SULPHUR DIOXIDE EMISSION REDUCTION FROM POWER PLANTS - CASE STUDY

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The actual challenges of Romanian power market are the increasing of fuels prices, the insecurity of supply and the environmental degradation. The forthcoming total liberalization of natural gas prices in Romania and their trend to the European ones will conduct to an increasing of electricity price based on gas-fired power plants higher than coal-fired power plants. Also, it is expected an increasing of electricity price due to the investments for the facilities needed to comply with environment legislation concerning the limits of SO_2, NOx and particulate matter emissions.

The paper presents a study case concerning flue gas desulphurization at a steam boiler fuelled with lignite. The paper concludes that the hybrid (semi)dry methods could not ensure the reduction of SO_2 level under the maximum level permitted according with the new Romanian legislation. The increasing of the natural gas in fuel mixture with lignite could represent a solution to comply with the new requirements.

Keywords: SO_2 emission, flue gas desulphurization, boiler, case study.

Abbreviation

LCP – Large combustion plants
FGD – flue gas desulphurization
GD- Government Decision
BAT – Best Available Technique
IPPC- Integrated Pollution Prevention and Control
NO_x - nitrogen oxides
SO_2 – sulphur dioxide
PM – particulate matter
EU – European Union
ERP - emission reduction plans

1. Introduction

The Directive 2001/80/EC was transposed into Romanian legislation by the Governmental Decision GD No. 541/2003 concerning the limitation of SO_2,

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NOx and PM emissions from LCP, modified and concluded by GD No. 322/2005 [1].

All LCP are under the incidence of the Directive 96/61/EC reffering at the integrated prevention and pollution control – IPPC[1]. The aim of the IPPC Directive is to achieve high-level protection of the environment as a whole in an integrated and balanced way. All installations covered by Annex I of the Directive are required to obtain an authorization (permit) from the relevant authorities.

Permits must be based on the concept of Best Available Technique (BAT). As from October 1999 the Directive applies to all new installations, while existing (pre-1999) installations need to comply with the obligations by 30 October 2007 at the latest. Till the transposition of Directive 2001/80/ in Romania's legislation, the limitation of emissions of certain pollutants into the air from LCP was regulated by the Minister's Order No. 462/1993 of Ministry of Waters, Forests and Environment Protection ”Technical conditions concerning atmosphere protection”.

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2. LCP Compliance with Directive 2001/80/CE requests.

During the period when were built the most power plants and cogeneration power plants, the flue gas dispersion by high stacks was considered as an efficient and sufficient way to protect the environment and the population health. By the initial project of power plants, the LCP were equipped only with electrostatic precipitators for reduce PM content of flue gas. The improving of the electrostatic precipitators performances after 1993 generated the continuous decreasing of PM emission.

Taking into account the justifications presented by different companies having LCP during the negotiation process concerning Romania's Accession to EU, they obtained transition periods till these could comply with the Directive 2001/80/CE requests – table 1 [1]. These transition periods was set up taking into consideration the term 1st January 2008 for compliance of the “existing installation” from Member State. Romania requested and obtained transition periods for 34 LCP to comply with maximum permissible level of emissions for SO_2.

Table 1

Complying mode with Directive 2001/80/CE requests, according with the assumed engagements of Romania by Accesion Treaty

Number of LCP	**Type of pollutant and the compliance at the 2001/80/CE Directive requests**		
	SO_2	NO_x	PM
Total out of which:	174	174	174
- In compliance in 2004	75	30	102
- Non-complying in 2004 out of which	*99*	*144*	*72*
Exemption	34	34	34
They will be shut down	10	10	10
They will comply till Romania's Accession	21	36	6
They request transitional period:	*34*	*64*	*22*
1 year transition period (T1)	1	9	2
2 years transition period (T2)	1	6	3
3 years transition period (T3)	6	15	6
4 years transition period (T4)	8	19	7
5 years transition period (T5)	3	4	-
6 years transition period (T6)	15	11	4

In Romania are running 16 LCP coal fuelled, with a thermal nominal capacity higher than 500 MWt. During all the transition periods the SO_2 NOx and PM emissions from all LCP under the incidence of the Directive 2001/80/CE must not be higher than the value presented within table 2 [1]. Additionally the emitted quantities must not exceed a certain percent from the total emissison from 2003 – table 3 [1].

Table 2

The maximum quantities of atmospheric pollutants emitted by LCP from Romania during 2007-2013

The maximum quantities of pollutants [t/an]	**SO_2**	**NO_x**	**PM**
2007	540 024	128 020	38 580
2010	336 161	114 395	23 258
2013	147 536	111 843	15 483
2016		79 771	
2017		73 586	

Table 3.

