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THE INFLUENCE OF FLUE GAS DESULFURIZATION IMPLEMENTATION ON LIGNITE COMBUSTION POWER PLANTS PERFORMANCE

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Abstract:

The objective of the paper is to determine the influence of Flue Gas Desulfurization (FGD) implementation on lignite combustion Power Plants performance, in fact to reveal the operation cost impact evolution. At the beginning, are presented the main desulfurization technologies used all over the world in power plants. From these alternatives, two of the most frequently used technologies are chosen for a detailed analysis – the wet technology and the semi-dry technology. It is presented the architecture of the structure, the function of each component and the performances for each of the two technologies.

By using the Multi Criteria Analysis method for data analysis, it is processed 8 criteria (considered the most relevant criteria) for evaluation of the FGD investment impact on existing coal fired Power Plants. The results of Multi Criteria Analysis reveal the importance top of the 8 criteria analyzed. Those criteria are associated with the two FGD technologies described before, resulting which technology is most advantageous to be implemented in case of 315 MW coal (lignite) fired Unit.

Considering the results of the Multi Criteria Analysis, on the most advantageous technology is processed for this size Unit, the specific consumptions – the reaction agent consumption, the power consumptions, the compressed air consumptions, the operation personnel cost and the annual maintenance cost for this FGD technology.

After this data processing, it results a certain specific increase of the operation cost of the 315 MW Unit.

This operation cost increase has to be considered by all Power Plant managers to face the impact of the environmental requirements on the operation cost of the Units.

The conclusion is that the entities involved in FGD implementation in coal fired Power Plants, can find the most important criteria in appreciation of one technology, also the top of the criteria and especially for this range of Unit size, could be seen the Unit operational cost impact of FGD.

The information is important for investors, Power Plant managers and officials which are interested in strategic development plans respecting the principle of sustainable development.

Keywords: FGD – Flue Gas Desulfurization; Multi Criteria Analysis; TPP – Thermal Power Plant

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1. Introduction

Operation of thermal, coal combustion fired power plants, leads to important airborne emissions of SO_2.

Due to rainfalls and other transformation occurs in the air, these pollutants become the source of acid rains, form in which they operates at soil level for destruction of perennial vegetation.

In the same time, in the specific conditions (high temperature and pressure, humidity among ash particles) of exhausted flue gas from the boiler to the stack in the atmosphere, the gas oxides exerts a strong corrosive action to the installations, part of flue gas path. By this way, is intensified the wearing process of those installations. In the first step, SO_2 form sulphurous acid, which by oxidizing process due to solar radiation, make in the second step the sulphuric acid.

The legislation for SO_2 regulation is EU directive 2001/80/EC of the European Parliament and of the Council, regarding the limitations of certain pollutants into the air from large combustion plants, which is transposed into Romanian legislation GD 541/2003, modified and completed by GD 322/2005. For SO_2, the limits the emissions for the plants larger or equal with 500 MWt, at maximum 400mg/Nm^3, or in special case due to the fuel, the desulfurization rates has to be minimum 94%. Also these regulations establish some deadlines for complying with requests for each power plant in Romania.

2. Flue gas desulfurization technical solutions

The flue gas desulfurization technical solutions, mostly used worldwide are as follows:

- Wet type
- Semi dry type
- Magnesium type
- “CASOX” catalytic oxidation type
- “OG” type
- NKK LIMAR –Bag”, dry type
- “Blue Sky 2000” type
- “LILAC” semi-dry type
- Direct desulfurization and deNO$_X$ in boiler
- “IHI in-line” type
- Dry type for removing HCl and SO_2
- „Chiyoda Thoroughbred CT 121” type
- Ammonia forced oxidation
- Electro catalytic type (ECO® Process)
- Electron beam type (e-SCRUB® Process)

3. Description of desulfurization technical solutions

3.1. Wet desulfurization

The wet type desulfurization uses as reagent the limestone and the final product is gypsum. The limestone reduces the SO_2 in flue gas, by direct contact as droplet solution, inside a device named absorber. In the upper part of the absorber is a mist eliminator which role is to retain the water particle drops. The limestone slurry, mixed with SO_2 is then oxidized by air in the lower part of the absorber, to produce the calcium sulphate which is extracted as gypsum slurry, and finally dewatered and reused in gypsum form.

