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DYNAMIC ELEMENTS DURING NATURAL CIRCULATION STEAM GENERATOR OPERATION

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The present paper analyses the effects of transitory regimes which occur in a nuclear power plant stem generator after an increase of steam consumption by the turbine. A mathematical model for the steam pressure evolution in time as a response to steam flow increase is proposed.

After recognizing the importance of water level control in a steam generator, the limiting cases when, due to auto vaporization, the water level decreases to tubes bundle level were determined. Below this level, the vessel operation is not allowed.

The results obtained after numerical simulation are presented for the real case of a nuclear power plant Candu 600 steam generator.

Keywords: natural circulation steam generator; transitory regimes; mathematical modeling; numerical simulations; dependences.

1. Introduction

The steam generators (SG) which are installed in Candu 600 nuclear power plants are vertical type, natural circulation of light water on the secondary side, the inlet and the outlet of primary coolant heavy water being at the bottom of the equipment, Fig. 1. As a characteristic of this type of steam generators one can mention the large volume of light water inside the equipment.

During normal operation of the nuclear power plant, with the reactor at power, the steam generators are the main heat sink, removing the heat developed inside the nuclear fuel and by the main circulating pumps, transferring it to the light water from the secondary side, which is then vaporizing. The steam produced in this way is delivered to the turbine in order to produce electricity.

Being the main heat sink of fuel heat, the water level inside the steam generator represents an important parameter for the safe and efficient reactor operation.

The present paper intends to analyze the dynamic response of the steam generator when, during steady operation, an increase of steam consumption appears. The steam consumption increase determines a decrease in steam

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generator pressure and hence the variation of all functional parameters of the equipment. Because the heat produced by the reactor remains constant, due to light water self vaporizing, the steam generator level decreases. It is quite important that this level decrease is not leaving the tube bundle uncovered which have the effect of a poor heat transfer and finally leading to reactor forced shutdown due to coolant temperature and pressure increase. Along with the commercial aspect of production loss, this regime is dangerous due to the fact that it can lead to a not proper fuel temperature control.

During the transient regime all the parameters evolve in time, depending on the amplitude of steam increase to turbine.

The supplementary steam flow could be produced by the steam generator using self resources, during a certain time frame, without requiring supplementary heat from the reactor. Four main ways of supplementary steam production can be identified:

a. self vaporizing of an amount of light water inside the steam generator drum due to decrease of water saturation enthalpy, as a direct consequence of steam pressure decrease;
b. water vaporizing due to heat received from the large quantity of steam generator metal in direct contact with the water and from an amount of thermal insulation;
c. the steam heat variation;
d. during the transient regime, until the nominal parameters are achieved, the feedwater pressure and flow are considered constant. In the same way, the heat generated inside the reactor is considered constant. As a result, saturated steam pressure and enthalpy will be lower than the initial ones, this meaning a supplementary heat received from the reactor leading to a supplementary amount of water vaporizing.

All the above ways to produce steam will consume the water inside the steam generator. Taking care that the level inside the steam generator must not decrease below a certain value, determined by the tube bundle level, in paper the steam generator ability to produce supplementary steam and the time frame when the steam generator can be safely operated will be determined.

2. Paper development

The physical model for the natural circulation steam generator is presented in Fig. 1 [1, 2]. The steam generator is vertical type, provided with internal preheater on the cold side, with two stages of humidity separators on the top side. In addition to the feedwater, on the steam generator secondary side, a condensate flow (10) from the steam separator reheater, is added which is acting between medium pressure and low pressure turbine. The feedwater (7) enters the SG through a nozzle directly in the internal preheater. The steam leaves the SG at the top of the equipment (9). In order to maintain proper water chemistry, right from the top of the SG tubsheet, a continuous blowdown flow is extracted (11).

The primary coolant (8) transfers the heat to the light water (6) in the steam generator. The coolant is circulated through the core (2) with the coolant pumps (3), heating up, and enters the steam generator (5). It is then distributed inside the “U” tubes (12) where it transfers the heat to the secondary side. The coolant leaves the SG through the outlet chamber (4).