The maximum percentage from the emitted pollutants in 2003 during 2007-2013

year	**The percent from the quantity emitted in 2003 [%]**		
	SO_2	NO_x	PM
2007	91	87	93
2010	58	80	61
2013	30	76	38
2016		70	
2017		65	

After the exhaustive inventory of the LCP in Romania, the operators were notified of the obligation to transmit the ERP. The submitted ERP represents declarations of liability of the operator, and the authorities can use this documents, if necessary[2].

3. Techniques to reduce sulphur oxide emissions

Measures to remove sulphur oxides, mainly SO_2, from flue-gases during or after combustion have been used since the early 1970s, first in the US and Japan and then, in the early 1980s, in Europe. Nowadays there are many different ways of reducing the SO_2 emissions generated by the combustion of fossil fuels.Up to the year 2000, there were 680 FGD systems installed in twenty seven countries worldwide and 140 currently under construction or planned in nine countries. [3].

The capital costs are relatively high for a wet limestone scrubber, but, on the other hand, the operating costs are moderate due to the advanced automation, reliability and as a saleable byproduct. The capital costs can vary widely. They depend on the site specifications and technical and economic conditions such as plant size, SO_2 inlet concentration, SO_2 emission limits, the redundancy strategy, annual operating hours, operating years, management of gypsum or residues, interest rates, number of units on site, FGD market situation, etc. The capital cost for the wet lime/limestone scrubber process is mainly influenced by the flue-gas flowrate. FGD retrofit installations are much more expensive than green field installations. The capital costs for a wet limestone scrubbing process varies from EUR 35 – 50 per kWel, and the operation and maintenance costs are between EUR 0.2 – 0.3 per kWh (energy input). The typical SO_2 removal costs are between EUR 750 – 1150 per tonne of SO_2 removed, and the effect on the price of electricity EUR 3 – 6 per MWh (electricity produced)[3].

Spray dry absorbers usually operate at 20 – 30 K above the saturation temperature, where the saturation temperature of flue-gas is between 45 – 55 °C. Thus, most plants do not require a reheating of the clean flue-gas, although the required stack temperature must still be met in some way. The spray dry scrubber is suitable for low-to-moderate fuels containing sulphur and for use in smaller facilities. The equipment includes slurry preparation, handling and atomization equipment, all of which have to be able to withstand erosion from the slurry. The dry solid byproduct can be used in a range of different construction purposes.

The spray dry scrubber process is well established as a commercially available technique. Of the total worldwide capacity equipped with dry FGD, 74 % (18655 MW of electricity in 1998) use spray-drying processes [3].

The capital cost for the spray-dry system mainly depends on the capacity of the plant and the type and layout of the spray absorber and the injection system. Reported capital costs differ a lot, depending on the type of power plant. The capital cost of a spray-drying system is approximately 30 – 50 % less than the capital cost of a wet limestone process for the same size of LCP, but the operation costs are higher due to higher sorbent costs. As spray drying uses lime, the use of a single-module spray dryer is limited to below 700 MWth units 700,000 m^3/h and to low and moderate fuels containing sulphur, in order to keep the operational costs within reasonable limits. Spray dry scrubber costs for a boiler case have been estimated to be EUR 18 – 25 MWel investment costs, and EUR 0.5 – 0.7 per MWh (heat input) operating and maintenance costs. The cost of the reduced pollutant was EUR 600 – 800 per tonne of sulphur dioxide removed. The effect on the price of electricity was approximately EUR 6 per MWh (electricity produced).[3]

The characteristics of duct sorbent injection technologies are low capital costs, the simplicity of the process, and their adaptability to difficult retrofit situations. However, they have a relatively low SO_2 removal efficiency. This disadvantage and the low sorbent utilisation efficiencies have made commercialisation difficult. However, duct sorbent injection has great potential for relatively old and small boilers, so various duct sorbent injection processes are currently being developed to improve SO_2 removal and reliability. The goal of SO_2 removal efficiencies in duct sorbent injection used to be, generally, at least 50 %. The emerging processes aim to achieve 70 – 95 % SO_2 removal efficiencies without appreciable additional capital costs and operational difficulties, the improvements being based on a better understanding of duct sorbent injection. Spent sorbent recycling is especially important in the economics of duct sorbent injection because shorter sorbent residence times (0.5 – 3.0 seconds) have led to lower sorbent utilization compared to conventional spray dry scrubbers. Only 15 to 30 % of $Ca(OH)_2$ by weight usually reacts with SO_2 without spent sorbent recycling. This means that 70 to 85 % of unreacted $Ca(OH)_2$ collected in the ESP is disposed of with the dry fly ash. Low sorbent utilisation is a disadvantage in duct sorbent injection processes. Spent sorbent recycling has recently been adopted in many processes to improve sorbent utilisation and to enhance SO_2 removal performance.[3]