The chemical reaction is shown in formula (1):

$$CaCO_3 + SO_2 + 2H_2O + (1/2)O_2 \rightarrow CaSO_4 * 2H_2O + CO_2 \qquad (1)$$

This is the most used technical solution worldwide for the high flue gas volumes. The performance of such equipment is up to 98% desulfurization rate, the diagram of this type being presented in figure 1.

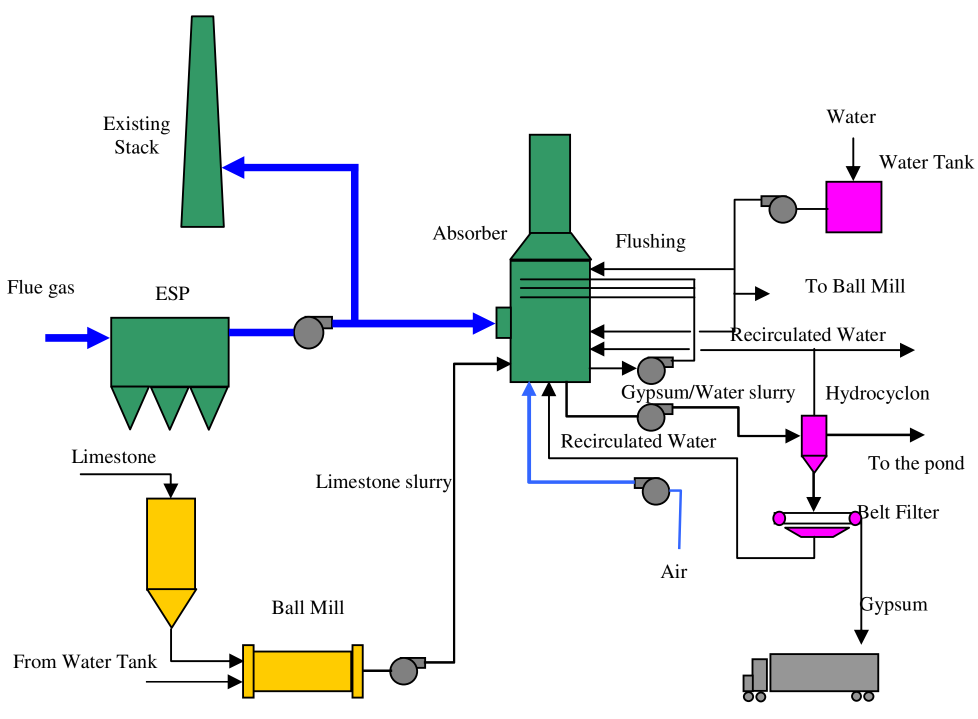

Figure 1. Wet desulfurization diagram

3.2 Semi dry desulfurization solution

The reagent is the lime and the by-product is calcium sulphite. The main chemical reaction is shown in formula (2):

$$SO_2 + CaO + \frac{1}{2}H_2O \rightarrow CaSO_3 \text{ x } \frac{1}{2}H_2O \qquad (2)$$

The flue gas, after exiting the ESP (Electro Static Precipitator), enters the bag filters inside which the desulfurization reaction took place. The collected dust inside the bags is transported to the mixer or humidifier. The role of the humidifier is to mix the bag collected dust with lime and water. The homogeneous mixture is inserted in the reactor, placed upstream bag filters. The main diagram of this solution is presented in figure (2).

