The Feed Water Level Improved Automated Control for Steam Generators of Nuclear Power Plants

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***Abstract*—This research deals with developing the approach to design the improved automated control systems for the feed water level in steam generators of nuclear power plants. It is developed the general theory required to build the mathematical models of nuclear power plants steam generators to have the suitable mathematical models to design the improved automated control systems for the feed water level. It is proposed the generalized approach for defining the parameters of improved automated controllers for the feed water level on the basis of the developed general theory of mathematical models of the steam generators. The relationships between the proposed and classical approaches to design the automated systems for the feed water level in steam generators of nuclear power plants are theoretically researched, and the influence of evaporation mirror area on the parameters of the feed water level linear controllers is shown. The results of computer simulations of the feed water level in the steam generators to show some opportunities of the proposed approach are presented.**

Keywords—nuclear power plant, steam generator, automated control system, feed water level, mathematical model, design

I. INTRODUCTION

Steam generators are the principal structural elements both for the wide used types of nuclear power plants with the pressurised water nuclear reactors [1], [2] both for the new generations of small modular nuclear reactors [3]. It was proposed a lot of different design configurations for the steam generators for the nuclear power plants, but at present we have only two widely used kinds, namely vertical and horizontal types [1], [2]. Vertical type steam generators are the most used because of such type is foresaw on the nuclear power plants designed by the manufacturers in Europe, United State, Chine, S. Korea and Japan, but horizontal type steam generators are inherent only on the VVER nuclear power plants operated in the eastern Europe, but we have a lot of them. Nevertheless, we have a lot of researches deal with the vertical and horizontal types of the steam generators at present, and the articles [1], [2] are only some of similar researches.

Generation of the steam is due to utilising the heat from the core of the nuclear reactor, so, except generating the steam, steam generators have the significant purpose in cooling the core of the nuclear reactor, and steam generators are very important for minimizing the risks of dangerous nuclear accidents [4], [5], [6]. Feed water level in the housing vessel has the significant importance to provide the safety operation of steam generators, and it is necessary to have the automated systems providing reliably the required feed water level, because this level must be controlled continuously during the operation. Due to these circumstances, a lot of different researches deal with the different particulars about feed water level automation systems are at present. Some of these researches are based on the classical control theory like [7], some of them are about to have the optimal control like in [8] for example, and others are about operating in different ranges like [9] and taking into account different processes particular operational modes, like [10] for example. We have a lot of researches including [11], [12] for example about the heat and mass transfer processes in the steam generators, because such processes are the key for normal operating the steam generators and for changing the feed water level in steam generators. Thus, this research is in current interests because of considering the important problems about automation control of the feed water level required for improving the design of the steam generators and their automation systems to provide reliable and safe operation.

The existed automated systems for the feed water level for the steam generators of the nuclear power plants are designed on the basis of the classical linear theory of the automated control. The existed automated systems reach the limits of possible perfectness in the bounds of used theories, so further improving of such systems requires the new approaches developing to replace or supplement the classical control theory to design the automated systems for the feed water level for the steam generators of the nuclear power plants. Thus, the global purpose of this research is in developing suitable generalised approach to design the improved automated control systems for the feed water level in steam generators of nuclear power plants.

To realize this global purpose the follows particulars will be researched and developed:

- It will be developed the general theory required to build the mathematical models of nuclear power plants steam generators, so to have the suitable mathematical models to design the improved automated control systems for the feed water level.
- It will be proposed the generalized approach for defining the parameters of improved automated controllers for the feed water level on the basis of the developed general theory of mathematical models of the steam generators. The relationships between the proposed and classical approaches do design the automated controllers will be shown to understand the sense of the improved automated controllers.
- Theoretical researches and computer simulations about influencing the evaporation area on the feed water level control processes in the steam generators will be accomplished to show opportunities of the proposed approach.

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This research is actually the effort to understand the general way to consideration the complicated mutually connected processes in steam generators of nuclear power plants from the point of view of designing the feed water level automated control systems.