Hybrid sorbent injection is a combination of furnace sorbent injection and duct sorbent injection to improve SO_2 removal efficiency. A feature of hybrid sorbent injection is the application of limestone as a sorbent. This is desirable as limestone is cheaper than lime, which is generally used in spray dry scrubbers. Some hybrid sorbent injection processes have reached commercial status because of the following main operational features: relatively high SO_2 removal rate, low capital and operational costs, easy to retrofit, easy operation and maintenance with no slurry handling, reduced installation area due to compact size of equipment, no waste water treatment needed.[4]

4. A case study case concerning FGD at a steam boiler fuelled with lignite

The aim of this case study was to check if hybrid sorbent injection, which has the above mentioned advantages, could be applied at the retrofitting of a steam boiler of 166,66 kg/s (420 t/h) running on lignite with the low calorific value P_{ci} = 6700 kJ/kg and using natural gas (98.5% methan) with the low calorific value P_{ci} = 35600 kJ/m^3 as additional fuel .

The lignite ultimate analyse is shown in the table 4.

Tabelul 4

The lignite ultimate analyse

Components		Concentrations limits[%]	Average value[%]
Carbon	C	18,3 – 21,9	19,2
Hydrogen	H	1,7 - 2,0	1,9
Nitrogen	N	0,6	0,6
Combustibile sulf	S^c	0,5 – 1,2	0,8
Oxygen	O	9,3	9,3
Moisture	W	41 – 45	45
Ash	A	22 – 24	23.2

The case study was made in the following conditions:

- the average values of fuels composition;
- FGD by hybrid sorbent injection efficiency: 85%;
- Lignite:natural gas thermal input rate : 95....40:5...60[kJ/kJ];
- Produced steam range: 50-100% from the nominal flow.

The annual SO_2 emission for a boiler output of 98% from the nominal steam flow, before and after desulfurization are presented in the Figure 1. The annual SO_2 emissions decrease with the reduction of the steam output and with the increasing of the natural gas share in the boiler fuel ratio. It is obvious that in all the cases, by a hybride process of desulphurization, the annual quantities of SO_2 emission have a dramatic decreasing.

The influence of the value of the real volum of flue gas on the SO_2 concentration in the flue gas before and after desulphurization is represented in the Figure 2. The value is calculated for the same amount of sulphur in coal - 0,8%, but for different ratio between others components, the boiler being fuelled only with lignite and the desulphurization process efficiency being 85%.

According with the new regulation, the maximum value for SO_2 emission for this type of boiler is 400 mgSO_2/m^3 flue gas. Comparing the values of SO_2 concentration in flue gas obtained by applying a hybrid process of desulphurization with the maximum value imposed by EU legislation (transposed into Romanian legislation) - 400 mg SO_2/m^3 flue gas, it is obvious that this target could not be obtained without using natural gas as additional fuel.