An important characteristic of this type of steam generator is the large quantity of light water $m_2^{'}$ inside the SG during operation. Hence, the indicator $m_2^{'} / \dot{m}_2$, the ratio between the light water mass inside the SG and the steam flow can be computed. Usually, this ratio is between 200 ÷ 300 (kg·s)/kg. The large quantity of water inside SG is accumulating a considerably high amount of heat which could be used for steam production in case of suddenly steam consumption increase, for a finite time interval.

During normal operation, the SG produces a steam flow $\dot{m}_{2i}$, kg/s, at the initial time considered in the analysis, τ_i. During a time frame defined by $\Delta\tau = \tau_i - \tau_f$, s, the steam flow increases to the final value $\dot{m}_{2f}$, kg/s. The steam flow increase $\Delta\dot{m}_2 = \dot{m}_{2f} - \dot{m}_{2i}$, kg/s, can not be anyway high and it is strictly dependent on the steam generator design features which could represent heat accumulation and on the flow increase amplitude. It is vital to know exactly how large could be this flow increase in order to not exceed the equipment operational limits, imposed mainly by the water level on the secondary side.

The steam flow increase in time could be linear, exponential or step variation, when the increase is almost instant, so $\Delta\tau$ could be approximated as 0 s. Of course this last regime is not met during equipment operation, but the results obtained using this approximation could be considered close to the real phenomenon.

When the steam flow increases, the steam pressure will decrease to the final value, p_f. During the transient time frame, all the physical water parameters will vary: the enthalpy and saturation temperature decrease, while vaporization latent heat increases.

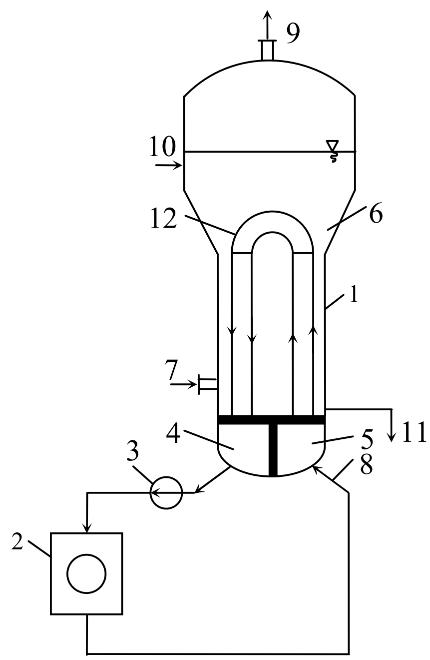

Fig. 1. Natural circulation SG; 1 – steam generator, 2 – reactor, 3 –coolant pump, 4 – SG coolant outlet 5 – SG coolant inlet, 6 – secondary side light water, 7 – feedwater, 8 – coolant circuit, 9 – steam outlet, 10 – reheat condensate, 11 – blowdown flow, 12 - "U" tubes bundle.

The SG heat balance equation, during a transitory phase, when a steam flow increase is imposed is written as [1, 2, 3]:

$$\frac{d}{d\tau}\left(m_2^{'}i^{'}+m_2^{''}i^{''}+\gamma m_m c_m t_s\right)=\dot{m}_1\left[\left(i_1^{'}+r_1x_1\right)-i_1\right]\eta_{GA}+\left(\dot{m}_{2i}+\dot{m}_p\right)i_{al}+$$
$$+\dot{m}_c i_c-\dot{m}_2(\tau)i^{''}-\dot{m}_p i^{'}, kW. \qquad (1)$$

Equation (1) describes in the left member the variation of the water, steam and metal (which is in contact with the light water) heat content in time. In the right side it is the SG heat balance based on the flows which enter and leaves the system. The following notations were made:

τ - time, s;