II. General Theories

Having the general theory allows imaging the sense of the problem about design the feed water level automated control systems and it gives us understanding about required particulars which must be considered.

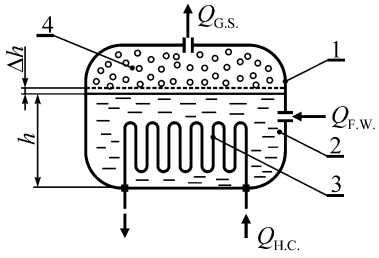
The steam generators are actually the complicated technical systems, so their reliable mathematical models must be complicated too. At the same time, the level of complexity of the mathematical model must be in agreement with the purpose of using these models, because of using the excessively complicated models can create significant difficulties not allowing to solve the considered problem, but from other side, the mathematical model cannot be excessively simple too. To satisfy the required complexity to have the mathematical models suitable for designing the improved feed water level automation systems for steam generators of nuclear power plants it is proposed to use the approach of step by step complicating the mathematical models.

A. The Feed Water Level

If we want consider the automated systems for the feed water level, then we must understand the reasons of changing the feed water level in the housing vessels of the steam generators (Fig. 1). It is clearly understood, that changing Δh of the feed water level is due to difference between the feed water supply and the generated steam consumption (Fig. 1). Taking into account this circumstance, we will have the follow ordinary differential equation with the corresponded initial condition:

$$A(h)\frac{dh}{dt} = Q_{\text{F.W.}} - \kappa Q_{\text{G.S.}},\ h(t_0) = h_0, \qquad (1)$$

where $h = h(t)$ is the height of the feed water level; $A(h)$ is the area of evaporation mirror; $Q_{\text{F.W.}}$ is the supplied feed water volume consumption; $Q_{\text{G.S.}}$ is the generated steam volume consumption; κ is the parameter of recalculating the volume of the generated steam to the volume of the correspondent feed water; t_0 is the given initial time and h_0 is the given height at the initial time.



1 – housing vessel; 2 – feed water;

3 – heat exchanges tubes; 4 – generated steam

Fig. 5. General schematisation of the steam generator

The differential equation (1) must be necessary involved into the mathematical model required for designing the feed water level automated control systems. It is proposed to consider the differential equation (1) as first step of building the mathematical models for the feed water level in steam generators, so the most complicated models will be built as the continuation of the differential equation (1).

B. The Heat and mass transfer

The differential equation (1) shows that the feed water level in the steam generators has decreasing due to the volume consumption $Q_{\text{G.S.}}$ of the generated steam, so we must have estimation for this consumption. It is clearly understood that:

$$Q_{\text{G.S.}} = Q_{\text{G.S.}}\left(h, T_{H.C.}^{\text{inp}}, T_{H.C.}^{\text{out}}, Q_{H.C.}, Q_{\text{F.W.}}, T_{\text{F.W.}}\right), \qquad (2)$$

where $T_{H.C.}^{\text{inp}}$, $T_{H.C.}^{\text{out}}$ are the input and outer temperatures and $Q_{H.C.}$ is the consumption thru the steam generator of the heat carrier; $T_{\text{F.W.}}$ is the temperature of the supplied feed water.

The relation (2) must be considered as the result of the heat and mass transfer processes like in [11], [12], so it is possible having this relation (2) approximately as the result of computer simulations of the correspondent initial-boundary value problems representing the heat and mass transfer processes. Nevertheless, using the differential equation (1) and the relation (2) we will can define changing the feed water level during the time for the given time depending of the values of $T_{H.C.}^{\text{inp}}$, $T_{H.C.}^{\text{out}}$, $Q_{H.C.}$, $Q_{\text{F.W.}}$ and $T_{\text{F.W.}}$.

