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Parameters Settings of NPP Automatic Regulators via Analytical Simulators

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Abstract

Purpose of I&C system is monitor and control of processing procedure and equipment for reaching main goal of NPP – electric energy generation providing nuclear and radiological safety and economic efficiency of processing procedure. One of the main functions of NPP I&C system is control of technological processes in nuclear unit equipment via automatic regulators providing optimality of electric energy generation process. Algorithms of I&C systems, especially laws of control, are realized on hardware and software complex (HSC) TPTS (technological hardware-software instrumentality). Control functions implemented on functional modules TPTS51.1412 and TPTS51.1411, which perform linear and pulse control. A great number of automatic regulators is used in process of electric energy generation on NPP. All automatic regulators can be divided to 4 groups. Despite nuclear units are standard (they have same reactor system project), they have unique characteristics – nuclear units differ by technological characteristics of reactor system equipment and technological equipment providing electric energy generation process control. That's why parameters of respective automatic regulators for each nuclear unit correct after theoretical calculations in nuclear unit checkout process that cause specific economic and energetic losses. For solving this problem there is provided to use analytical simulators of NPP nuclear units, which are used for researches of reactor system physics and researches of behavior of technological equipment respective nuclear unit.

Keywords: Analytical simulator, feedback control system, nuclear power plant, control and instrumentation system, automatic regulator

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1. Introduction

Each nuclear power plant (NPP) unit is equipped with digital control and instrumentation system (I&C). Purpose of I&C system is monitor and control of processing procedure and equipment for reaching main goal of NPP – electric energy generation providing nuclear and radiological safety and economic efficiency of processing procedure [1]. I&C system includes control subsystems divided by functional purpose. I&C system has hierarchical structure and consists of following levels: level of liaising with technological object of control, level of lower automation, top level (human-machine interface) – top unit level of monitor and control. One of the main functions of NPP I&C system is control of technological processes in nuclear unit equipment via automatic regulators providing optimality of electric energy generation process. Automatic regulators provide keeping of regulating quantity in prescribed limits in stationary mode and desired characteristics of control performance [2].

2. Linear and pulse control

Algorithms of I&C systems, especially laws of control, are realized on hardware and software complex (HSC) TPTS (technological hardware-software instrumentality) through computer-aided design system (CAD) GET-R. Functional modules racks perform acquisition and primary processing of input analog and discrete signals from sensors of technological parameters, proceed necessary calculations, and also perform automatic regulator and feedback and remote control such actuators as pump, slide-type valve, solenoid coil, switch, control valve. Control functions implemented on functional modules TPTS51.1412 and TPTS51.1411, which perform linear and pulse control. Linear control function generates analog control signal value in compliance with law of control, which is a combination of P-, I-, D-terms, and realizes direct transmission of set point value. Three functions of module TPTS51.1412 – REK, SWB and RLG – are used for linear control implementation. REK-function can perform analog control signal value in compliance with law of control, which is a combination of P-, I-, D-laws, and realizes direct transmission of set point value (optional preset value). SWB-function can realize different modes of control preset value performing. RLG-function can operate control valves in following modes:

- Remote (manual): increase/decrease of control signal value in compliance with operator commands;
- Automatic: increase/decrease of control signal value in compliance with selected law of control and preset value.

Graphic icons of REK-function, SWB-function, and RLG-function of module TPTS51.1412 in CAD GET-R are presented on figures 1, 2 and 3 respectively.

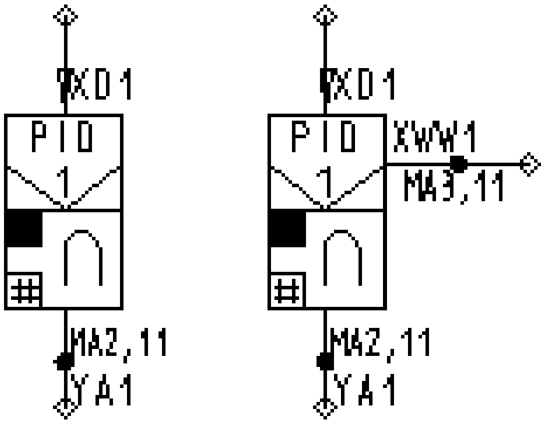

Figure 1: Graphic icon of REK-function.

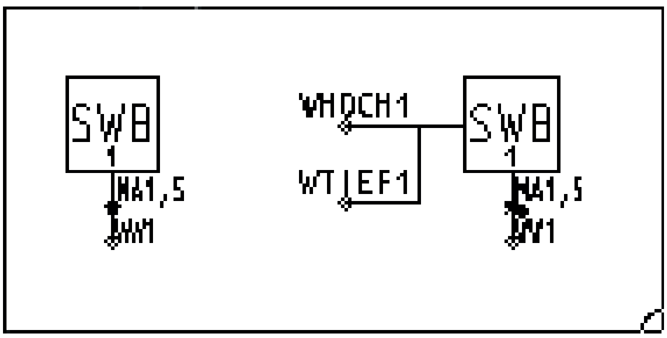

Figure 2: Graphic icon of SWB-function..

