CONTROL OF THE STEAM TEMPERATURE IN SUPERHEATER

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Abstract: Thinking at boiler like an automate object, setting the pressure and temperature's steam becomes system's charge which must be local charges for dynamic duties and boiler's safety. Setting the live steam temperatures made through injection capacity command INJ 1 and INJ 2, and setting of pressure is made through combustible capacity command.

The steam temperature depend from the steam flow capacity, the evacuate gas flow capacity, which are entrance size boiler's and these depend from combustion process, so that from air flow capacity and combustible flow capacity.

1. INTRODUCTION

The equipments of automation must permit to be in manual charge and automaton operation of power groups in order to ensure:

-keeping the equipments inside restrictions of safety and use

-checking the limits and the conditions of use and ensuring every recent value and unmoved record of parameters value.

The operator's warning and attention with alarm system about the nearness operating trouble's limits

-putting the equipments out of order if functioning restrictions were neglected.

The automatic system's use of power groups must ensure two categories of charges: system charges, which are controlled by power system or users and local charges, which are controlled by intern safety of the group:

a)The system charges consist of furnishing of economical load of a unit in power system, at certain tension and frequency.

In general, the setting power is ensured by using flow capacity steam efficiency in steam turbine, and setting up the tension with assign of generator's source voltage.

b)Local charges are made from system's charges because some intern parameters compete at working done the charges in system, these must maintain in normal limits for function in order to performance the group.

So, for checking the power of power group through steam capacity furnished by boiler, the steam must be at some pressure and temperature.

This measure must be holding on in some limits to not appear problems at boiler and turbine:

-for turbine a huge steam expansion may generate steam condensation in turbine;

-for boiler, which , from dynamic point of view, is a slow process different from turbine and generator, the sudden variation of steam debtor may produce serious perturbation in water-steam cycle which puts in order the interblock system.

Thinking at boiler like an automate object, setting the pressure and temperature's steam becomes system's charge which must be local charges for dynamic duties and boiler's safety. Setting the live steam temperatures made through injection capacity command INJ 1 and INJ 2, and setting of pressure is made through combustible capacity command.

Local charges consist in:

-setting the burning process, ensuring the burning air for a complete and economic burn of combustibles and exhausting burned gaze;

-setting the water level in tambour's boiler with cylinder.

From analysis of flow sheet results complex charges for automate systems of power groups and keeping in mind that thermal energy and, in a special mood, electric energy which are produced, can not be stocked (that is the reason for stocking, which must be equal with the consumption anytime).

For a high efficiency and lead's steering, the automatic's equipment are grouped depending on charges which are made. Their function are based on receiving information from the process through sensors and gages and this actuated concerning process through actuator with continuous and discontinuous action.

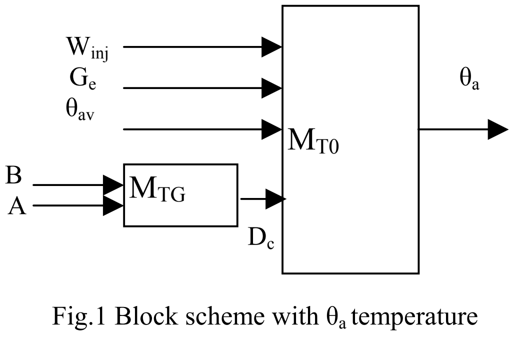

Fig.1 Block scheme with θ_a temperature

For setting the live steam's temperature, the superheat is divided in two or more parts, in connection's points it is assembled apparatus which could permit the steam condensation's injection.

Because of the modern steam boiler with huge capacity, a single way of superheating with one contrivance of injection are inefficient for setting the temperature in a low limits, usually there are three ways of superheating with two injections.