$m_2^{'}, m_2^{''}$ - the water and steam weight, kg;

m_m - the SG metal weight, for the fraction which is in contact with the water and transfers the ccumulated heat a, kg;

γ - the fraction of heat transferred to the water by the SG metal;

c_m - metal specific heat capacity, kJ/(kg·K);

$i^{'}, i^{''}$ - saturation enthalpy of light water and dried steam, time dependent through instant pressure, kJ/kg;

t_s - water saturation temperature, time dependent, °C;
$\dot{m}_1$ - coolant flow, kg/s;
$i_1^{'}, i_1$ - liquid saturation enthalpy of the inlet coolant; coolant enthalpy at SG outlet, kJ/kg;
r_1 - coolant latent vaporization heat, kJ/kg;
x_1 - coolant title at the SG inlet;
η_{GA} - SG heat retaining coefficient;
$\dot{m}_p$ - blowdown flow, kg/s;
$\dot{m}_c$ - reheated condensate from the turbine, kg/s;
$\dot{m}_2(\tau)$ - instant steam flow, kg/s;
i_{al}, i_c - feedwater and reheated condensate enthalpy, kJ/kg.

SG heat balance equation, steady state operation, is written:

$$\dot{m}_1\left[\left(i_1^{'} + r_1 x_1\right) - i_1\right]\eta_{GA} + \dot{m}_c i_c = \dot{m}_{2i}\left(i_i^{''} - i_{al}\right) + \dot{m}_p\left(i_i^{'} - i_{al}\right), kW, \quad (2)$$

where $i_i^{'}, i_i^{''}$ represent water saturation enthalpy and saturation enthalpy of the dried steam at the initial moment of the transitory regime, kJ/kg.

The equations (1) and (2) are summed, obtaining the differential equation:

$$\frac{d}{d\tau}\left(m_2^{'} i^{'} + m_2^{''} i^{''} + \gamma m_m c_m t_s\right) = \dot{m}_{2i} i_i^{''} + \dot{m}_p\left(i_i^{'} - i^{'}\right) - \dot{m}_2(\tau) i^{''}, kW. \quad (3)$$

Because the blowdown flow represents a loss for the thermal cycle, it is limited to 0.1 % from the steam flow, hence in equation (3) it is a small quantity compared with the others and could be neglected.

Equation (3) can be now simplified and rewritten to highlight the time dependent variables:

$$\frac{d}{d\tau}\left[m_2^{'} i^{'}(\tau) + m_2^{''} i^{''}(\tau) + \gamma m_m c_m t_s(\tau)\right] = \dot{m}_{2i} i_i^{''} - \dot{m}_2(\tau) i^{''}(\tau), kW. \quad (3')$$

The steam flow increase will be imposed as linear in this paper and it will be characterized by the final value $\dot{m}_{2f}$, kg/s and the transient duration, $\Delta\tau$, s. The significant parameters evolution is presented in Fig. 2.

$$\dot{m}_2(\tau) = \dot{m}_{2i} + \Delta\dot{m}_2(\tau) = \dot{m}_{2i} + m\tau = \dot{m}_{2i} + \frac{\dot{m}_{2f} - \dot{m}_{2i}}{\tau_f - \tau_i}\tau = \dot{m}_{2i} + \frac{\Delta\dot{m}_2}{\Delta\tau}\tau, \quad (4)$$

where: $\Delta\tau$ transient duration, s, and $\Delta\dot{m}_2$ is the final steam flow increase, kg/s. Using Fig 2 a), it can be concluded that $m = tg\alpha = \Delta\dot{m}_2 / \Delta\tau, kg/s^2$. Analyzing this relationship, it can be said that m is the steam flow variation speed, a significant parameter for this type of transitory regimes.