C. The Automated control

The feed water level in the steam generators has some changes during operation, because of it is impossible to provide the full agreement between consumptions of supplying the feed water and generated steam. To provide the almost constant feed water level it is necessary to implement the correspondent automated control, which is reduced to control the consumption of the supplied feed water depending on the current state of the steam generator

$$Q_{\text{F.W.}} = Q_{\text{F.W.}}\left(h, T_{H.C.}^{\text{inp}}, T_{H.C.}^{\text{out}}, Q_{H.C.}, Q_{\text{G.S.}}, T_{\text{F.W.}}\right). \qquad (3)$$

The view of the function (3) must be defined taking into account the differential equation (1) and the relation (2) to provide the condition:

$$\left|h(t) - h_0\right| \le [\Delta h], \qquad (4)$$

where $[\Delta h]$ is the given permissible change of the feed water level in the steam generator.

III. Arroaches to Design the Improved Automation

We will imagine further the improved automation in general as the automation which take into account changing the different parameters, but not only the controlled parameters. Due to this imagination, the relation (3) defining the control for the feed water supplying consumption is corresponded to the improved automation, because the feed

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water consumption is depended not only from the controlled parameter h, and it uses different data about other state parameters of the steam generator.

A. Linearisation

The general idea of building the automation systems is to provide zeroing of the small disturbances of the feed water level from the initial position corresponded to the given required equilibrium state. Taking into account this idea, it is suitable to use the linearisation of the relations (1)-(3) near the given equilibrium state at the initial time.

We will consider further the follows particular case of the general relation (3) correspondent to the linear depending:

$$Q_{\text{F.W.}} = \bar{Q}_{\text{F.W.}} + \alpha_1 \Delta T_{H.C.}^{\text{inp}} + \alpha_2 \Delta T_{H.C.}^{\text{out}} + \alpha_3 \Delta Q_{H.C.} + \\ + \alpha_4 \Delta Q_{\text{G.S.}} + \alpha_5 \Delta T_{\text{F.W.}} - a_1 y - a_2 \frac{dy}{dt} - a_3 \int y dt, \quad (5)$$

where $\bar{Q}_{\text{F.W.}}$ is some given value representing the average value of the feed water consumption; α_1, α_2, α_3, α_4, α_5 and $a_1 > 0$, $a_2 \geq 0$, $a_3 > 0$ are the parameters of the improved feed water level controller; $\Delta T_{H.C.}^{\text{inp}}$, $\Delta T_{H.C.}^{\text{out}}$, $\Delta Q_{H.C.}$, $\Delta Q_{\text{G.S.}}$ and $\Delta T_{\text{F.W.}}$ are the deviations of the state parameters near their values corresponded to the equilibrium state at the initial time; $y(t) = h(t) - h_0$ is the deviation of the feed water level near the height h_0 at the initial time.

Due to the relation (5), designing the improved controller for the feed water consumption of the steam generator is reduced to defining the parameters α_1, α_2, α_3, α_4, α_5 and a_1, a_2, a_3. The parameters α_1, α_2, α_3, α_4, α_5 need to take into account influencing of changing the state parameters $T_{H.C.}^{\text{inp}}$, $T_{H.C.}^{\text{out}}$, $Q_{H.C.}$, $Q_{\text{G.S.}}$ and $T_{\text{F.W.}}$ of the steam generator on the controlled parameter h, but the parameters a_1, a_2, a_3 are to take into account changing the controlled parameter h, and are the parameters of the correspondent PID -controller.

Linearisation of the relation (2) near the given equilibrium state at the initial time will lead to the follows:

$$Q_{\text{G.S.}} = Q_{\text{G.S.}}^{(0)} + \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial h} y + \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial T_{H.C.}^{\text{inp}}} \Delta T_{H.C.}^{\text{inp}} + \\ + \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial T_{H.C.}^{\text{out}}} \Delta T_{H.C.}^{\text{out}} + \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial Q_{H.C.}} \Delta Q_{H.C.} + \\ + \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial Q_{\text{F.W.}}} \Delta Q_{\text{F.W.}} + \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial T_{\text{F.W.}}} \Delta T_{\text{F.W.}}, \quad (6)$$

where notion $Q_{\text{G.S.}}^{(0)}$ is the value corresponded to the equilibrium state at the initial time and the notion $^{(0)}$ is used to show, that the corresponded partial derivatives are calculated for the state parameters corresponding to the equilibrium state at the initial time.