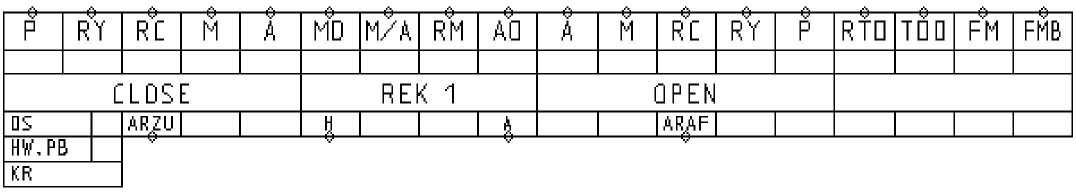

Figure 3: Graphic icon of RLG-function.

Setting the parameters of standard function blocks REK, SWB and RLG is performed via their parametric mask. Set parameters of REK-function are given in table 1.

Pulse control function forms discrete control signals (commands open and close) in compliance with law of control, which is a combination of P-, I-terms. Three functions of module TPTS51.1411 – RES, SWB and RLG are used for pulse control. RES-function can form discrete control signals (commands «Open» and «Close») in compliance with law of control, which is a combination of P-, I-terms. SWB-function of this module is similar to SWB-function of module TPTS51.1412. RLG-function can operate control valves in following modes:

Table 1: Parameters of REK-function.

Parameter name	Description
ASW	Deadband
ADSV	Incremental step of deadband
ADGR	Adaptation rate back
FG	Edge frequency
XDE	Input of derivative element
TY	Travel time of actuator
KP	Coefficient for proportional term
TN	Time response of integral-term
TV	Time response of derivative term
VD	Coefficient for derivative term
AP	Control operating point
APRG	Coefficient of the second power of nonlinear conversion element
BPRG	Coefficient of the first power of nonlinear conversion element
YMIN	The lowest value of output control signal
YMAX	The highest value of output control signal
YN	Metered value
ASW	Deadband
ASWF	Deadband lockup
RR	Backing of error ratio
INF	Tracking of integral term
RNYN	Tracking of setpoint value
OGUG	Output control signal range extension
PROGA	Disabling of nonlinear element
IAA	Integral term value
DENT	Disabling of derivative term
YREV	Backing of control signal

- Remote (manual): outputting commands «Open» and «Close» in compliance with operator commands;

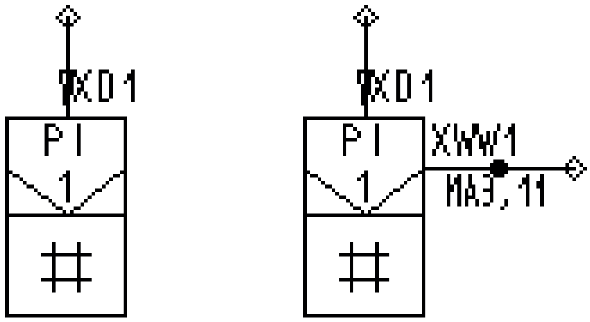

Figure 4: Graphic icon of RES-function.

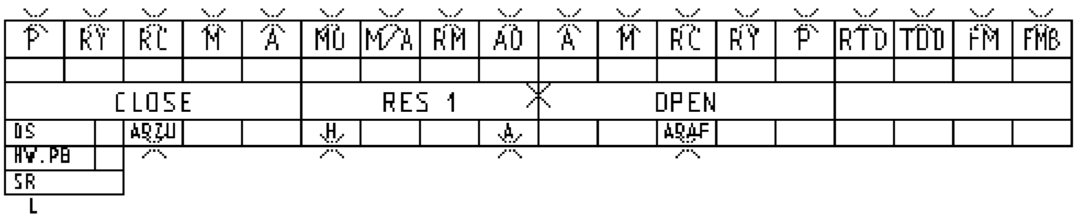

Figure 5: Graphic icon of RLG-function.

- Automatic: outputting commands «Open» and «Close» in compliance with selected law of control and preset value.

Graphic icons of RES-function and RLG-function of module TPTS51.1411 in CAD GET-R are presented on figures 4 and 5 respectively (graphic icon of SWB-function for pulse control is similar to icon of SWB-function for linear control).

Setting the parameters of standard function blocks RES, SWB and RLG is performed via their parametric mask. Set parameters of RES-function are given in table 2.

