ISSUES REGARDING THE FURNACE OPERATION OF THE STEAM GENERATOR IN DYNAMIC REGIME

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Abstract - The paper is structured in four parts. In the first part is evoked the importance of the steam generator in the operation of power plants, presents the energy processes complexity, stressing the importance of their management and automation to increase energy efficiency of each link in the chain. In the second part are presented the physical and mathematical model of furnace. Modelling is based on physical model of the furnace boiler, simplifying assumptions adopted and the conservation equation of energy. In the third part the block diagrams are presented variation curves obtained and output data. The theoretical model proposed is implemented in Matlab-Simulink obtained simulations for the furnace in dynamic regime.

Keywords: mathematical model, simulation, process, steam generator

1. INTRODUCTION

One of the trends of research in Romanian energy sector is to ensure alignment with international practice on the analysis of processes and computerization of energy processes. A major contribution to emission reductions can be achieved by proper management of energy resulting from use of fossil fuels in power plants. For these power plants, heat transfer is strongly affected by the efficiency with which fuel is used.

The use of computers in industrial process control and energy processes in particular, can monitor and direct process control.

Most models are made specifically for the control or test new technical solution.

So, overall models are reduced appropriately to enable the dynamic analysis of the thermal power plant.

Modeling for the dynamic simulation is done after the following algorithm applied all equipment: the presentation of the physical model; precision processes that describe the operation of equipment; assumptions adopted for the realization of the model; equations of the mathematical model adopted; representation of the mathematical model in an operational form.

Taking as its starting point the operational aspects of the real, mathematical modelling, simulation and automatic control of steam generator plant, the paper proposes the development of a mathematical model in absolute units and furnace steam generator simulations of steady and dynamic regime. This study was elaborated on a natural circulation steam generator of 420t/h, with drum and two gas roads, from power units of 50 MW. To operation with primary fuels – lignite of Oltenia and support fuel – HFO, the set points are: the nominal flow 420 t/h, nominal pressure of live steam 137 bar, nominal temperature of live steam 540°C, nominal pressure of feed water entering the economizer 158 bar, nominal temperature of feed water entering the economizer 230°C, steam generator efficiency at the nominal load - operation with lignite fuel, 85%.

2. PHYSICAL AND MATHEMATICAL MODEL OF FURNACE

It has been introduced in many studies of the energy, the concept of adiabatic furnace homogenization, as a real or imaginary surface combustion, cutting of the resulting adiabatic combustion temperature. By this we can unitarily handle the combustion chamber but also of the specific focus conventional steam generators, [1].

Physical processes which describe the operation of the adiabatic furnace are: the combustion of the fuel (solid, liquid or gaseous) and homogenization (by turbulent mixing and transportation), real physical volume.

The physical model of the adiabatic furnace is given in figure 1:

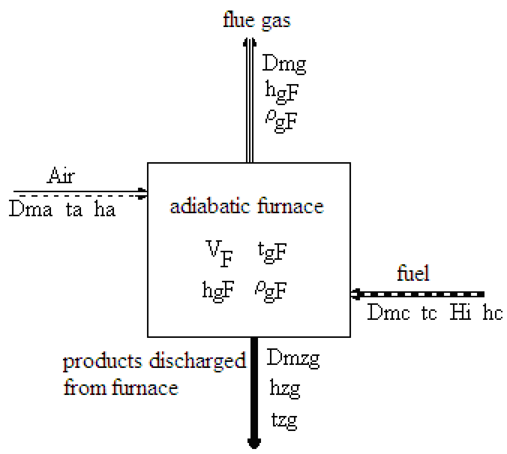

Fig.1. Physical model of furnace

The assumptions adopted in the implementation of the mathematical model are:

- the composition and the preheating temperature of fuel remain constant ;

- the mass concentration of water vapor in air, x, is kept constant in time ;
- the total mass is not variable in time ;
- air and gases are considered ideal gases, which allowed the calculation of the density on the equation of state of an ideal gas .