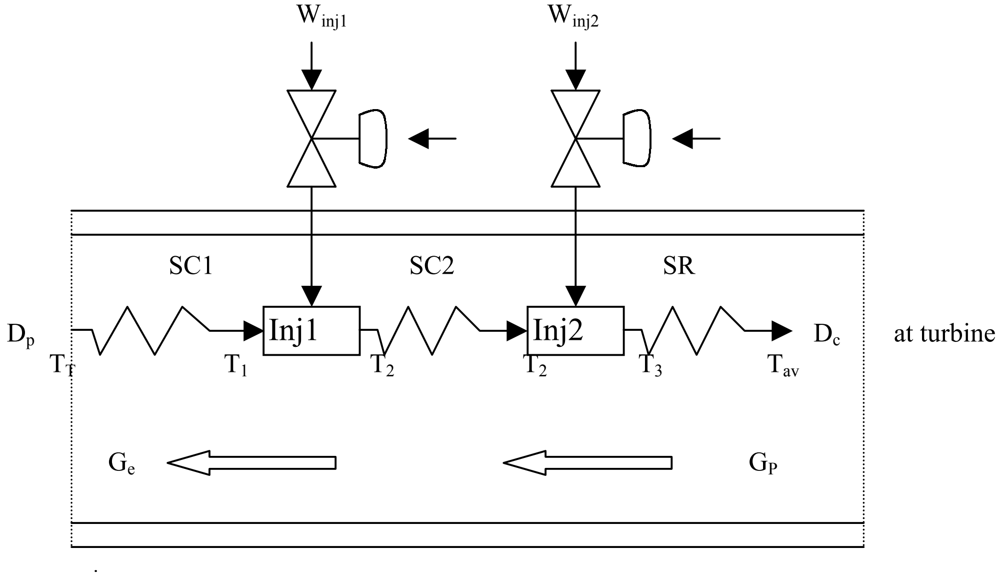

Fig.2 The structure of superheater with condensation injection

2. THE MATHEMATIC STRUCTURE

The mathematical structure of superheater

The technological process

The first step of steam's superheating is made up from changing surface of boiler's warmth on steam cycle, starting from the tambour till the first refrigeration (cooling) injector.

The exchange warmth is done through convection.

The steam capacity is of 407.83 t/h.

The steam traverses the superheater's in counter-current above burning gaze.

In this surface the steam is superheating, being at a saturation temperature like 396.7^0C

The superheat is made up with tubes of Φ 32*5(mm).

The steam superheating, in the first way, is made up in the following change's surface of warmth:

	Surface(m^2)	Kcal/h
The ceiling wall	159	1.65
The back wall	110	1.14
The lateral road wall II	430	2.14
The unfailing road wall II	320	2.42
Superheat I A on the road II of gaze	1370	13.5
Superheat I B on the road I of gaze	817	13.9
Total	3210	35.25

were it was indicated the warmth capacity which was received hundred percent from charge.

For the hole superheat we need:

-the interior volume(bulk) of the tubes

-the total steam capacity

-the volume of burning gaze

The equation of the process:

The equation of thermal balance for steam

$$\rho^{(1)}{}_a c^{(1)}{}_a V^{(1)}{}_a \frac{d\theta^{(1)}{}_a}{dt} = a_1 A_1 (\theta_g{}^{(1)} - \theta_a{}^{(1)}) + \rho_{ai}{}^{(1)} c_{ai}{}^{(1)} \theta_{ai}{}^{(1)} F_{ai}{}^{(1)} - \rho_a{}^{(1)} c_a^{(1)} \theta_a{}^{(1)} F_a{}^{(1)} \qquad (1)$$

The equation of thermal balance for gases

$$\rho^{(1)}{}_g c^{(1)}{}_g V^{(1)}{}_g \frac{d\theta^{(1)}{}_g}{dt} = \rho_{gi}{}^{(1)} c_{gi}{}^{(1)} \theta_{gi}{}^{(1)} F_{gi}{}^{(1)} - \rho_g{}^{(1)} c_g^{(1)} \theta_g{}^{(1)} F_g{}^{(1)} - a_1 A_1 (\theta_g{}^{(1)} - \theta_a{}^{(1)}) \tag{2}$$

Linearing the equations (1) and (2) around a constant point of function:

$$\Delta F_{ai}{}^{(1)} = \Delta F_a{}^{(1)} ;\ \Delta F_{gi}{}^{(1)} = \Delta F_g{}^{(1)} \tag{3}$$

$$T_8 \frac{d\Delta\theta_a{}^{(1)}}{dt} + \Delta\theta_a{}^{(1)} = K_1 \Delta\theta_g{}^{(1)} + K_2 \Delta\theta_{ai}{}^{(1)} + K_3 \Delta F_a{}^{(1)} \tag{4}$$

$$T_9 \frac{d\Delta\theta_g{}^{(1)}}{dt} + \Delta\theta_g{}^{(1)} = K_4\, \theta_{gi}{}^{(1)} + K_5 \Delta F_g{}^{(1)} + K_6\, \Delta\theta_a{}^{(1)} \tag{5}$$

