from 3 different collieries. The electrostatic precipitator unit initially consisted of filter casings mounted in parallel (A+B), each with 2 separate filter zones. Each filter zone was initially supplied by one high-voltage power unit (78kVs / 2100mAari.). As it was customary at the time, the gap between the collecting electrodes was 250mm. One air preheater was mounted before each electrostatic precipitator, and one induced draught fan was fitted after each electrostatic precipitator, with ducts discharging into a stack.
The electrodes in precipitator A were replaced in 1984. The gap was increased to 300mm, and the electrical zones were divided over the wideness, so that now 4 high voltage power units could be installed.
With installation of a desulphurisation unit was installed in 1987, an ancillary precipitator (C) was placed after filters A+B, to reduce the dust content to <150mg/Nm3. The acceptance measurements in the same year returned readings of <100mg/Nm3.
In 1997, the discharge electrodes (discharge point) on precipitator A were replaced with spring electrodes (ABB type), because the existing electrodes were subject to increasingly frequent electrode fractures.

2.2 Current state of the system before optimization

The data for the various filter units are shown in Table 1. The acceptance measurements in 1987 were taken with the plant burning run-of-mine coal consisting of 3 Ruhr coals (non bituminous coal), and recorded dust content levels of <100mg/Nm3 after filter C. These coals ceased to be available from 1996 when some of these collieries closed. Plants then switched to imported coals. The dust content figures at the outlet of the ESP in this type of operation were:

ESP A : 550-650 mg/Nm3
ESP B : 750-800 mg/Nm3
ESP C : ~250-300 mg/Nm3

This increase in clean gas dust concentration after ESP C regularly caused contamination within the desulphurisation plant, giving rise to repeated unplanned boiler shutdowns. Cost-intensive cleaning was carried out during these shutdowns, involving large expenditure of effort.

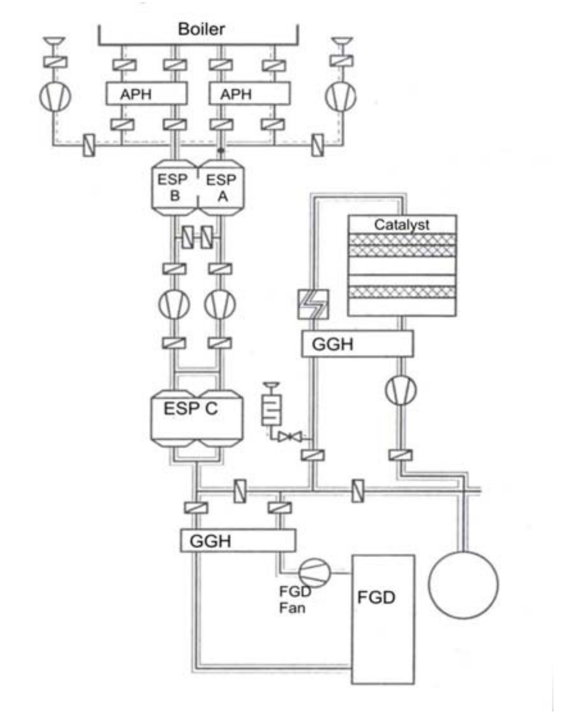


Figure 1

Table 1

Description	ESP A	ESP B	ESP C
Number of electrically separated fields	4	2	4
Active field length	11.5m	11.5m	10m
Height of collecting electrodes	10m	10m	14m
Number of channels	54	67	65
Channel gap	300mm	250mm	400mm
Gas speed	1.11m/s	1.1m/s	0.98m/s
Precipitation surface area	12420m2	15410m2	18200m2
Type of discharge electrodes	Discharge point electrode in frame	Spring electrode in frame	Stick electrode with points

3 Condition of the electrostatic precipitator system before optimization

3.1 Rapping systems for the electrodes

Tumble hammer rappers are used in all precipitators, both for discharge electrodes and for collecting electrodes. Collecting electrode rapping is applied to the side of all electrostatic precipitators at the bottom end of the plates. The discharge electrodes in the case of electrostatic precipitator A+B are also subjected to rapping on inlet side at 2 levels above the height. In the case of electrostatic precipitator C, discharge electrode rapping is applied as top rapping.
At the rapping mechanisms on electrostatic precipitators A+B only normal maintenance is to be done; the cleaning effect of discharge electrode rapping on electrostatic precipitator C is not effective.