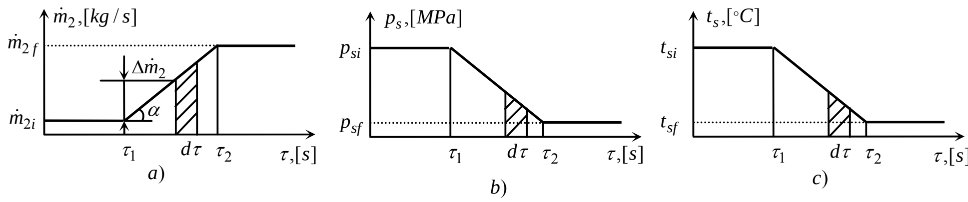

Fig. 2. Steam and water parameters variation at steam flow increase
a) –steam flow evolution b) – steam pressure c) – saturated water temperature.

Using (4), the steam flow increase with the pressure decrease can be determined: $\Delta\dot{m}_2(\tau)=\dot{m}_2(\tau)-\dot{m}_{2i}=m\tau=\dfrac{\Delta\dot{m}_2}{\Delta\tau}\tau$. (5)

Knowing the steam flow variation law (4) upon replacement in (3), a new relationship is obtained, as a function of steam flow increase:

$$\frac{d}{d\tau}\left(m_2^{'}i^{'}+m_2^{''}i^{''}+\gamma m_m c_m t_s\right)=\dot{m}_{2i}\left(i_i^{''}-i^{''}\right)+\dot{m}_p\left(i_i^{'}-i^{'}\right)-\Delta\dot{m}_2(\tau)i^{''},kW, \quad (6)$$

or, taking into acount (5):

$$\frac{d}{d\tau}\left(m_2^{'}i^{'}+m_2^{''}i^{''}+\gamma m_m c_m t_s\right)=\dot{m}_{2i}\left(i_i^{''}-i^{''}\right)+\dot{m}_p\left(i_i^{'}-i^{'}\right)-m\tau i^{''},kW. \quad (6')$$

But the steam flow increase can be derived using the decrease in time of the water and the steam mass:

$$-\frac{d}{d\tau}\left(m_2^{'}+m_2^{''}\right)=\dot{m}_{2i}+\dot{m}_p-\left[\dot{m}_2(\tau)+\dot{m}_p\right]=\Delta\dot{m}_2(\tau)=m\tau,kg/s. \quad (7)$$

After integration of (7), one obtains:

$$\int_{m_{2i}^{'}+m_{2i}^{''}}^{m_2^{'}+m_2^{''}} d\left(m_2^{'}+m_2^{''}\right)=-\int_0^{\tau} m\tau d\tau \text{ or, } m_2^{'}+m_2^{''}=m_{2i}^{'}+m_{2i}^{''}-0.5m\tau^2. \quad (8)$$

Analyzing this final expression, it can be observed that the sum $m_{2i}^{'}+m_{2i}^{''}$ is the initial mass of water and steam, so it is a known process constant, dependent on SG design features and which varies in a parabolic way with the time τ. If the equation is written for the final moment of the regime, τ_f, the final mass of the water and the steam is obtained:

$$m_{2f}^{'}+m_{2f}^{''}=m_{2i}^{'}+m_{2i}^{''}-0.5\frac{\Delta\dot{m}_2}{\Delta\tau}\Delta\tau^2=m_{2i}^{'}+m_{2i}^{''}-0.5\Delta\dot{m}_2\Delta\tau. \quad (9)$$

Taking care that the equipment volume is constant, the following correlations can be derived:

$$V_{GA}=V_{2i}^{'}+V_{2i}^{''}=V_2^{'}+V_2^{''}=V_{2f}^{'}+V_{2f}^{''}=const, \quad (10)$$

or:

$$V_{GA}=m_{2i}^{'}v_{2i}^{'}+m_{2i}^{''}v_{2i}^{''}=m_2^{'}v_2^{'}+m_2^{''}v_2^{''}=m_{2f}^{'}v_{2f}^{'}+m_{2f}^{''}v_{2f}^{''}.$$

