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Powder Collection from Flue Gases Resulting from the Burning of Lignite in Boilers from High Power Energy Power Plants

In the current economic context, marked by the increasingly broader recognition of interdependences between environment and development, we witness the increase of society's demands on the environmental protection, demands materialised in increasingly more severe international rules. This paper sets out the most significant achievements, but it especially emphasises the solutions taken into account in the applications in the near future, so that the dust emissions on the stack would fall within the national legislation on environmental protection, which is sometimes hard to achieve, taking into account it is acted on some existing plants within a limited space.

Keywords: coal, frequency, voltage.

1. Introduction

At the level of development reached by the civilisation, life without the existence of electricity and heat can no longer be imagined, and the energy demand is increasingly greater. Therefore, the need to modernise the existing production capacities of new installation capacities is obvious, but this development of the energy sector must be done without breaching the principles of sustainable development, therefore with the lowest possible impact on the environment. The current trend is that in the shortest possible time and using the most abundant primary energetic resource (coal), to produce electricity and/or heat without polluting emissions.

In order to comply with the Directive 2001/80/EC and Directive 2008/1/EC and with the commitments assumed under the Gothenborg Protocol, Romania must achieve, in a relatively short period of time, investment into environmental objectives that involve substantial financial resources to reduce the polluting emissions on IMA with a rated thermal power equal to or higher than 50 Mw, by implementing the best available techniques (BAT).

Compliance with the limit emission values provided by the new Directive 2010/75/EU regarding industrial emissions, which enters into force in 2016, respectively 20mg/ m^3N, will be done by means of the desulphurisation plant which, by spraying the limestone suspension into the combustion gases will provide the reduction of dust emissions from 50 mg/m^3N to 20 mg/ m^3N.

2. Description of the technological flow

Text The steam boiler that is part of a power unit of 330 MW is a forced flow and intermediary overheat boiler with a single ascending flue gas drum. It is designed to operate in block diagram, aiming to produce steam in order to supply a 330MW turbo-generator. The transformation of steam potential energy first into mechanical energy and then into electrical energy occurs therein.

The coal (lignite with lower calorific power P_{ci}=1600-2100 kcal/kg) is transported from the warehouse by means of w conveyor system to the six coal mills the boiler is provided with. The grinding and partial drying process occurs in the coal mills. Through the fan effect, the coal dust is guided to the boiler burners. Along with the primary air, the coal dust is sprayed into the furnace, wherein the ignition and combustion process occurs. The secondary air necessary for the combustion process is also inserted through burners. A high flow of high temperature flue gases and a high amount of solid residues in the form of slag and ash results by burning the coal. The flue gases give much of the heat of the thermal agent that circulates through the heat exchange surfaces (water, steam). Of the amount of resulted solid waste, approximately 5% are separated in the furnace funnel as slag and ash. The flue gases along with the ash particles in suspension are directed towards the slack on two symmetrical gas ways, due to the pressure created by the two flue gas fans which the boiler is provided with.

On the gas way, there are also 2 rotary air preheaters, located between the boiler and the two electrostatic precipitators. The fly ash that leaves the boiler along with the flue gases is (partially) retained mechanically and collected in the hoppers on the gas head and hoppers under PAR1+2. The flue gases cooled off in PAR, along with a significant amount of ash (67÷72) g/ m^3N are guided to the two electrostatic precipitators that are part of the electrical cyclones.

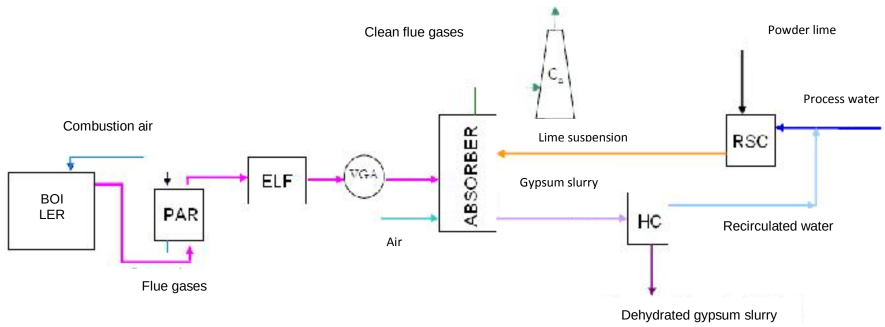

Figure 1. Diagram of the ash route from one 1035t/h boiler with pulverised coal combustion

In the electrostatic precipitators, the ash is electrostatically retained and collected in the dust hoppers at the level imposed by the limits stipulated in the project. A small amount of ash that leaves from the electrostatic precipitator (ELF) is driven along with the flue gases to the atmosphere through the slack. On the units equipped with desulphurisation system, the flue gases and particles suspended in the gases that come out of the ELF are led towards the absorber of the desulphurisation system where they are passed in countercurrent through the lime suspension spraying area. By this process, a reduction of the emissions of sulphur oxides and a reduction of the emissions of powders from 50 mg/ m^3N at maxim 20 mg/ m^3N occur.