The linearised differential equation (1) will have the view:

$$A_0 \frac{dy}{dt} = Q_{\text{F.W.}} - \kappa Q_{\text{G.S.}}, \; y(t_0) = 0, \quad (7)$$

where $A_0 = A(h_0)$.

B. Parameters of the improved controller

To define the controller parameters α_1, α_2, α_3, α_4, α_5 and a_1, a_2, a_3 it is necessary to substitute the relations (5) and (6) to the differential equation (7) and taking into account the additional relation $\Delta Q_{\text{G.S.}} = \kappa \Delta Q_{\text{F.W.}}$ we will have the follows results for the parameters of the feed water level controller

$$\bar{Q}_{\text{F.W.}} = \kappa Q_{\text{G.S.}}^{(0)}, \; \alpha_1 = \kappa \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial T_{H.C.}^{\text{inp}}}, \; \alpha_2 = \kappa \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial T_{H.C.}^{\text{out}}}, \\ \alpha_3 = \kappa \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial Q_{H.C.}}, \; \alpha_4 = \kappa^2 \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial Q_{\text{F.W.}}}, \; \alpha_5 = \kappa \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial T_{\text{F.W.}}}. \quad (8)$$

As the results of the parameters (8), the differential equation (7) we will be reduced to the following view:

$$\left(A_0 + a_2\right) \frac{dy}{dt} + \left(a_1 + \kappa \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial h} \right) y - a_3 \int y dt = 0, \\ y(t_0) = 0. \quad (9)$$

Let introduce the new variable:

$$y = \frac{dx}{dt}, \; x(t_0) = 0, \quad (10)$$

where $x = x(t)$ is the introduced new variable.

Relation (9) reformulated using the new variable (9) will have the view of the ordinary differential equation with the initial conditions:

$$\left(A_0 + a_2\right) \frac{d^2 x}{dt^2} + \left(a_1 + \kappa \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial h} \right) \frac{dx}{dt} + a_3 x = 0, \\ x(t_0) = 0, \frac{dx}{dt}(t_0) = 0. \quad (11)$$

The characteristic equation corresponded to the differential equation (11) has the following view:

$$\left(A_0 + a_2\right) \lambda^2 + \left(a_1 + \kappa \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial h} \right) \lambda + a_3 = 0. \quad (12)$$

where λ is the characteristic root.

To provide the condition $\operatorname{Re} \lambda < 0$ providing the stability of the solution of the differential equation (11) it is necessary choosing the parameter of the PID-controller in agreement with the following condition:

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$$a_1 + \kappa \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial h} > 0 . \quad (13)$$

To exclude big changing of the feed water level during the transient processes defined by the mathematical model (11) it is necessary to choose the PID-controller parameters so, that the imagine parts of the characteristic roots (12) will be negative:

$$\operatorname{Im} \lambda < 0 . \quad (14)$$

The restriction (13) for the roots of the characteristic equation (12) will lead to the following relation:

$$\left(a_1 + \kappa \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial h} \right)^2 - 4\left(a_2 + A_0\right) a_3 < 0 . \quad (15)$$

Thus, we have all necessary conditions (8), (13) and (15) to define the area of the possible values of the parameters defining the improved automated control (5) of the feed water supplying to provide the required feed water level in steam generators of nuclear power plants.