Further development leads to: $V_{GA}\rho_2^{"} = m_2^{'}\rho_2^{"} / \rho_2^{'} + m_2^{"}$. (11)

Solving (8) and (11) leads to finding the equations which describe the mass variation of the water and the steam:

$$m_2^{'} = \frac{m_{2i}^{'} + m_{2i}^{"} - 0.5m\tau^2 - \rho_2^{"}V_{GA}}{1-\rho_2^{"}/\rho_2^{'}} \cong$$
$$\cong -\left(1+\rho_2^{"}/\rho_2^{'}\right)\left[\left(m_{2i}^{'} + m_{2i}^{"} - 0.5m\tau^2\right)\rho_2^{"}/\rho_2^{'} - \rho_2^{"}V_{GA}\right], \quad (12)$$

where approximation $1/\left(1-\rho_2^{"}/\rho_2^{'}\right) \cong 1+\rho_2^{"}/\rho_2^{'}$ is used. $\rho_2^{"}$ is the dried steam density, kg/m^3, and $\rho_2^{'}$ saturated water density, kg/m^3.

The equation (6) can be solved analytically or numerically. In this paper, the numerical computation was preferred. The following hypothesis were assumed:

a) the blowdown term will be neglected;
b) the approximation $i^{'} = c_p t_s$, is used where c_p is the specific heat capacity of saturated water, kJ/(kg·K), considered constant.

The operator $\frac{dt_s}{d\tau} = \frac{dt_s}{dp_s}\frac{dp_s}{d\tau}$ will be adopted.

In order to derive the differential equation, due to the fact that all water and steam properties are dependent on the saturation pressure, the following relationships were determined:

$$t_s(p) = 104.52\,p_s^{0.2368}; \quad i^{'}(p) = 409.03\,p_s^{0.2651}; \quad i^{"}(p) = 2863.6\,p_s^{-0.0061};$$
$$\rho_2^{'}(p) = 1197.2\,p_s^{-0.1099}; \ \rho_2^{"}(p) = 0.447\,p_s^{1.032}; \ r(p) = 3299.2\,p_s^{-0.178}. \quad (13)$$

The relationships are valid in the range 3.0 MPa ÷ 5.0 MPa which covers the transitory regimes in this paper.

Now it can be derived $dt_s / dp_s = 24.75\,p_s^{-0.7632}$. (14)

It is noted that $m_{GA} = m_{2i}^{'} + m_{2i}^{"} + \gamma m_m \frac{c_m}{c_p}$. This has the significance of all masses which are implied in the supplementary steam production. This term can be exactly determined.

Replacing (12) in (4), one obtains:

$$\frac{d}{d\tau}\Big\{i^{'}\left(1+\rho_2^{"}/\rho_2^{'}\right)\left(m_{2i}^{'} + m_{2i}^{"} - 0.5m\tau^2 - \rho_2^{"}V_{GA}\right) -$$
$$- i^{"}\left(1+\rho_2^{"}/\rho_2^{'}\right)\left[\left(m_{2i}^{'} + m_{2i}^{"} - 0.5m\tau^2\right)\rho_2^{"}/\rho_2^{'} - \rho_2^{"}V_{GA}\right] + \gamma m_m c_m t_s\Big\} =$$
$$= \dot{m}_{2i}\left(i_i^{"} - i^{"}\right) + \dot{m}_p\left(i_i^{'} - i^{'}\right) - m\tau i^{"}. \quad (15)$$

Analyzing (13) it can be seen that the ratio of vapour and liquid densities is small $\rho_2^{"}/\rho_2^{'}$ being $3.7\,p_s^{1.1}10^{-4}$. For this reason $\rho_2^{"}/\rho_2^{'}$ will be neglected.