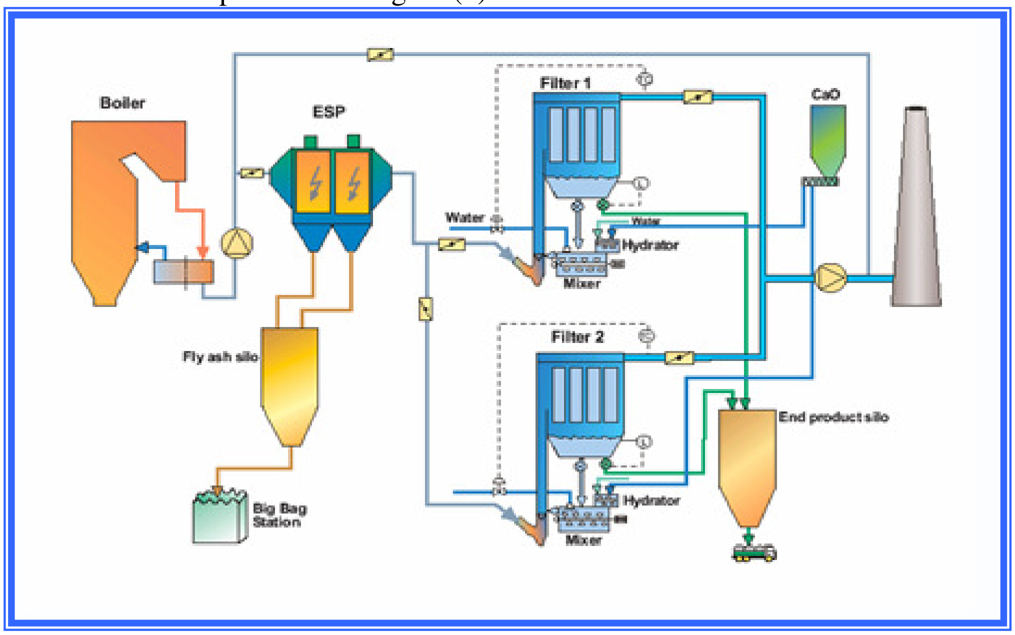

Figure 2. Semi dry desulfurization diagram

The performances of these solutions rise up to 90% - 94% desulfurization rate, being applicable for low and medium flue gas flow rates.

4. Multi Criteria Analysis for establishing the importance top of the appreciation criteria for FGD

The Advanced Multi Criteria Analysis method [2] is a method usually applied for establishing some appreciations order of many variants of one product, or for establishing the order of appreciation criteria.

It is remarkable that the multi criteria analysis is, referring the chosen criteria, an analysis which gets an objective character of its results, due to the following reasons:

- the criteria order is established by comparing each two criteria one by one
- it took account, by a simple mathematic expression, of relative position between two criteria, meeting 3 possibilities: one criteria is more important than the other, one criteria is as important as the other, one criteria is less important than the other

- when analysing by comparison different variants, analysis is made separately, referring to each criteria.

The Multi Criteria Analysis consists of 5 stages as follows:

- establishing the criteria
- find out the weighting factor for each criteria
- identify all possible variants
- associate an importance mark
- elaborating the consequences matrix

The criteria are:

a. The investment cost
b. FGD efficiency
c. The reagent cost
d. The utilities cost – power; water, compressed air
e. The annual overhaul cost and maintenance cost
f. The adapting rate to existing equipment
g. The time availability of FGD
h. The possibility for future upgrading of FGD performance, due to increasing the environmental protection emission limits

Establishing the importance of each criterion is vital element for the assessment in design stage for implementation of an FGD Project in a Power Plant, because the decision factor (managers) has to view a global and correct image of all implication of each element.

Thus, is possible if it is get more importance to the investment cost – for example, which is desirable to be as less as possible, to reach the subsequent situation that due to high reagent cost, high utilities cost, low efficiency, etc. the expenses to override much the economy achieved by a lower investment cost.