C. Comparing with the classical controller

As opposed to the improved automation in general, we will define the classical automation as the automation which take into account changing only the controlled parameters, but not other parameters, which can have influence on the controlled parameters. For automated control of the feed water level in the steam generator the classical approach is actually the simplest particular case of the general approach (5), (6):

$$Q_{\text{F.W.}} = \bar{Q}_{\text{F.W.}} - a_1 y - a_2 \frac{dy}{dt} - a_3 \int y dt, \; Q_{\text{G.S.}} = Q_{\text{G.S.}}^{(0)} . \quad (16)$$

Substituting the relations (16) to the differential equation (7) with using the variable (10) will lead to the following results for the parameters of the automated control (16):

$$\bar{Q}_{\text{F.W.}} = \kappa Q_{\text{G.S.}}^{(0)} , \quad (17)$$

$$a_1 > 0 , \quad (18)$$

$$a_1^2 - 4\left(a_2 + A_0\right) a_3 < 0 . \quad (19)$$

It is clearly understood that the relations (17)–(19) are the particular case the corresponding general relations (8), (13), and (15). So, we can imagine the improved controller (5) as the classical controller (16) with the corrected value $\bar{Q}_{\text{F.W.}}$:

$$\bar{Q}_{\text{F.W.}} = \bar{Q}_{\text{F.W.}}\left(\Delta T_{H.C.}^{\text{inp}}, \Delta T_{H.C.}^{\text{out}}, \Delta Q_{H.C.}, \Delta Q_{\text{G.S.}}, \Delta T_{\text{F.W.}}\right) . \quad (20)$$

The suitable correction (20) on changing the general state of the steam generator will help to the classic PID-controller in supporting the required feed water level. Comparing the conditions (13), (15) and (18), (19) shows that the heat and mass transfer processes in steam generators can have the significant influence on the feed water level automation control system. It is important that the heat and mass transfer processes (2) in the steam generator will have no significant influence on the feed water level PID-controller, if such processes will satisfy the following condition:

$$\kappa \frac{\partial Q_{\text{G.S.}}^{(0)}}{\partial h} \approx 0 . \quad (21)$$

To define the parameters of the improved controller (5) for the feed water level in steam generators of nuclear power plants it is necessary to have the improved mathematical model of the heat and mass transfer processes, and this model must provide to have the relation (2) and to define the partial variables from the correspondent relations (8). At the same time, defining the parameters of the classical controller (16) is reduced to estimating the average steam capacity as well as to defining the parameters of the corresponded PID-controller, and the complicated mathematical models of the heat and mas transfer processes are not required for this. It is actually difficult to build the improved mathematical models of the heat and mass transfer processes and to operate with such models, so the classical approaches to design the feed water level automated systems for steam generators of nuclear power plants are commonly used. At the same, the classical approaches had reached the limits of perfectness, and the feed water level improved controllers are required for the steam generators of nuclear power plants to provide the optimal [8] and full-range [9] controls for example.

IV. Researches and Results

Although, the approach for defining the parameters of improved automated controllers for the feed water level is proposed in the most general view, but it is possible to give the important result about influencing of the evaporation area on the controllers parameters. We will assume further that the condition (21) is satisfied.

A. Influience of the evaporation mirror area

The evaporation area is the key parameter having the significant influence on the processes in the steam generators including on the feed water level automation processes. Taking into account the relation (21), the condition (15) can be transformed to the following view:

$$a_3 > \left[a_3\right], \; \left[a_3\right] = \frac{a_1^2}{4\left(a_2 + A_0\right)} , \quad (22)$$

where $\left[a_3\right]$ is the boundary value for the integral part of the PID-controller.

We can see from the condition (22) that increasing of the evaporation mirror area has the same effect as increasing the parameter of the integral controller. Thus, increasing the evaporation mirror area leads to decreasing the sensitivity of the feed water level on the disturbances in equilibrium between the consumptions of the generated steam and supplying the feed water.

It is interesting to compare the evaporation mirror areas for the vertical and horizontal types of steam generators (Fig. 2) widely used on the nuclear power plants at present. Such comparison is really important to understand the properties of different types steam generators as the automation objects regarding to the feed water level.

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For the vertical type steam generators (Fig. 2a) we will have the following estimation of the evaporation mirror area:

$$A(h) = \pi R^2, \tag{23}$$

where R is the internal radius of the steam generator housing vessel.