The coefficients T and K, which are written in equations (4) and (5) in a constant mood, are determined by the followings:

$a_1=55.38$[J/m^{2}Ks]
$A_1=3210$[m^2]
$\theta_g{}^{(1)}=820$[K]
$\theta_a{}^{(1)}=669.8$[K]
$c_{a1}{}^1=4399.3$[J/KgK]
$\theta_{a1}{}^{(1)}=618.85$[K]
$F_{a1}{}^{(1)}=113.29$[Kg/s]
$c_a{}^1=4416.11$[J/KgK]

$F_a{}^1=F_{ai}{}^1$
$\rho_{gi}{}^1=0.353$[Kg/m^3]
$c_{gi}{}^1=1761.06$[J/KgK]
$\theta_{gi}{}^{(1)}=1042.15$[K]
$F_{gi}{}^1=164.16$[m^3/s]
$\rho_{ai}{}^1=103.08$[Kg/m^3]
$V_a{}^1=25$[m^3]
$V_g=52$[m^3]
$\rho_g{}^1= 0.375$[Kg/m^3]
$c_g{}^1=1577.9$[J/KgK]
$\theta_g{}^{(1)}=820$[K]

$$F_g{}^1=F_{gi}{}^1 T_8=\frac{\rho^{(1)}{}_a c^{(1)}{}_a V^{(1)}{}_a}{c_a{}^{(1)} F_a{}^{(1)} + a_1 A_1} = \frac{103.08 * 4416.11 * 25}{4416.11 * 113.20 + 55.38 * 3210} = 16.8\ \text{[s]}$$

$$K1=\frac{a_1 A_1}{c_a{}^{(1)} F_a{}^{(1)} + a_1 A_1} = \frac{55.38 * 3210}{678070.9019} = 0.26$$

$$K_2=\frac{c_{ai}{}^{(1)} F_{ai}{}^{(1)}}{c_a{}^{(1)} F_a{}^{(1)} + a_1 A_1} = \frac{4399.3 * 113.29}{678070.9019} = 0.74$$

$$K_3=\frac{c_a{}^{(1)} \theta_a{}^{(1)} - c_{ai}{}^{(1)} \theta_{ai}{}^{(1)}}{c_a{}^{(1)} F_a{}^{(1)} + A_1 a_1} = \frac{4416.11 * 669.8 - 4399.3 * 618.8}{678070.9019} = 0.35$$

$$T_9=\frac{\rho_g{}^{(1)} c_g{}^{(1)} V_g{}^{(1)}}{\rho_g{}^{(1)} c_g{}^{(1)} F_g{}^{(1)} + a_1 A_1} = \frac{0.375 * 1577.9 * 52}{0.375 * 1577.9 * 164.16 + 55.38 * 3510} = 0.11\ \text{[s]}$$

$$K_4=\frac{\rho_{gi}{}^{(1)} c_{gi}{}^{(1)} F_{gi}{}^{(1)}}{\rho_g{}^{(1)} c_g{}^{(1)} F_g{}^{(1)} + a_1 A_1} = \frac{0.353 * 1761.06 * 164.16}{274905.324} = 0.37$$

$$K_3=\frac{\rho_{gi}{}^{(1)} c_{gi}{}^{(1)} \theta_{gi}{}^{(1)} - \rho_g{}^{(1)} c_g{}^{(1)} \theta_g{}^{(1)}}{\rho_g{}^{(1)} c_g{}^{(1)} F_g{}^{(1)} + A_1 a_1} = \frac{0.353 * 1761.06 * 1042.15 - 0.375 * 1577.9 * 820}{274905.324} = 0.6$$

$$K_6=\frac{a_1 A_1}{\rho_g{}^{(1)} c_g{}^{(1)} F_g{}^{(1)} + a_1 A_1} = \frac{55.38 * 3210}{274905.324} = 0.65$$