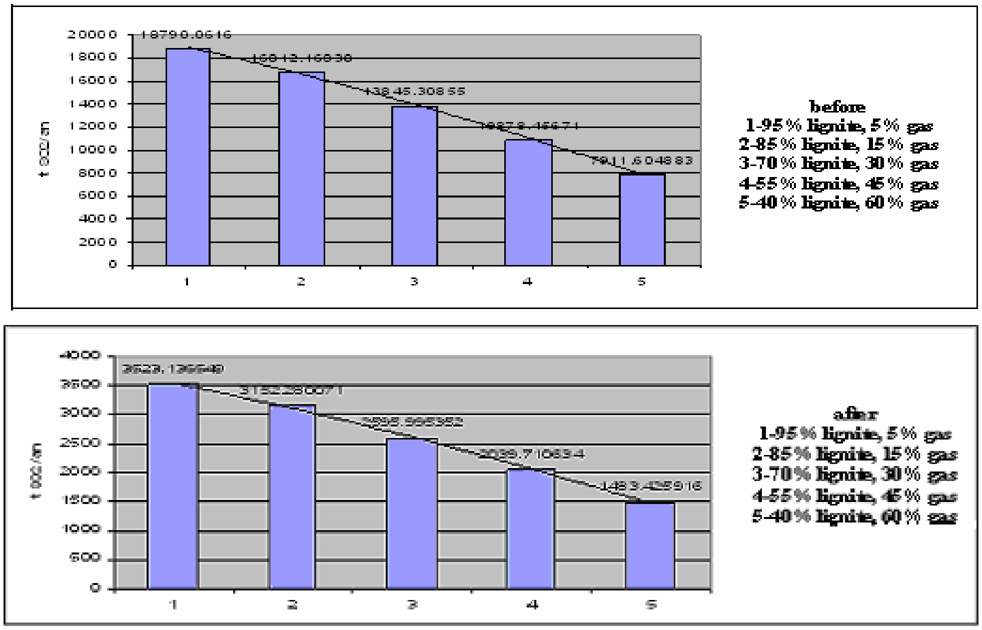

Fig.1. The annual SO_2 emission for a boiler output of 98% from the nominal steam flow before and after desulfurization for the different thermal input share of lignite and natural gas

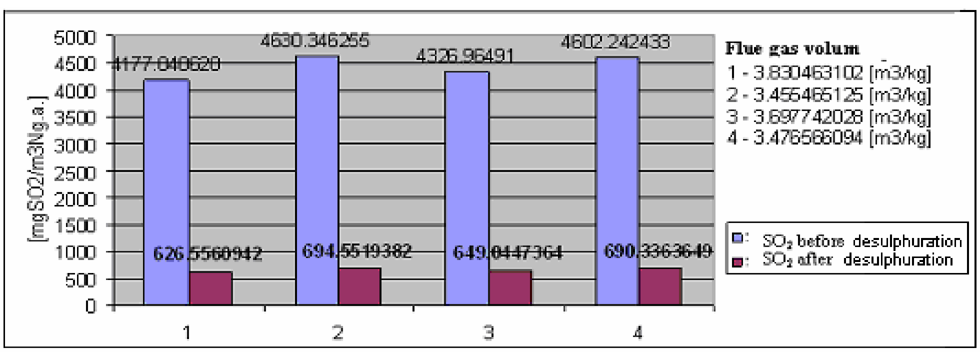

Fig. 2. The influence of the value of the real volum of flue gas on the SO2 concentration in flue gas before and after desulphurization

Figure 3 presents the influence of natural gas thermal input ratio on SO_2 concentration in flue gas. For a lignite with 0,8% combustible sulphur, it is necessary to have a minimum thermal imput of 21.1% natural gas.in order to not exceed 400 $mgSO_2/m^3$ flue gas.

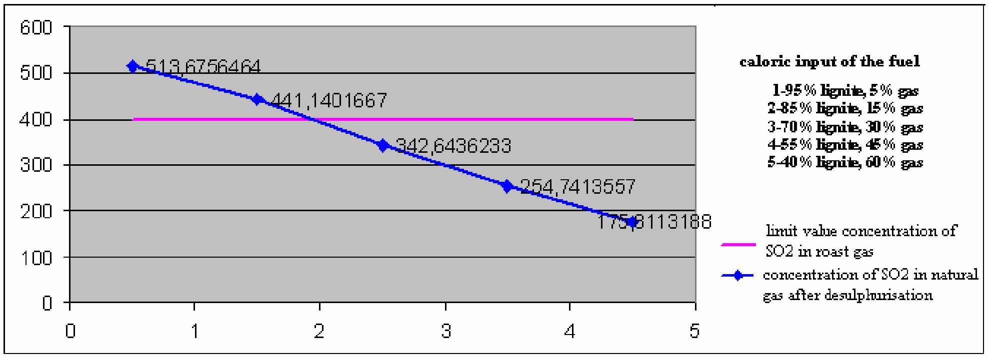

Fig. 3 - The influence of natural gas thermal input ratio on SO_2 concentration in flue gas

5. Conclusion

The forthcoming total liberalization of natural gas prices in Romania and their trend to the European ones will conduct to an increasing of electricity price based on gas-fired power plants higher than coal-fired power plants. Also, it is expected an increasing of electricity price due to the investments for the facilities needed to comply with environment legislation concerning the limits of SO_2, NO_x and particulate matter emissions.

A study case concerning flue gas desulphurization at a steam boiler fuelled with lignite shows that the hybrid (semi)dry methods could not ensure the reduction of SO_2 level under the maximum level permitted according with the new Romanian legislation. The increasing of the natural gas in fuel mixture with lignite could represent a solution to comply with the new requirements.

To full comply with the new maximum limit of SO_2 concentrations in flue gas without using natural gas like additional fuel in the case of Romanian lignite it is necessary to use wet FGD methods, which involve higher investments and higher price of electricity than (semi)dry FGD.

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