3.2 Discharge electrodes and collecting electrodes

The degree of dirt accumulating at the electrodes varies extremely. In case of the collecting electrodes, some plates within the plate arrays accumulate large deposits of dust. At these points, there is no longer a contact between the plate and the rapping beam. The high level of mechanical stress due to the rapping impact gives rise to material fatigue at these points, and ultimately causes fracture. The effects on dust precipitation are very significant, since arcing frequently occurs at these points during operation.
The bottom half of the discharge electrodes in electrostatic precipitator C are very dirty because the rapping impact from the top is not sufficient.

3.3 Gas distribution fittings and guiding plates

Electrostatic precipitator A

Deflectors are installed in the inlet duct. In the inlet hood (Figure 2), there are two perforated plate walls, but no gas distribution facilities in the outlet hood. All hoppers are equipped with two baffle plates each; guiding plates are fitted to the side walls and below the roof beams to prevent bypass flow.

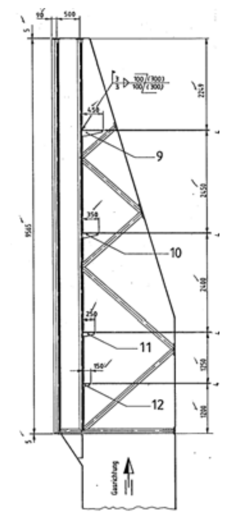


Figure 2

Electrostatic precipitator B

Deflectors are installed in the inlet duct. In the inlet hood (Figure 3), there is one perforated plate wall with deflectors fitted in front of it, and again no gas distribution facilities in the outlet hood. Only the last of the 3 hoppers is fitted with a baffle plate. Guiding plates are fitted to the side walls to prevent bypass flow.

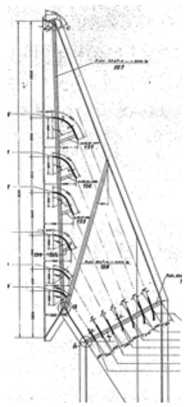


Figure 3

Electrostatic precipitator C

Deflectors are installed in the inlet duct. In the inlet hood (Figure 4) there are 3 perforated plate walls; a bulkhead made of collecting electrode plates is installed in the centre of the outlet hood. The plates are 500mm wide, with a gap of 230mm between plates. The deflector plates on the side walls are inadequate; there are no baffle plates in the hoppers. Bypass flows can arise in both areas.

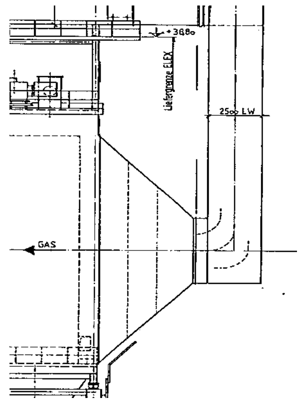


Figure 4

3.4 Electrical equipment

The electrostatic precipitators A+B are equipped with microprocessor controllers of different types, electrostatic precipitator C with analogue controllers on the high-voltage power units. The rapping equipment control unit is fully integrated in the main control system.

4 Optimization measures

4.1 Optimizing rapping system

Preventive maintenance was carried out on all rapping equipment to ensure reliable operation over the next years. All bearings and drives were replaced.

The rapping cycles were optimized with the aid of computer calculation taking into account the dust arising, quantities of flue gas, the filter geometries, and the various drive shaft speeds. This covered the 3 ESP even if they are regarded as a 4-zone electrostatic precipitator. An interlock was also created between the collecting electrode rappers in zones 3 and 4, to minimize the dust peaks during rapping cycles of these zones.

4.2 Discharge electrodes and collecting electrodes

The alignment of the electrodes to each other was corrected, since the frames were in some cases seriously warped, resulting in a narrow gap between the frame and the plates. Some frames were broken and had to be reinforced at various points. The plates that had torn away from the rapping beam and were no longer rapped under this conditions, were fixed back to the rapping beams with iron plates. These plates were machined on the inside to fit exactly the profile of the collector electrode plates, re-establishing a force locking connection. This means, the rapping is applied to the plate again, ensuring cleaning.