We can see form the relation (23) that the evaporation mirror area of the vertical types steam generators is not depended on the height of the feed water level. It is necessary to understand that the result (23) is actually the primary estimation, because of considering the exact geometry and internal systems constrictions will lead to corresponded corrections.

For the horizontal type steam generators (Fig. 2b) we will have the following primary estimation of the evaporation mirror area:

$$A(h) = 2L\sqrt{h(2R-h)}, \tag{24}$$

where L is the length of the steam generator housing vessel.

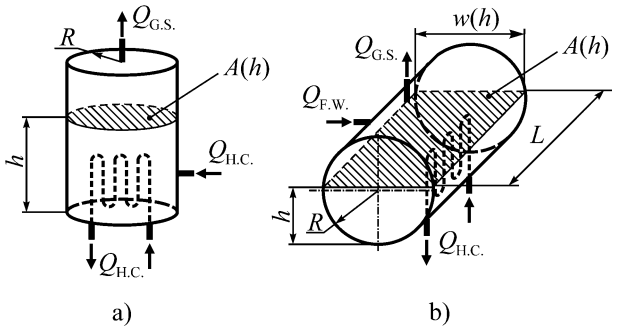

Fig. 6. Schematical representation of the evaporation mirrors ares for the vertical (a) and horizontal (b) types of steam generators

To compare the vertical and horizontal types of steam generators we will assume that the height of the feed water level in horizontal type steam generators is approximately the following:

$$h \approx 1,25R. \tag{25}$$

The value (25) is in agreement with the physics of the processes in the steam generators. Substituting the value (25) into the relation (24) leads to the approximate estimation:

$$A(h) \approx 1,94LR. \tag{26}$$

It is understood that for the horizontal type steam generators have the follow relation of the characteristic sizes:

$$L > 3R. \tag{27}$$

Using the inequality (27) and the approximate relation (26), we will have the following approximate estimation for the evaporation mirror area of the horizontal type steam generators:

$$A(h) > 5,8R^2. \tag{28}$$

Comparing the relation (23) and the inequality (28) shows that the horizontal type steam generator can provide the evaporation mirror area almost twice bigger than the vertical type steam generator with the same radius of the housing vessel. So, the horizontal type steam generators have the inherent smaller sensitivity of the feed water level on the disturbances in equilibrium between the consumptions of the generated steam and supplying the feed water. This circumstance can be important and must be clearly understood for the operational staff.

B. Computer simulations

To illustrate the transient processes of the feed water level stabilisation processes in the steam generators we will assume that relation (21) is satisfied and we will use the following mathematical model

$$\begin{aligned} &(A_0 + a_2)\frac{d^2x}{dt^2} + a_1\frac{dx}{dt} + a_3 x = \Delta Q(t), \\ &x(0) = 0, \frac{dx}{dt}(0) = 0, \end{aligned} \tag{29}$$

where $\Delta Q(t) = Q_{F.W.}(t) - \kappa Q_{G.S.}(t)$ is the disturbance of the equilibrium state between the consumptions of the generated steam and of the feed water supplying.

To make the computer simulation we will use the well-known Scilab free software. Because of the deformational equation (29) is linear, the Laplace transformation is suitable

$$X(s) = \int_0^\infty x(t)e^{-st}dt, \tag{30}$$

where $X(s)$ is the new variable instead of the $x(t)$ and s is the new variable instead t.

Laplace transformation (30) allows representing the linear problem (29) by means of the following transfer function:

$$W(s) = \frac{s}{(a_2 + A_0)s^2 + a_1 s + a_3}. \tag{31}$$

The computer model representing the feed water level stabilisation processes in the steam generator corresponding with the mathematical model (29) reduced to the transfer function (31) is developed using the Scilab tools and is presented on Fig. 3.