The mathematical model that describes the operation of the adiabatic furnace is constituted by the equation of energy conservation, [1]. For the conventional steam generator that operating with coal or liquid fuel, the energy conservation equation is:

$$\frac{d}{d\tau}\left(V_F \rho_{gF} h_{gF}\right) = D_{mc}\left(h_{comb} + h_i\right) + D_{ma} h_a - D_{mg} h_{gF} - D_{mzg} h_{zg} - Q_p \quad (1)$$

where : V_F is the volume of furnace, m^3; ρ_{gF} – density of gases, kg/m^3; H_i – the lower calorific value of fuel, kJ/kg ; D_{mc}, D_{ma}, D_{mg}, D_{mzg} – the mass flow of fuel, air, gases and ash, kg/s ; Q_p – losses in furnace, kW; h_{gF}, h_{comb}, h_a, h_{zg} – the enthalpy to the gases, fuel, air and ash.

To simplify the simulation is intended that in relation (1) occur measurable quantities of process data, constant data, specific of steam generator, or data that are determined simply from tables and charts and simple mathematical relationships.

So:

$$\frac{d}{d\tau}\left(V_F \rho_{gF}\right) = D_{mc} + D_{ma} - D_{mg} - D_{mzg} = 0 \quad (2)$$

and

$$D_{ma} = D_{mc} \cdot \lambda \cdot M_{taum} \quad (3)$$

$$D_{mzg} = D_{mc} \cdot M_{zgF} \quad (4)$$

where: λ is the coefficient of excess air; M_{taum} – theoretical mass of moist air needed for combustion, depending on fuel composition, [kg/kg]; M_{zgF} – mass of ash withheld in furnace, according to the type of furnace and initial content the inorganic, kg/kg.

Coal continues to be the raw material for producing electricity even if it is unfriendly to nature and the environment due to pollutants that are released by combustion.

Block diagram of the furnace also allows combustion calculation, based on the characteristics primary fuels – lignite of Oltenia and support fuel - HFO.

In table 1 are given the energy characteristics of fuels.

Table 1. The characteristics of the fuels

Characteristics		Coal	HFO
Chemical composition,%	C^{mc}	63,06	87,1
	H^{mc}	4,91	10,7
	O^{mc}	26,20	0,7
	S_c^{mc}	4,095	1
	N^{mc}	1,719	0,1
	A^{mc}	37,09	0,2
	W_t^{mc}	41,77	0,1
Lower calorific value, H_i ,kJ/kg		6372,2	40595

Using Matlab-Simulink software has been carried out the scheme for simulating the operation of the furnace.

The scheme allows:

- calculation of the combustion;
- calculation of the exit temperature of gases in the furnace.

The calculation of the combustion imposes, in a first stage, the determination to the equivalent fuel (the coal-HFO mixture).

The second stage aims at determining the combustion products. Therefore, is determined:

- the theoretical amount of oxygen required for combustion, Nm^3/kg comb.:

$$V_{O2}^0 = 1{,}867\frac{C^i}{100} + 5{,}6\frac{H^i}{100} + 0{,}7\frac{S_c^i}{100} - 0{,}7\frac{O^i}{100} \quad (5)$$

- the theoretical volume of dry air required for combustion, Nm^3/kg comb.:

$$V_a^0 = \frac{1}{0{,}21}\left(1{,}867\frac{C^i}{100} + 5{,}6\frac{H^i}{100} + 0{,}7\frac{S_c^i}{100} - 0{,}7\frac{O^i}{100}\right) \quad (6)$$

- the theoretical volume of humid air needed for combustion, Nm^3/kg comb.:

$$V_{aum}^0 = 1{,}0161 V_a^0 \quad (7)$$

- the theoretical volume of triatomic gases:

$$V_{RO2}^0 = 1{,}867\frac{C^i + 0{,}375 S_c^i}{100}, \text{ Nm}^3\text{/kg comb.} \quad (8)$$

- the theoretical volume of diatomic gases (N_2):

$$V_{N2}^0 = 0{,}79 V_a^0 + 0{,}8\frac{N^i}{100}, \text{ Nm}^3\text{/kg comb.} \quad (9)$$