4.3 Optimizing of gas distribution

Optimized gas distribution at the ESPs A+B was implemented according to our company's philosophy, whereby we seek to achieve a little bit higher gas speed in the upper part of the ESP than in the bottom part (Figure 5). The principle here is that some of the dust already moves downwards due to gravity and because of the lower speed within the filter area. The reduced flow in the lower part makes it easier for the dust to fall into the filter hopper, reducing re-entrainment.

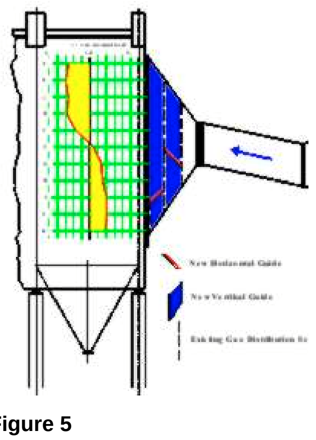
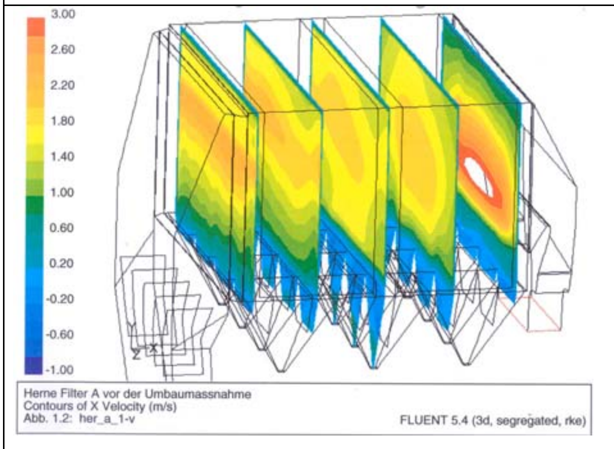
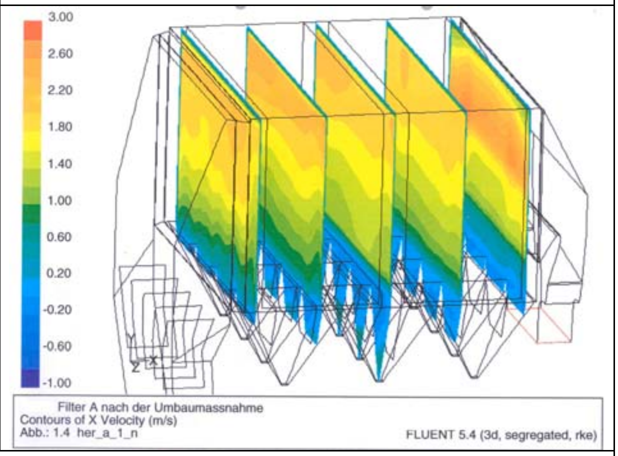