The equations of weight balance, without accumulation in surfaces:

$$\Delta F_{ai}{}^{(1)} = \Delta F_a{}^{(1)} \tag{6}$$

$$\Delta F_{gi}{}^{(1)} = \Delta F_g{}^{(1)} \tag{7}$$

There is applied Laplace's change in null initial condition:

$$(T_8 s+1)\Delta\theta_a{}^{(1)}(s)=K_1\Delta\theta_g{}^{(1)}(s)+K_2\Delta\theta_{ai}{}^{(1)}(s)+K_3\Delta F_a{}^{(1)}(s) \tag{8}$$

$$(T_9 s+1)\Delta\theta_g{}^{(1)}(s)=K_4\,\theta_{gi}{}^{(1)}(s)+K_5\Delta F_g{}^{(1)}(s)+K_6\,\Delta\theta_a{}^{(1)}(s) \tag{9}$$

There area resulting a block scheme like in the figure3:

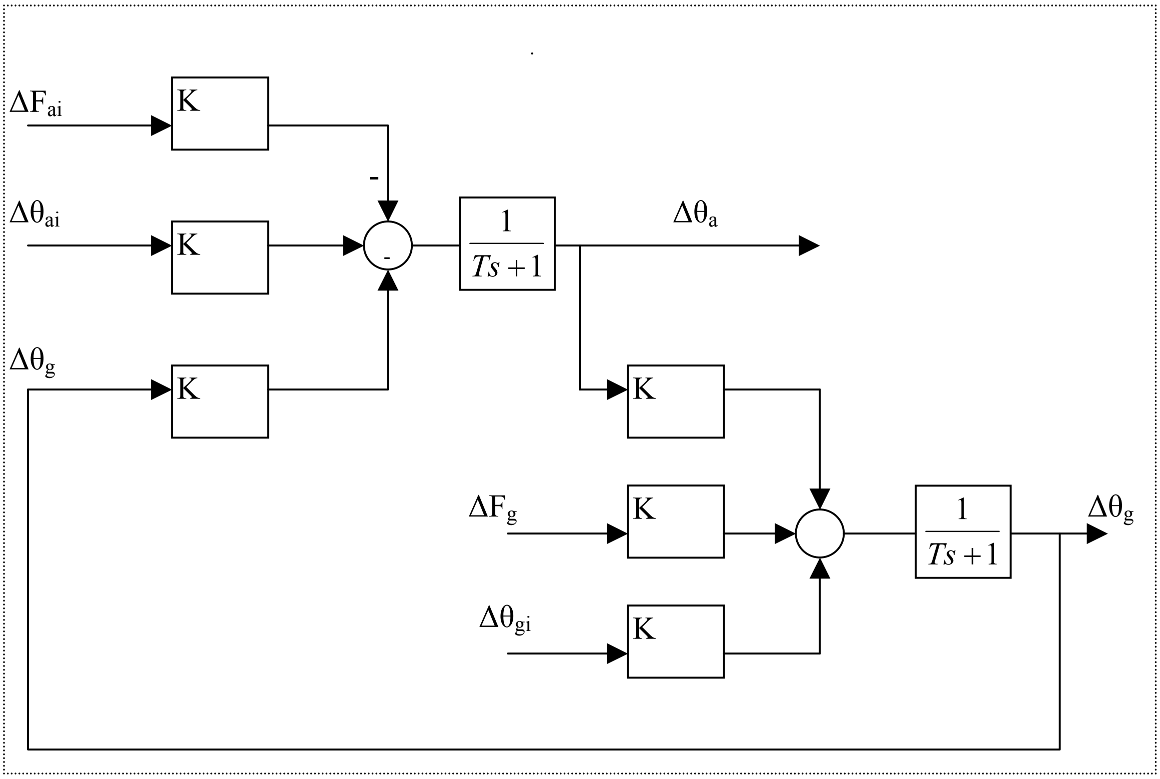

Fig.3 Block diagram of the superheater

The mathematical model of refrigeration injector

The technological process

Before the superheat II it is done an water injection for setting temperature

In constant conditions it is found the value from the following table:

-steam capacity at entrance in refrigerator

-steam capacity after injection

-enthalpy entrance steam

-enthalpy water's injection

-steam temperature

-stress (pressure)

The power balance equation

Using the notes from table 1 and table2

Notation	Significance
$i_{ai}^{(i)}$	The enthalpy of steam at the entrance on i element from the cycle of superheating
(L),W_{inj}	the water capacity after injection
(L),i_w	The enthalpy water's injection
i_{ae}	The steam's enthalpy at the emergence on i element from the cycle of superheating
L=1:2	

$$F_{ai}^{(2)} i_{ai}^{(2)} + W_{inj}^{(1)} i_w^{(2)} \qquad (10)$$

The balance's equation of capacity

$$F_{ai}^{(2)} + W_{inj}^{(1)} = F_a^{(2)} \qquad (11)$$

changing

$$i_a^{(2)} = i_{ai}^{(2)}\left(1 - \frac{W_{inj}^{(1)}}{F_a^{2}}\right) + \frac{W_{inj}}{F_a} i_w^{(1)}$$

for i=cθ, then:

$$c_a^{(2)}\,\theta_a^{(2)} = c_{ai}^{(2)}\,\theta_{ai}^{(2)} \frac{F_{ai}^{(2)}}{F_{ai}^{(2)} + W_{inj}^{(1)}} + \frac{W_{inj}^{(1)} i_w^{(1)}}{F_{ai}^{(2)} + W_{inj}} \qquad (12)$$

$$\theta_a^{(2)} = \frac{c_{ai}^{(2)}}{c_a}\theta_{ai}\frac{F_{ai}^{(2)}}{F_{ai}^{(2)}+W_{inj}^{(1)}} + \frac{W_{inj}^{(1)}}{F_{ai}^{(2)}+W_{inj}^{(1)}}\frac{i_w^{(1)}}{c_a^2} = \frac{1}{c_a^{(2)}}(c_{ai}^{(2)}\theta_{ai}^{(2)} - \frac{(c_{ai}^{(2)}\theta_{ai}^{(2)} - i_w^{(1)})W_{inj}^{(1)}}{F_{ai}^{(2)}+W_{inj}^{(1)}} =$$

$$= \frac{1}{c_a^{(2)}}(c_{ai}^{(2)}\theta_{ai}^{(2)} - \frac{c_{ai}^{(2)}\theta_{ai}^{(2)} - i_w^{(1)}}{\frac{F_{ai}^{(2)}}{W_{inj}^{(1)}}+1})$$

Linearing around a constant point of operating

$\Delta\,\theta_a^{(2)} = K_7\,\Delta\,\theta_{ai}^{(2)} - K_8\,\Delta\,W_{inj}^{(1)} + K_9\,\Delta\,F_{ai}^{(2)}$ (13)

The coefficients T and K, which are written in equations (10),(11), (12), and (13) in a constant mood, are determined by the followings:

$W_{inj}^{(1)}$=2.36[Kg/s]

F_{ai}=113.29[Kg/s]

i_w=1837203.75[J/Kg]

i_{ai}=3084830.88[J/Kg]

c_{pai}=4416.11[J/Kgk]

θ_{ai}=669.8[K]

θ_a=665.15[K]

c_{pa}=4412.6[J/KgK]

$$K_7 = \frac{F_{ai}^{(2)}c_{ai}^{(2)}}{(F_{ai}^{(2)}+W_{inj}^{(1)})c_a^2} = \frac{113.29*4416.11}{(113.29+2.36)4412.6} = 0.98$$

$$K_8 = \frac{c_{ai}^{(2)}\theta_{ai}^{(2)} - i_w^{(1)}}{(\frac{F_{ai}^{(2)}}{W_{inj}^{(1)}}+1)^2}\frac{F_{ai}^{(2)}}{(W_{inj}^{(1)})^2} = 9492.75$$

$\Delta\,\theta_a^{(2)}(s) = K_7\,\Delta\,\theta_{ai}^{(2)}(s) - K_8\,\Delta\,W_{inj}^{(1)}(s) + K_9\,\Delta\,F_{ai}^{(2)}(s)$ (14)