The following input data is used to make the simulations:

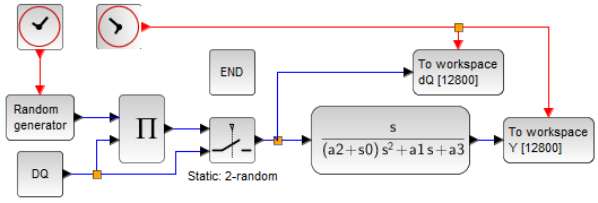

Fig. 7. The Scilab Xcos model for tcomputer simulation of the feed water level in the steam generator housing vesselz

The used value (32) of the evaporation mirror area A_0 is approximately corresponded to the horizontal type steam

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generators of the VVER-1000 nuclear reactor. We will consider the results for the constant disturbance value:

$$\Delta Q = 0,2\frac{\mathrm{m}^3}{\mathrm{s}}. \qquad (33)$$

On Fig. 4 we can see that the PID-controller with the parameters satisfying the condition (14) allow having the smaller disturbances of the feed water level, but we will have the oscillations of the feed water level during the processes of stabilisation of the feed water level.

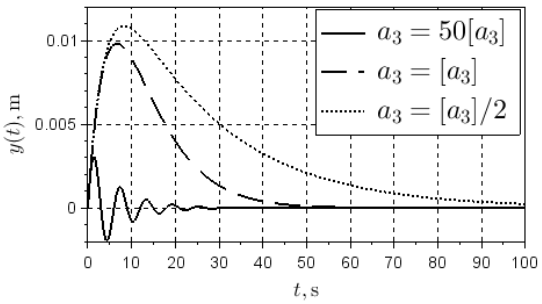

Fig. 8. Influence of integral part of the PID-controller on the transient processes of feed water level stabilisation

The results presented on Fig. 5 show that the bigger evaporation mirror area provides the smaller disturbances of the feed water level during the transient processes for the equal parameters of the PID-controller. Thus, the steam generators with the bigger evaporation area provides the better conditions for operating the feed water level automated control systems.

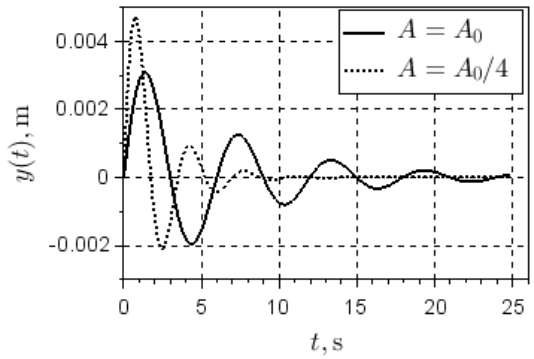

Fig. 5. Influence of the evaporation mirror area integral part of the PID-controller on the transient processes of feed water level stabilisation

CONCLUSIONS

Some important problems about developing the improved systems for feed water level automated controls in the housing vessels of steam generators of nuclear power plants are considered in this research, and the following conclusions are due to this.

It is developed the general theory about the mathematical models of feed water level automation control systems of nuclear power plants steam generators. It is shown that to have the suitable mathematical models to design the improved automated control systems for the feed water level it is necessary to have the complicated mathematical models of the heat and mass transfer processes allowing estimations the steam generation capacity depending on the consumption as well as the input and output temperatures of the heat carrier, on the current heigh of the feed water level, as well as on the consumption and the temperature the feed water.

It is proposed the generalized approach to define the parameters of improved automated controllers for the feed water level on the basis of the developed general theory. It is shown the relationships between the proposed and classical approaches do design the automated controllers. It is shown that the improved automated controllers can imagine as the classical PID-controller with the corrected value of feed water supplying which will help in supporting the required feed water level and in providing the optimal and full-range controls.

By means of analytics and of computer simulations it is shown that the evaporation mirror area has significant influence on the parameters of feed water level PID-controllers as well as on the transient processes of this level stabilisation for the given values of those parameters. The proposed inequality for defining the possible feed water level PID-controllers parameters gives only the parameters values area, but substantiation of the exact values requires the computer simulations to provide the limited disturbances of the feed water level during the transient processes.

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