3. Electric cyclone

3.1. Overall Presentation

A 330MW energetic unit is equipped with an electrical cyclone which consists of two electrostatic precipitators and an automation and electric power supply system.

The two electrostatic precipitators are constructively identical and are assembled in parallel with the gas flow.

The main equipment of the electrostatic precipitator is located inside the separation chamber: the emission system and the settling system. The settling electrodes are located vertically at a constant distance between them, which is called the electrostatic precipitator step. Halfway between the settling electrodes, there are the emission electrodes, supplied with continuous voltage of negative polarity. The inner equipment of the ELF is structured in 3 electrical fields arranged in the direction of the gas flow. A field is divided into 2 mechanically and electrically independent semi-fields. Each ELF is energised by 6 high voltage equipment (one on each semi-field). The overall block diagram of an IDE is presented in Figure 2.

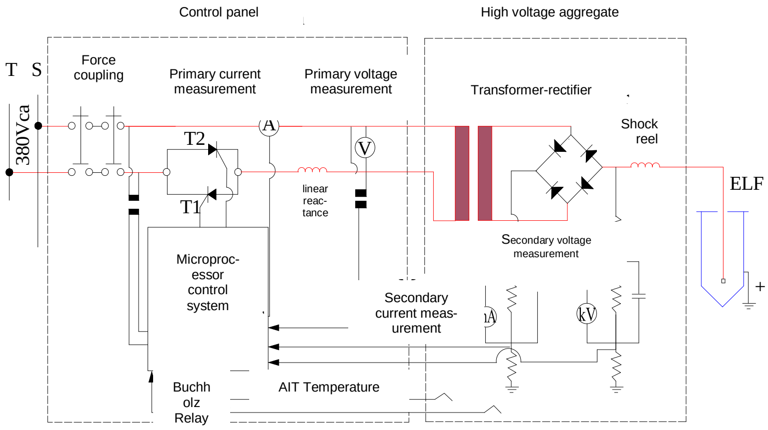

Figure 2. The overall block diagram of an electrical cyclone (IDE)

3.2 General Considerations on the Retention of Powders in Electrostatic Precipitators

The operation of the electrical cyclone (IDE) is based on the principle of electrical separation of ash particles suspended in gases that cross a very strong electrical field, produced due to the Corona type discharges. The gas flow with dust particles in suspension crosses the inlet and the levelling system from the connection, entering in the active area of the electrostatic precipitator consisting of the emission system connected to the negative pole of the source producing the high voltage and the settling system connected to the ground potential. The very high electrical potential applied to the emission electrodes (tens of kilovolts) determines the occurrence of some Corona discharges very close to the ionisation electrodes. Under the influence of an intense bombardment with electrons, the particles suspended in gases are electrically charging and are deviated into the direction of the power lines towards the settling grounded electrodes, settling thereon. The dust collected on the settling and emission electrodes are removed by means of some shaking systems that operated based on the principle of mechanical shocks. The speed of the particle in the normal direction of the collecting plate is called migration velocity, noted with w and depends on many factors, including: the particle size, the particle charge (q_p), intensity of the settling field (E), velocity of gases, dynamic viscosity of the gases (μ_g), the mass of the particles (m_p) and the Cuningham correction factor (C_u).

The migration of the particles can be characterised by the solution of the following differential equation:

$$\frac{dw}{dt}+\frac{3\cdot\pi\cdot\eta_g\cdot d_p}{m_p(Cu)}\cdot w=\frac{q_p}{m_p}\cdot E \qquad (1)$$

The movement of the electrically charged dust particles to the settling electrodes and their collection also depends on factors related to the kinematics of the gases, such as velocity and its levelling degree in the section of electrostatic precipitators, besides the size of the charge and intensity of the field.