- the theoretical volume of water vapor, Nm^3/kg comb.:

$$V_{H2O}^0 = 0{,}112 H^i + 0{,}01244 W_t^i + 0{,}00161 \cdot x \cdot V_a^0 \quad (10)$$

- the theoretical volume of dry combustion gases:

$$V_{gu}^0 = V_{RO2}^0 + V_{N2}^0, \text{ Nm}^3\text{/kg comb.} \quad (11)$$

- the theoretical volume of the combustion gases:

$$V_{ga}^0 = V_{gu}^0 + V_{H2O}^0, \text{ Nm}^3\text{/kg comb.} \quad (12)$$

- the real volume of the combustion gases:

$$V_{ga} = V_{ga}^0 + (\lambda - 1) V_{aum}^0, \text{ Nm}^3\text{/kg comb.} \quad (13)$$

- the actual flow of the combustion gases:

$$D_{gN} = B \cdot V_{ga}^{0}\text{, Nm}^3\text{/kg comb.} \qquad (14)$$

3. THE SIMULATION OF THE STEAM GENERATOR FURNACE

The model developed took into account of the following conditions, [4]:

- the calculated data does not differ by more than 1% than the base tables;
- the calculation results to be obtained in less time than the sampling time (0.2 ... 0.5 s), real-time system.

In figure 2 is given the scheme for determining the equivalent fuel chemical composition.

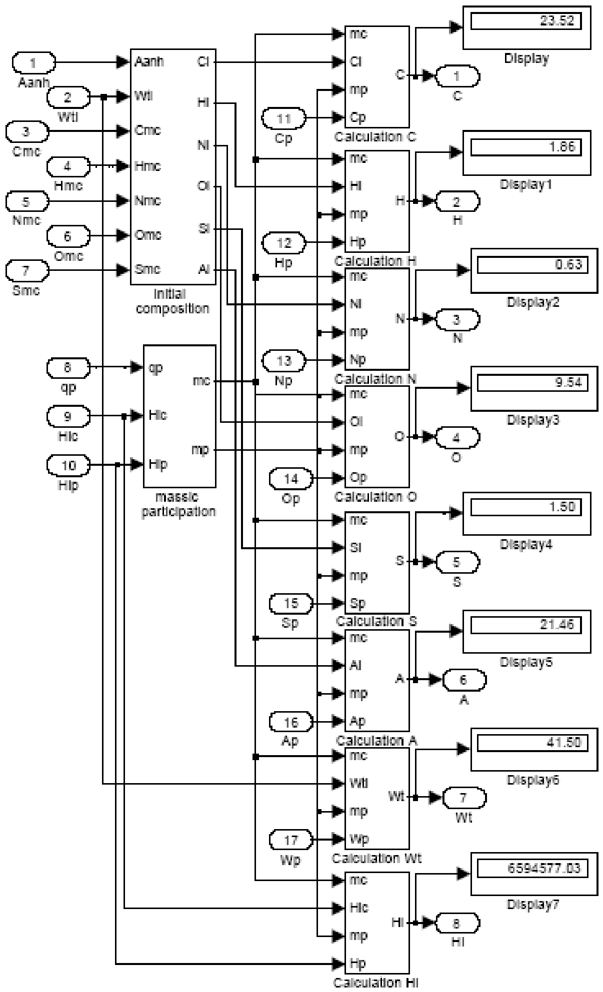

Fig. 2. Scheme for determining the equivalent fuel chemical composition

In figure 3 is given the scheme for the calculation of the combustion products.