Weighting coefficients γ_i were calculated applying the **FRISCO** formula, presented in formula (3):

$$\gamma_i = \frac{p + \Delta p + m + 0{,}5}{-\Delta p' + \frac{N_{crt}}{2}} \qquad (3)$$

Were: p : is the sum of obtained points of the considered element

Δp : is the difference between the points of the considered element and the points of the element placed at the last level

m : is the number of overrode criteria (considering the points achieved) by the considered criterion

N_{crt} : is the number of the criteria

Δp ' : is the difference between the points of the considered element and the points of the first element

The calculation of the weighting coefficients are shown in table 1:

Table 1

Weighting coefficients

	a	b	c	d	e	f	g	h	Points	Level	Weighting Coefficient γ_i
a	1/2	0	1	1	1	1	1	1	**6,5**	**1,2**	**4,75**
b	1	1/2	1	1	0	1	1	1	**6,5**	**1,2**	**4,75**
c	0	0	1/2	0	1	1	0	1	**3,5**	**5,6**	**2,25**
d	0	0	1	1/2	1	1	1	1	**5,5**	**3**	**3,20**
e	0	1	0	0	1/2	1	1	1	**4,5**	**4**	**2,17**
f	0	0	0	0	0	1/2	0	1	**1,5**	**7**	**0,44**
g	0	0	1	0	0	1	1/2	1	**3,5**	**5,6**	**1,29**
h	0	0	0	0	0	0	0	1/2	**0,5**	**8**	**0,10**

The obtained top of the criteria is shown in table 2:

Table 2

Criteria top

Poz.	Criterion	Weighting Coefficient γ_i
1	Investment cost	**4,75**
2	FGD efficiency	**4,75**
4	Utilities costs	**3,20**
3	Reagent cost	**2,25**
5	Annual overhaul cost and maintenance cost	**2,17**
7	Time availability of FGD	**1,29**
6	Adapting rate to existing equipment	**0,44**
8	The possibility for future upgrading of FGD performance	**0,10**

Considering two of the most used technologies for FGD: the wet solution and the semi dry solution, awarding the importance marks is made according to Table 3.

Table 3

Awarding the importance marks

Crt. No.	**Criterion**	**Mark**	
		WET	**SEMI DRY**
1	Investment cost	8	10
2	FGD efficiency	10	8
4	Utilities costs	8	9
3	Reagent cost	10	7
5	Annual overhaul cost and maintenance cost	8	10
7	Time availability of FGD	10	9

6	Adapting rate to existing equipment	9	8
8	The possibility for future upgrading of FGD performance	10	7

The calculation of consequences matrix is shown in Table 4:

Table 4

Consequences matrix

Nr. Crt.	**Criterion**	γ_i	**WET**		**SEMI DRY**	
			Mark	**Mark** x γ_i	**Mark**	**Mark** x γ_i
1	Investment cost	**4,75**	8	38	10	47,5
2	FGD efficiency	**4,75**	10	47,5	8	38
4	Utilities costs	**3,20**	8	25,6	9	28,8
3	Reagent cost	**2,25**	10	22,5	7	15,75
5	Annual overhaul cost and maintenance cost	**2,17**	8	17,33	10	21,67
7	Time availability of FGD	**1,29**	10	12,86	9	11,57
6	Adapting rate to existing equipment	**0,44**	9	4	8	3,56
8	The possibility for future upgrading of FGD performance	**0,10**	10	1	7	0,7
	Total			**168,79**		**167,54**

In the above table, we can see that for the wet solution, the most important criterion is FGD efficiency and for semi dry solution, the most important criterion is investment cost.

The total reveals the wet type FGD as being the most advantageous technical solution in a holistic comparison.

5. The impact of FGD operation to Power Plant running

Considering the results of the previous chapter, for the wet type FGD and also taking account of all specific consumptions for a 315 MW Unit, lignite fired (Işalniţa TPP), it was calculated all the operation costs.