Shaking the emission and settling electrodes is done by means of a system operating on the principle of mechanical shocks.

The advanced dust removal levels imposed by the environmental legislation can be achieved only by theoretically analysing all fundamental processes that occur inside the electrostatic precipitator, factors that condition them and by optimising them through experiments, taking into account that not all conditions existing in the electrostatic precipitators can be included in mathematical expressions; the processes are interrelated, and in general, they cannot be analysed independently.

4. Measures to reduce dust emissions in compliance with the directive 2001/80/ec

The solutions to modernize and size the electrical cyclone were primarily based on the technical aspects regarding the functional requirements, reliability, safety and stability in operation, but not least to comply with the increasingly more severe restrictions imposed by international rules on environmental protection.

We shall further present the solutions that have been applied, but especially which are to be implemented in order to have some electrical cyclones with a high level of retention of dust from flue gases, in compliance with the current and future rules on environmental protection.

4.1. Modernisation solutions implemented

Optimisation of the distribution of the electrical field intensity from the active area of the electrostatic precipitators:

Use of settling electrodes with the active height of 13.5 m

Layout of the inner equipment at a 2h=400mm step

Layout of the emission electrodes in the structure of the emission frame at a step of 320mm instead of 160mm, as it was in the old solution.

Use of Isodyn B5 S type symmetrical emission electrodes on the field no. 1 and no. 2 and Isodyn B15S on the field no. 3. Increase of the mechanical separation level and optimisation of the gas flows in the active area of the electrostatic precipitators

The optimisation of gas flow has an important role among the factors influencing the ELF performance. It has been proven both theoretically and experimentally that an adequate gas flow through ELF considerably improves the dust removal level. The performance of the electrostatic process to remove the dust from combustion gases is also determined, inter alia, by the cinematic spectrum of flowing in the active area of the electrostatic precipitator. It has been shown experimentally that when the non-uniformity of the velocity field in the active section increases, the yield of the electrostatic precipitators drops significantly. [2], [7],[9].

The yield achieved in this case will be:

$$\eta = \eta_{teor} - \Delta\eta \qquad (2)$$

The theoretical yield (η_{teor}) can be calculated with the Deutsch relation:

$$\eta_{teor} = 1 - e^{\frac{W \cdot L}{h \cdot V_{med}}} \qquad (3)$$

The yield deduction $(\Delta\eta)$ due to non-uniformity of speeds can be determined by the relation:

$$\Delta\eta = \frac{e^{\frac{WA}{FV_{med}}} A \cdot \Delta V_{med} \cdot \ln e^{-W}}{V_{med}^2 \cdot F} \qquad (4)$$

$$\Delta V_{med}^{'} = \frac{\sqrt{\sum_{i=1}^{n} (V_i - V_{med})^2}}{n} \qquad n \geq 1 \qquad (5)$$

Besides the decrease of the efficiency shown above, the non-uniformity of the local velocity field in ELF, as well as the distribution of inappropriate local speeds in the ELF inlets can cause other effects that are detrimental to the process of retaining the solid particles from the combustion gases, such as the re-drive in the areas with high local speeds.

The losses by re-driving become important where local speeds exceed the speed to remove the particles from the electrodes. Local circulation areas can also be formed on the inlet connections, which are caused by intense macro-turbulence and lead to re-driving the particles settled in the hopper.

In order to reduce the level of non-uniformity of velocities, to find some gasodynamically optimal solutions that would lead to the improvement of gas flow from the electrostatic precipitator, complete laboratory studies were necessary for each individual case, studies based on aerodynamic methods and models, as well as on actual systems.

Based on an analysis by numerical simulation and physical modelling, the following were set forth: the shape of the input connection and has channel upstream of the electrostatic precipitator, the equipment model of the input connection with a system of shutters and sieves [3], [10].

Modernisation of the automation and electric power supply system primarily, this modernisation refers to:

The use of high voltage equipment provided with microprocessor-based control units that have an automatic control of the high voltage aggregates

Equipping the cabinets of auxiliary services with operator console to display the data and useful graphical screens

Developing the software by introducing subroutines for serial transmission of data and processing of signals from opacimeters to optimise the electric power consumption of high voltage equipment.

By implementing these solutions, the concentration of powders in flue gases on the outlet from the electrostatic precipitators of units 4 and 5 at CE Turceni is of max. 50mg/m^3_N.

The symbol of electrostatic precipitators modernised on unit no. 4 is: 43 / 13.5 / 2 x 9 + 8 / 0.400.