Figure 5

4.3.1 Flow simulation using the "FLUENT" computer software

<table>
<tr><th>Flow simulation before optimization</th><th>Flow simulation after optimization</th></tr>
<tr><td></td><td></td></tr>
<tr><td>ESP A</td><td>ESP A</td></tr>
<tr><td>
</td><td>
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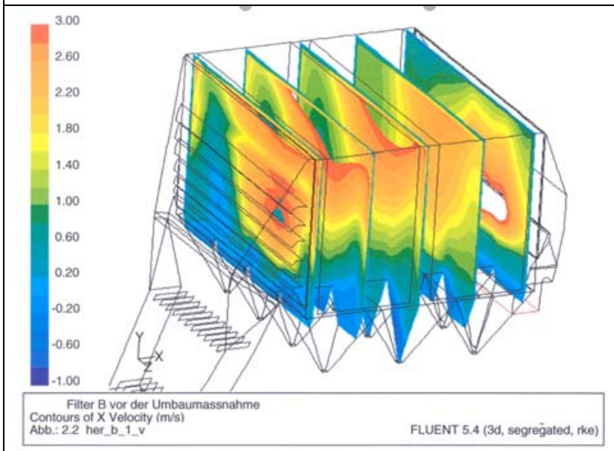
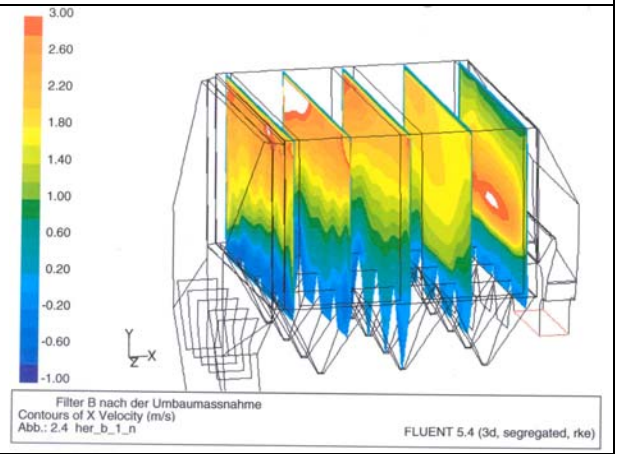
<tr><td>
</td><td>
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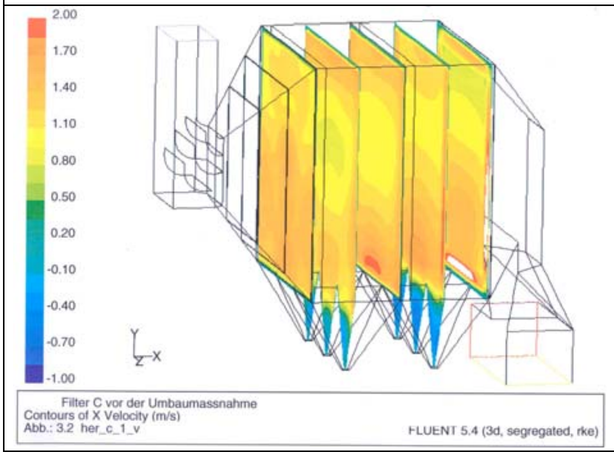
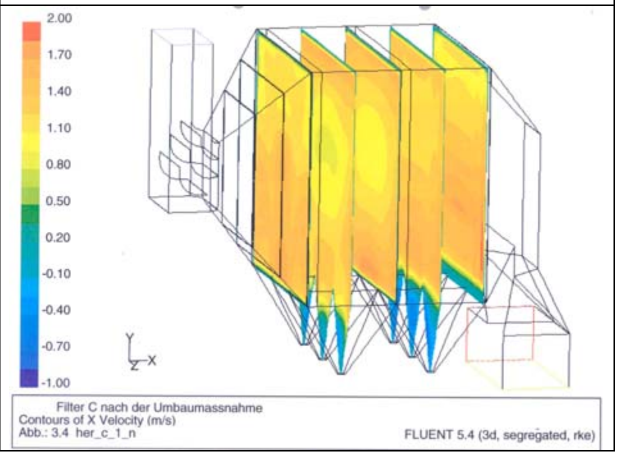
<tr><td>
</td><td>
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4.3.2 Modification of electrostatic precipitator A

It is evident from the flow simulation that in the case of electrostatic precipitator A the flow is already higher in the top part than in the bottom part, which is in accordance with our company philosophy. The existing fittings were therefore retained at this point. It also shows that the flow in the centre of the outlet hood is extremely high. For this reason a gas distribution wall was installed in this hood. This wall consists of suspended U beams to which flat bars are attached horizontally. This construction makes it possible to carry out fine adjustments by moving the individual components after installation. As the illustration shows, the flow at the outlet hood is significantly improved by this additional distribution wall.

4.3.3 Modification of electrostatic precipitator B

The flow simulation shows that the flow is horizontally inclined. It was observed that the arrangement of the deflectors in the duct in front of it was not optimal. This inclination was corrected by adjusting the existing deflectors and installing two new plates. The existing gas distribution fittings in the inlet hood were retained because of space constraints. Merely two additional guide plates were installed in the upper part.
A gas distribution wall was installed in the outlet hood area on the same principle as in the case of ESP A.

4.3.4 Modification of electrostatic precipitator C

No further equipment was fitted because of the existing uniform flow both in the inlet area and in the outlet area of the electrostatic precipitator and for reasons of cost. Merely some additional holes were made into the plate wall in the filter outlet in the upper part in order to increase the flow in this area.