The results are shown in Table 5 below:

Table 5

Operation costs

Raw materials, reagent		Unitary cost/consumption/Unit	Remarks
Limestone	Quantity	18.400 kg/h	The consumptions are considered for a 315 MW, lignite fired Unit
	price	147,20 €/h	
Process water	Quantity	133.060 kg/h	
	price	66,53 €/h	
Instrumental air	price	1,00 €/h	
Power	Quantity	9.870 kWh/h	
	price	493,50 €/h	
Operation personnel	price	19,27 €/h	
Total operation cost	price	**727,50 €/h**	
Overhauls and maintenance	price	139,52 €/h	
TOTAL		**867,02 €/h**	
Increasing of actual operation cost		**3,03 €/MWh**	
Increasing of actual operation cost + capital depreciation		**5,06 €/MWh**	

It was considered that FGD equipment for a 315 MW Unit, requires the next operation personnel: 5 shifts/ 3 operating personnel and 1 shift per day/ 2 operating personnel.

The assumptions considered for the impact analysis are as follows:

- the Unit capacity is 315 MW, lignite fired
- the Unit is a rehabilitated capacity
- the capital depreciation for FGD was considered 15 years
- after taking out of operation this Unit, FGD will operate for a new 330MW Unit
- all the specific consumptions were those of 315 MW Unit

The participation of each cost to the total cost is shown in Figure 3 below:

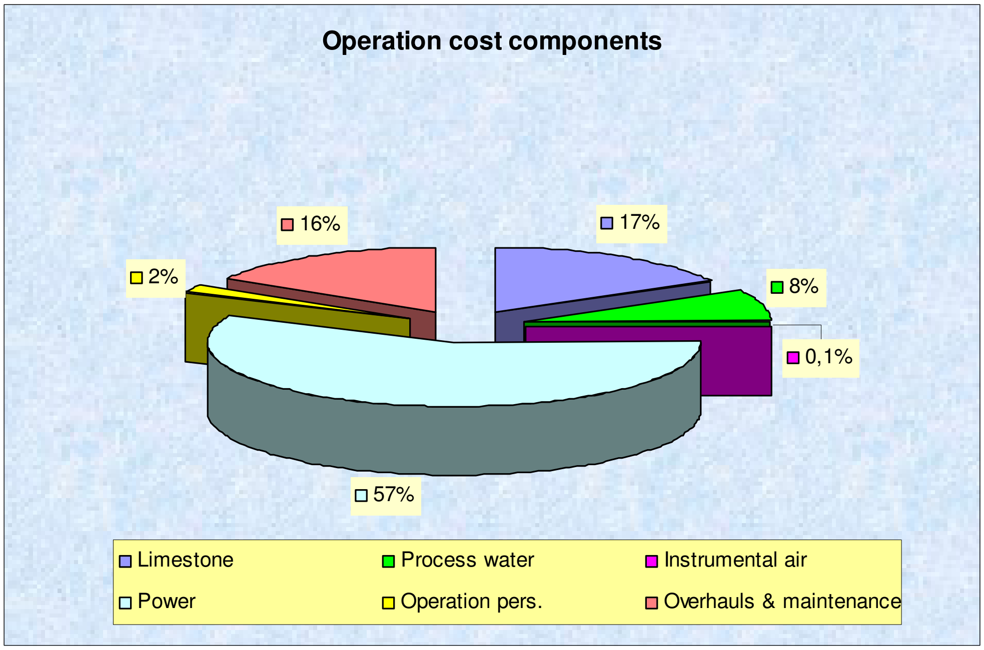

Figure 3. Operation cost components participation

6. Conclusions

- The paper emphasizes, after a deep analysis of main evaluation criteria for FGD, that the wet type technology is revealed to be on the first place, in a holistic comparison with semi dry type FGD.
- Also, from the analysis can be remarked that in appreciation of the two FGD technologies, the most important criteria are the FGD efficiency for the wet type and investment cost for the semi dry type.
- An important advantage of the wet type FGD is that it is the possibility for future upgrades of the performances, to meet the environmental protection requirements in case of reduction of emissions limits.
- The real impact of operation of FGD for a 315 MW lignite fired Unit, to the overall costs, as shown in chapter 5, reveals an unitary cost increase with 3.03 €/MWh and considering the capital depreciation, the increase is 5.06 €/MWh.

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