Now (15) becomes:

$$\frac{d}{d\tau}\left[c_p t_s \frac{m}{2}\left(\frac{2m_{GA}}{m}-\tau^2\right)+r\rho_2'' V_{GA}\right]=\dot{m}_{2i}\left(i_i''-i''\right)-m\tau i''. \quad (16)$$

After the derivation, it is obtained the final form:

$$\frac{dp_s}{d\tau}p_s^{-0.76}\left[c_p m\left(\frac{2m_{GA}}{m}-\tau^2\right)+117.6V_{GA}p_s^{1.62}\right]=$$

$$=0.08i_i''\dot{m}_{2i}-228.4\left(\dot{m}_{2i}+m\tau\right). \quad (17)$$

3. Numerical experiments. Graphical representation. Interpretation

To solve the equation (17), the 4th order Runge-Kutta method has been used. This method avoids the derivative $f(\tau; p_s)$ calculus which appears in Taylor series development. RK is a direct method which allows good solution stability [7, 8]. The initial condition is established for the beginning of the transitory phase, when the SG is operating at nominal pressure of 4.69 MPa. The function becomes: $f_i(\tau; p_s)= f(0;4.69)$.

The following constants which are characteristic for the natural circulation SG were used (for nominal operating conditions): light water mass $m_2' = 35000$ kg, steam mass $m_2'' = 200$ kg, metal mass $m_m = 140000$ kg. The initial steam flow is $\dot{m}_{2i} = 260$ kg/s at $p_s = 4.69$ MPa.

In practice, it can be imposed to obtain of a supplementary steam flow during a well established time frame. In this way the parameter $\Delta\dot{m}_2 = \dot{m}_{2f} - \dot{m}_{2i}$, kg/s can be determined. Knowing the time interval, $\Delta\tau$, s, one obtains m, the steam flow variation speed.

A first set of results were obtained after imposing $\Delta\dot{m}_2 = 25$ kg/s, which is a 10% variation from the initial steam flow. In Fig. 3, the pressure evolution for different time intervals $\Delta\tau$ is presented.

It can be concluded that the saturation pressure decreases with time. In addition to this, if the steam flow increase is slow, at the final moment, the pressure inside the SG is lower than the cases when the steam flow increase was rapid. If the increase in flow is over 100 seconds time interval, the final pressure is 4.2 MPa (10% decrease in pressure); if the increase in flow happens over 500 seconds interval, the final pressure value would be 2.7 MPa, a 40 % decrease from the nominal pressure value. These values show the fact that the SG internal resources to produce steam are limited and they are consuming in time. As a conclusion, with SG initial masses increase, the dynamic response of SG is better. Unfortunately, for a built SG, further improvement is not possible but the dynamic response could be improved with carefully maintaining the thermal insulation of the equipment.