4.3.5 Measures to avoid bypass flow

Baffle plates were installed in the hoppers of all filters to reduce bypass flow (Figure 6). Especially profiled plates were fitted at the top of these baffles to minimise flow underneath the discharge frames in the individual channels. Plates also had to be inserted in the roof area and in the side areas of the individual zones of electrostatic precipitator C. There was a very serious possibility of bypass flow at the sides, because here the distance between the last collecting electrode and the side wall is 500mm, and was not fully covered before. There was a further potential danger of bypass flow in the middle of the filter where supports are installed as part of the engineering design. In the side area of the supports there was also a space of 500mm, which had to be covered.

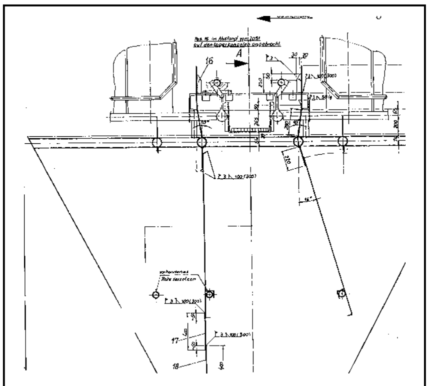


Figure 6

4.4 Optimizing control of the high-voltage power units

The high-voltage regulators were converted to RICO microprocessor controllers, because this controller was already installed at one filter, and the manufacturer is located near the power station. As usually for the application of micro-controllers, up to 16 parameter sets can be stored in programs. Other features are of course also provided, such as semi-pulse, back corona detection, power-off rapping, etc. In this case some standard programs were stored, e.g. start up of the boiler and boiler soot blowing. Further steps included the storing of programs for various coal mixtures so that filter operation could be more rapidly adjusted to the various modes of operation.
An energy optimized mode of operation was not provided in this particular application, because the customer always wishes to achieve the highest possible degree of separation efficiency.