$\Delta\,F_{ai}^{(2)}(s) + \Delta\,W_{inj}^{(1)}(s) = \Delta\,F_a^{(2)}(s)$

There area resulting a block scheme like in the figure4:

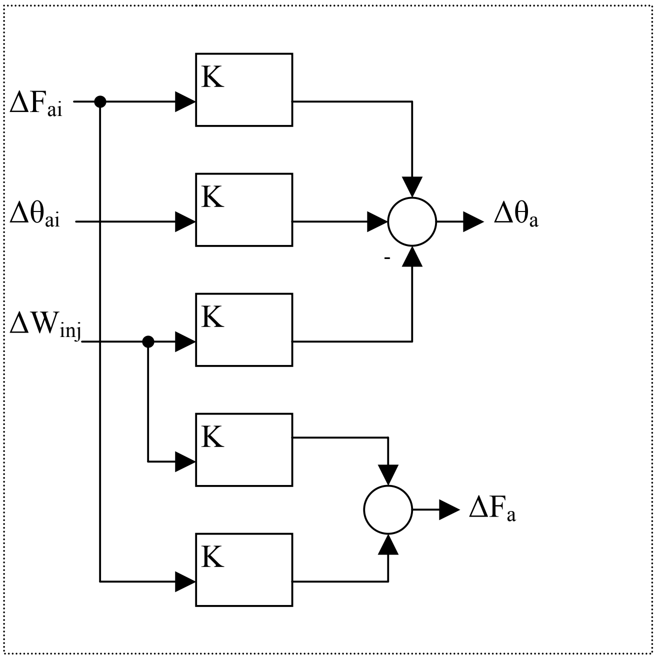

Fig.4 Block diagram of the refrigeration injector

3. EXPERIMENTAL RESULTS

I implemented the simulation structure, using Matlab programs, in conformity with the structure of superheater system presented in fig.2 and block diagrams of each module (SC1, SC2, SR, Inj1, Inj2). Also, I simulated the control system of the steam temperature $\Delta\theta_a$, at the output of the superheater. The modeling results are presented in fig.5.where on vertical we read $\Delta\theta_a$ and horizontal line we read time t[s]

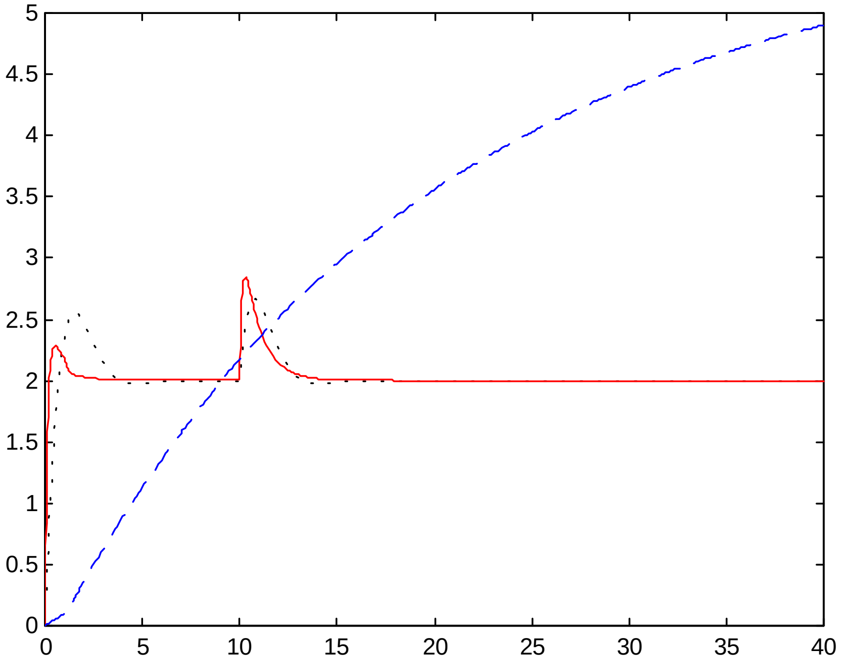

Fig.5 Experimental results

4.CONCLUSION

In the practical implementation of control systems for power plant, it is necessary to realize a lot of simulation experiments, to validate the synthesis programs.

This paper offer a solution for study the industrial control systems for boiler components, with application in modeling and process.

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