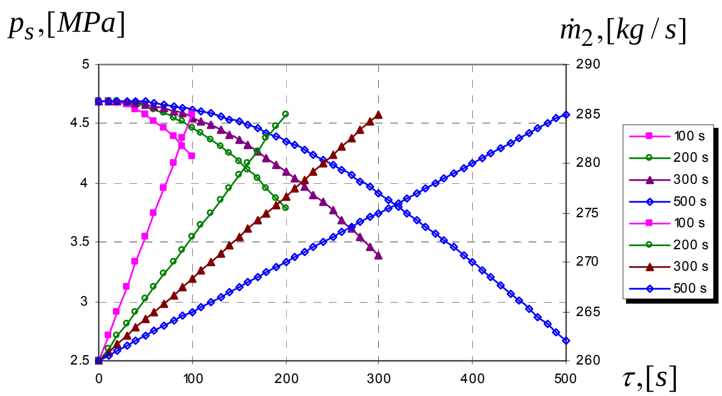

Fig. 3. SG pressure and steam flow evolution for an increase in flow of 25 kg/s

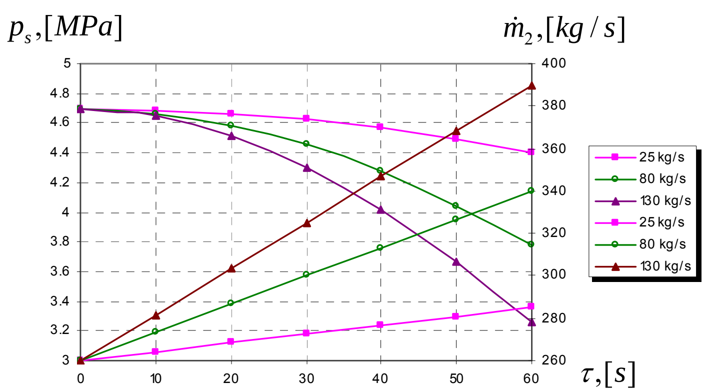

Fig. 4. SG pressure and steam flow evolution for an increase in flow of 25 kg/s, 80 kg/s, 130 kg/s during a time interval of 60 seconds

The second set of results were obtained by imposing $\Delta\dot{m}_2 = 25$ kg/s, $\Delta\dot{m}_2 = 80$ kg/s, $\Delta\dot{m}_2 = 130$ kg/s which are variation of 10%, 30% and 50% from nominal flow, during a time interval $\Delta\tau$ 60 seconds and presented in Fig. 4. It can be concluded that for an increase in flow of 10 % during 60 seconds, the decrease in pressure in approx. 6 %, while for an increase in flow of 30 % the decrease in pressure in approx. 20 % and finally, for 50 % increase in flow leads to over 30 % decrease in pressure. The conclusion is that for a short time interval the steam generator is able to produce supplementary steam through self resources and without requiring additional heat from reactor. For large time interval, the decrease in pressure is high and affects the plant operation, challenging the ability to stay in operation.

Once the pressure evolution equation is given, all the others parameters can be found. All these dependences (water and steam densities, water and steam enthalpies) were plot in Fig. 5 for an increase in flow of 25 kg/s, during 500 seconds.

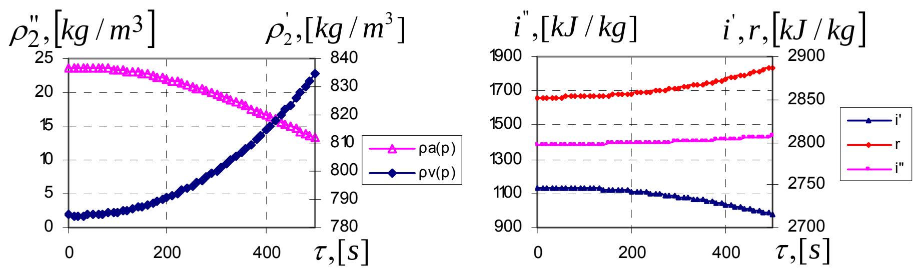

Fig. 5. SG water and steam parameters evolution in time (25 kg/s steam flow increase, 500 s)

4. Computing the level decrease in SG

Along with the pressure decrease, the vaporization of water leads to level decrease. For a NPP SG, it is a vital necessity to maintain an adequate level on the secondary side in order to continuously remove the reactor heat. If the level decrease below a certain value, the reactor must be shutdown and an alternate heat sink must be established. It is then important to know the ability of the SG to produce supplementary steam without exceeding the operational limits.

Let Fig. 6 represent a simplified cylindrical steam drum of the SG. h_i, m, represents the initial water level and $h_{\min}$, m, is the minimum level below which the reactor operation is not allowed. h, m, denotes the current level in the SG.

The normal operating level as well as the minimum level are known parameters. The minimum level is imposed above the tube bundle. The allowed level decrease is approximately 0.4 m.

As a function of steam flow increase, $\Delta\dot{m}_2$, (9) is rewritten:

$$m_{2f}^{'} + m_{2f}^{''} = m_{2i}^{'} + m_{2i}^{''} - 0.5\Delta\dot{m}_2\Delta\tau. \tag{18}$$

The water mass element which is vaporized during an infinite small time interval is defined by:

$$dm_2^{'} = \pi\rho_2^{'}r^2dz, \tag{19}$$

where: r is the drum radius, m; dz is the height of the water layer vaporized during $d\tau$, m.