The symbol of electrostatic precipitators modernised on unit no. 5 is: 45 /13.5/ 3 x 9 / 0.400.

4.2. Technical solutions proposed

This section will present the technical solutions that could be implemented to reduce the dust emissions in electrical cyclones (at the maximum value of 40 mg/ m^3N at the outlet from the electrostatic precipitators) related to the high power energetic groups in thermal power plants.

A. The technical solutions proposed primarily refer to:

- Over-elevation of electrostatic precipitators in order to increase the volume of the electric field and decrease the speed of gas flowing through the electrostatic precipitators
- Layout of the inner plant at a 2h=380mm step, according to Figure 3
- Use of a new type of a more efficient settling electrode
- Use of a new type of a high efficiency Isodyn B5M emission electrode (the distance between the peaks will be of 30 mm)
- Replacement of the systems supporting the emission and settling system
- Energising the electrostatic precipitators with high voltage equipment with high frequency operation, assembled on the roof beams (one EIT.IF for each semi-field).

By implementing these solutions, the authors estimate a concentration of powders in the combustion gases on the outlet from the electrostatic precipitators by max. 40mg/ m^3N

B. Mode of Operation of the High Frequency Converters

A high voltage equipment with high frequency operation (EIT.IF) schematically shown in Figure 2 is supplied with all three. The input rectifier creates a continuous intermediary voltage which is converted by the switch with high frequency AC semiconductors (20-50kHz). This voltage is inserted into the high voltage transformer and then rectified into DC by the high voltage rectifier connected to the transformer terminals. The rectified high voltage is transmitted as supply voltage to ELF.

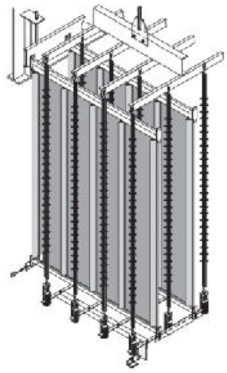

Figure 3. Model of layout of the emission electrodes (with spikes) against the settling electrodes

The output current (or the voltage) is adjusted by the variation of the closing and opening times of the switches with semiconductors from the primary circuit.

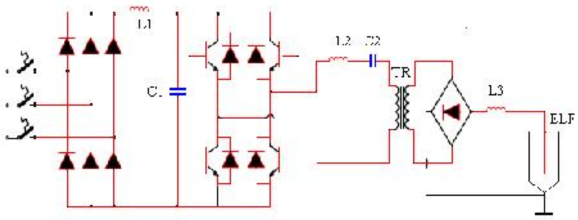

Figure 4. The principle electrical diagram of an equipment operating in high frequency [5]

The alternative component of the voltage, U_{AC} transmitted to the ELF, can be calculated with the relation[1].[6]:

$$U_{AC} = I_{AC} \cdot \frac{1}{2 \cdot \pi \cdot f \cdot C} \tag{6}$$

Where: f- frequency

C - the capacity of the supplied electrostatic precipitator section.

The equation above shows that it is inversely proportional to the frequency. Therefore, a high frequency converter would reduce the component of AC in the ratio of 400:1. Figure 5 shows the operating voltages for the “network frequency” and “high frequency” cases. Two oscillograms were measured in turn on the same electrostatic precipitator with the two different modes of supply and they were overlapped afterwards. The very big difference between the waveform of the voltages is clear. Figure no. 5 explains the current increase, based on the voltage – current curves of the two types of supplies.

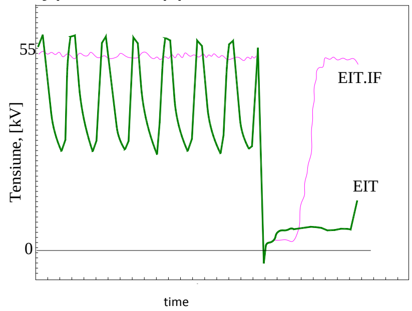

Figure 5. The voltage in the electrostatic precipitator obtained with an EIT and with an EIT.IF [8]

C. The advantages provided by the high voltage equipment with high frequency operation

- Better retention of dust particles
- Three-phase supply
- Reduced size of the entire equipment
- Rapid response of the high voltage control
- High secondary medium voltage
- Low consumption of absorbed power
- Use for various (low, medium and high) resistivities of the dispersed medium.
- Absorption of a smaller input current

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