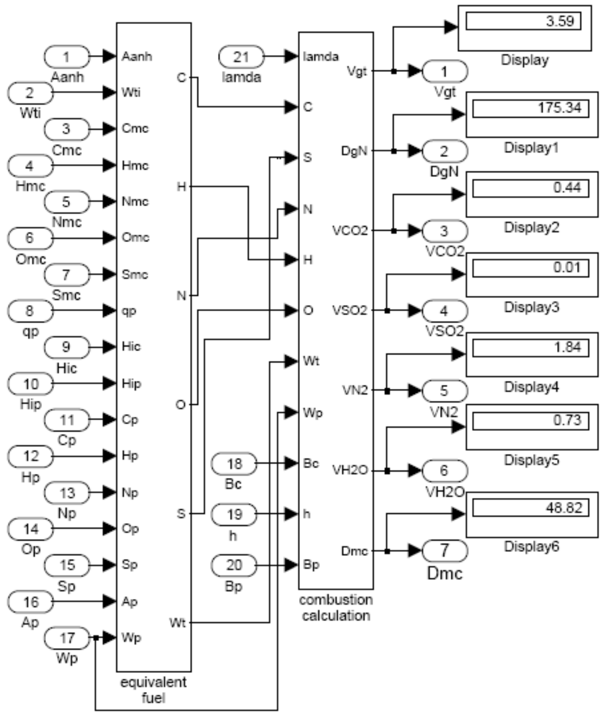

Fig. 3. Scheme for the calculation of the combustion products

Figure 4 described the scheme for simulating the operation of the steam generator furnace, considering the equation of energy conservation, (1).

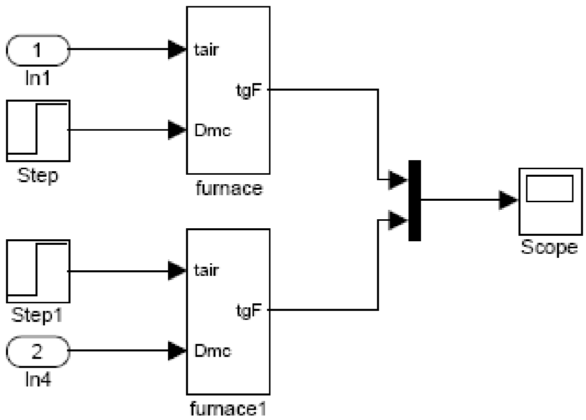

Fig. 4. Block diagram for calculating the adiabatic temperature of the furnace

Consider as known parameters the values operational variables - the fuel mass flow and the air temperature. The unknown variable is the temperature of the gases in the furnace, t_{gF}.

In figure 5 is given the time variation of the adiabatic temperature of the gases in the furnace in dynamic regime of operation.

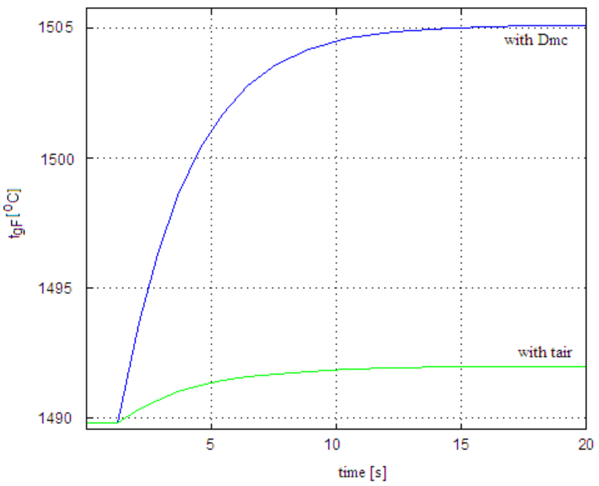

Fig. 5. The gases temperature variation in furnace

It is applied a step signal for each data input, D_{mc} and $t_{air.}$ In this case, there is much stronger influence of the temperature change in the flow of fuel gas into the furnace to the combustion air temperature variation, [4].

4. CONCLUSION

Block diagrams are presented variation curves obtained and output quantities.

It is noted that the model meet operating values taken as a basis to develop work; has the advantage of eliminating major recalculation sequence of parameters at each step - the patterns in relative units the entire set of coefficients are determined and entered into the model according to the parameters achieved in the previous reference system; remove linearization around to the point for stable operating, nonlinear features are included in the model, he found one point of operation on non-linear features and updates the parameter values; is characterized, with all its advantages mentioned above as a model more slowly – than that in relative units - through iterative calculation.

Also, the diagram gives the possibility to change the type of solid fuel used.

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