Based on (19), the water mass which is vaporized between initial level h_i and minimum level, $h_{\min}$ can be determined. It is noted $\Delta m_{2\max}^{'}$, kg, and represents the maximum mass which can be displaced until the minimum level is achieved. (19) is integrated between h_i and $h_{\min}$:

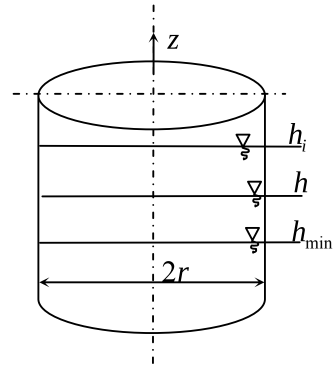

Fig. 6 Level evolution in SG

$$\Delta m'_{2\max} = 0.5\pi \rho'_2 r^2 z^2 \Big|_{h\min}^{hi} = 0.5\pi\rho'_2 r^2 \left(h_i^2 - h_{\min}^2\right), kg. \qquad (20)$$

Making further operations, one obtains:

$$\Delta \dot{m}_2 \Delta \tau < 0.16\pi\rho'_2 r^2 . \qquad (21)$$

Equation (21) allows finding of permissive transitory regimes for the SG. The left side of the equation defines families of regimes characterized by the time interval and flow increase. Replacing the known parameters, one obtains:

$$\Delta \dot{m}_2 \Delta \tau < 3509 . \qquad (22)$$

Adopting $\Delta \dot{m}_2$ 25 kg/s, 80 kg/s and 130 kg/s it can be obtained the time interval until the minimum level is achieved: 140 s, 44 s, 27 s. Smaller steam production increase 5 kg/s (2% from nominal steam flow) leads to 700 s interval. Using all these dependences the steam flow increase versus time interval until the minimum level is achieved can be plotted, Fig. 7. All points determined below the curve define a safe SG operation.

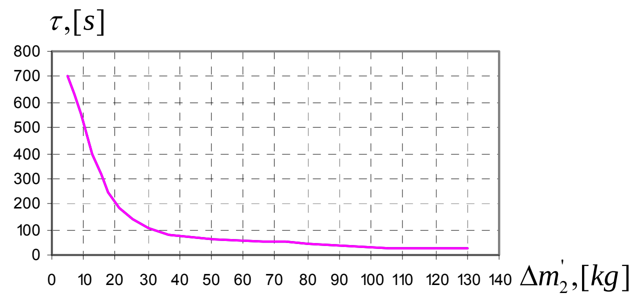

Fig. 7. Steam flow increase/time until minimum level is achieved

Another important relationship is the level decrease law, as a function of steam production increase. Knowing this law it is easy to estimate the time remaining until the minimum level is achieved. (25) is written now: $dm_2' = \pi\rho_2' r^2 dz = \Delta\dot{m}_2 d\tau$, or $\pi\rho_2' r^2 dz = m\tau d\tau$. Upon integration between initial level and minimum level, one obtains:

$$z = \tau\sqrt{\frac{1}{\pi\rho_2' r^2}\frac{\Delta\dot{m}_2}{\Delta\tau}}. \qquad (23)$$

5. Conclusions

The paper presents a complex mathematical model which describes the response of a natural circulation steam generator to a linear steam production increase. The model is important because it includes all the SG self possibilities to produce supplementary steam without a heat input increase from the reactor. The model was solved numerically using the Runge-Kutta method.

Using the SG characteristic dimensions and weights, the real variation curves for water and steam physical parameters were obtained.

In the developed equations, the parameters which characterize the self possibilities of the steam generator to produce supplementary steam, were highlighted, and, finally, its limitations imposed by the minimum level on the secondary side were obtained.

Steam flow increase versus time until minimum level is achieved was plotted. The curve could be rapidly used to determine the safe steam generator operation.

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