4.5 Energy optimization

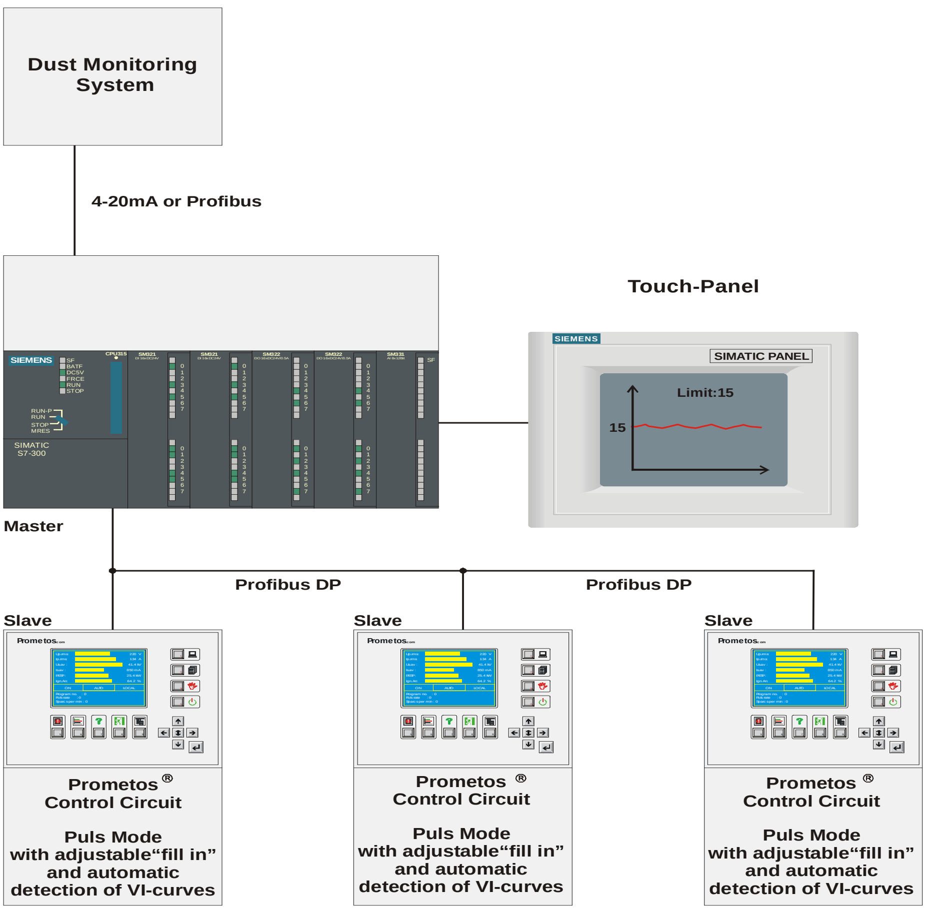
4.5.1 General

Modern electrostatic precipitators are often equipped with emission- monitoring devices to continually monitor and measure dust emissions. In that case, a master control circuit, known as energy optimization, can be implemented using the dust concentration measurement signal. Energy optimization enables the plant operator to set the required dust emission values as desired. Energy optimization then automatically ensures that the high-voltage supply units are set to receive the minimum energy consumption by the high voltage power units for this preset nominal value.
A significant energy saving in operation is achieved with the appropriate software and the high voltage regulators especially designed for it.

4.5.2 System requirements

- Continuous measurement of dust concentration. The result must be transmitted as a remote control signal 4...20 mA (0...20 mA) or via a DP serial process field bus interface as a numerical value.
- Programmable Logic Controller (PLC):
- This control unit is used as a master on a DP process field bus. If possible it should also receive information on the rapping cycles or control them itself. Information on calibration cycles of the dust density meter and its interfering signal is desirable.
- Control unit or touch panel to enter the settings and for visual display.
- Connection of the high-voltage regulators to the PLC via the DP process field bus.
- High-voltage regulators, version with DP interface.

<u>3. Block diagram</u>



4.5.3 Principle of operation

4.5.3.1 The components

The main feature of the energy optimizing system is the optimizing software stored in the PLC. The program controls the high-voltage regulators as part of the energy optimizing process. This is the only way to individually control of the various fields of the filter, which is essential to achieve maximum energy efficiency. It is evident that the zone around the gas inlet with its high level of dust requires a different setting from the last zone, where rapping is the major factor that has to be taken into account.

Further important components of the energy optimizing system are the output control circuits in the high-voltage regulators of the latest design. The regulators exactly calculate the electrical power supplied to the electrostatic precipitator zones for any graph of voltage and current. With these actual values and the rated value, power-control circuits with integral characteristics are established for each precipitator field.

4.5.3.2 Settings

Energy optimization has to be expressly activated by the plant operator using the control panel (touch panel). If the energy optimization system is deactivated, it has no access to the high-voltage control devices. If it is activated, a value must be set for dust concentration. In this regard, the legal provisions applying to the installation site must be complied with. For safety purposes a second value must be pre-set, the dust density limit value. It is higher than the set value, but is still below the required legal values. If the dust density limit value is exceeded, energy optimization is immediately deactivated. This ensures safe operation of the plant.

After activation, the program starts collecting the dust concentration readings from the dust density meter. The stored values of the last measurements are used during the calibration cycles of the dust density meter. The values are constantly monitored for plausibility by the energy optimization program. In the event of errors in the transmission of readings or data collection, energy regulation is immediately terminated.

4.5.3.3 Control circuits

The settings for the output control circuits in the regulators are individually generated from the dust density values, taking into account fixed presets, delay times and the control dynamic. They are transferred via the process field bus. Information from the rapper control unit is also taken into account.
As soon as a regulator receives a command to reduce output (setting <100 %), pulse mode operation is generated in such way that after a fully ignited half-wave, a preset number of half-waves with a smaller ignition angle follows (pulse mode with "fill in"). The amount of the smaller ignition angle is calculated by the high voltage regulator in such way that the output setting is achieved. The filter voltage resulting from this mode of operation effects in more efficient separation for most dusts than current limiting, which were generated by a uniform filter voltage.
The program automatically determines the optimum number of half-waves with a smaller ignition angle independently and by adopting characteristic curves.

5 Result of optimization measures

After the maintenance and optimization measures described above, the boiler plant has been operated with the same run-of-mine coal as before the overhaul. The plant operator still attached great importance to achieve comparable operating conditions of the electrostatic precipitator system, for verifying the given warranties. The permanently installed optical flue gas density meters indicated that the dust content figures after each of the 3 ESPs had been significantly reduced. The gravimetric dust measurements subsequently carried out after ESP C have shown readings between 56 and 72 mg/Nm3. This means, in compensation to the situation before optimization, the dust content of the clean gas has been reduced by 76%.
The maintenance work carried out, also ensures ongoing reliability and extended service life of the electrostatic precipitator system.