All nuclear unit automatic regulators are realized on this two types of functional modules excepting automatic regulator of reactor power immediately on-line with electric part of turbine control system and is realized on another HSC.

3. Automatic regulators on NPP

A great number of automatic regulators is used in process of electric energy generation on NPP. All automatic regulators can be divided to 4 groups. Automatic regulators providing control of reactor power, turbine power and generator power in basic mode and in tracking mode belong to the first group. Automatic regulators providing preset value of technological parameters of nuclear unit in transit modes caused by emergency protection system or preventive protection system belong to the second group.

Table 2: Parameters of RES-function.

Parameter name	Description
ASW	Response value
ADSV	Incremental step of response value
ADGR	Decreasing rate of response value
FG	Edge frequency of adaptive filter
TY	Full travel time of isolation valves
KP	P-term coefficient
TN	Time response of relaxation circuit
MIMPL	The lowest output command impulse time
XH	Hysteresis value for removal boundary cycle
ASWI	Internal response value
AXW	Effective departure sign reversal
ASWF	Locking of response value equal to ASW
RR	Error ratio sign reversal for later processing
RRBL	Disabling feedback (setting P-term)

Automatic regulators providing preset parameters of steam generators (SG) feeding on the power levels close to nominal belong to the third group. Automatic regulators providing preset technological parameters in routine shots and shutdowns of nuclear unit including service steam belong to the fourth group. For example, this division for nuclear unit with fast fission reactor looks like this:

- Main automatic regulators: automatic regulator of nuclear unit power, automatic regulator of reactor power, automatic regulator of reactor coolant pump rate of turn, automatic regulator of SG feeding, automatic regulator of turbine rotor rate of turn, automatic regulator of steam pressure before turbine valves;
- Emergency and stand-by mode automatic regulators: automatic regulators of pressure of fast reduction system with discharge of steam into the condenser, automatic regulators of Na temperature on the output of secondary heat exchanger;
- Automatic regulators of SG feeding parameters: automatic regulator of deaerator level, automatic regulator of level of the third step low pressure heater and etc.;

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- Starting and own needs automatic regulators: starting automatic regulator of SG feeding, automatic regulator of pressure in evaporator plant collector and etc.

4. Setting up automatic regulators NPP

What is the problem of setting up automatic regulators at nuclear power plants? Despite nuclear units are standard (they have same reactor system project), they have unique characteristics – nuclear units differ by technological characteristics of reactor system equipment and technological equipment providing electric energy generation process control. That's why parameters of respective automatic regulators for each nuclear unit correct after theoretical calculations in nuclear unit checkout process that cause specific economic and energetic losses. For solving this problem there is provided to use analytical simulators of NPP nuclear units, which are used for researches of reactor system physics and researches of behavior of technological equipment respective nuclear unit. For each unit there is developed his own analytical simulator with considering his unique characteristics. Parameters of nuclear reactor core, quantity and power of reactor coolant pumps, delivery pumps, condenser pumps, base areas and heights of reservoirs, characteristics of transformers and turbine, parameters of SG and etc. There is suggested to develop respective techniques of automatic regulators parameters setting via computer simulators of units and software realizing them.

5. Analytical and full sized simulators

Analytical simulator – hardware-software modelling complex, which is developed for training and proficiency maintaining of NPP main control room (MCR) operators, with using full sized mathematical model of nuclear unit working in real time mode. There is an analytical simulator of reserve control room of Kalininskaya NPP unit 4 on Figure 6.

Also, for automatic regulators settings it is suggested to use full sized simulators of nuclear units because they contain mathematical model similar to full sized mathematical model of analytical simulator working in real time mode. Full sized simulator – hardware-software modelling complex, which is developed for professional training of NPP MCR operators with using full sized model of MCR and complex all mode mathematical model of nuclear unit working in real time mode. The full sized simulator should correspond to the systems and equipment of nuclear unit-prototype and provide in

Figure 6: Analytical simulator of reserve control room of Kalininskaya NPP unit 4.

Figure 7: Full sized simulator of Kalininskaya NPP unit 4.

real time mode simulation of all operating modes of NPP (normal operation modes, transient modes, normal operation failures, design basis accidents and non-project accidents to simulation limits). There is full sized simulator of Kalininskaya NPP unit 4 containing workstations of reactor part chief engineer and turbine part chief engineer with respective segmented console, and also workstation of plant supervisor/unit supervisor on Figure 7.

There is a main format of full sized simulator of Beloyarskaya NPP unit 4 with main equipment of all three circuits (reactor coolant pumps of primary and secondary circuits, transitory and secondary heater, turbine, deaerator, turbine condenser, feed water pumps) on Figure 8.

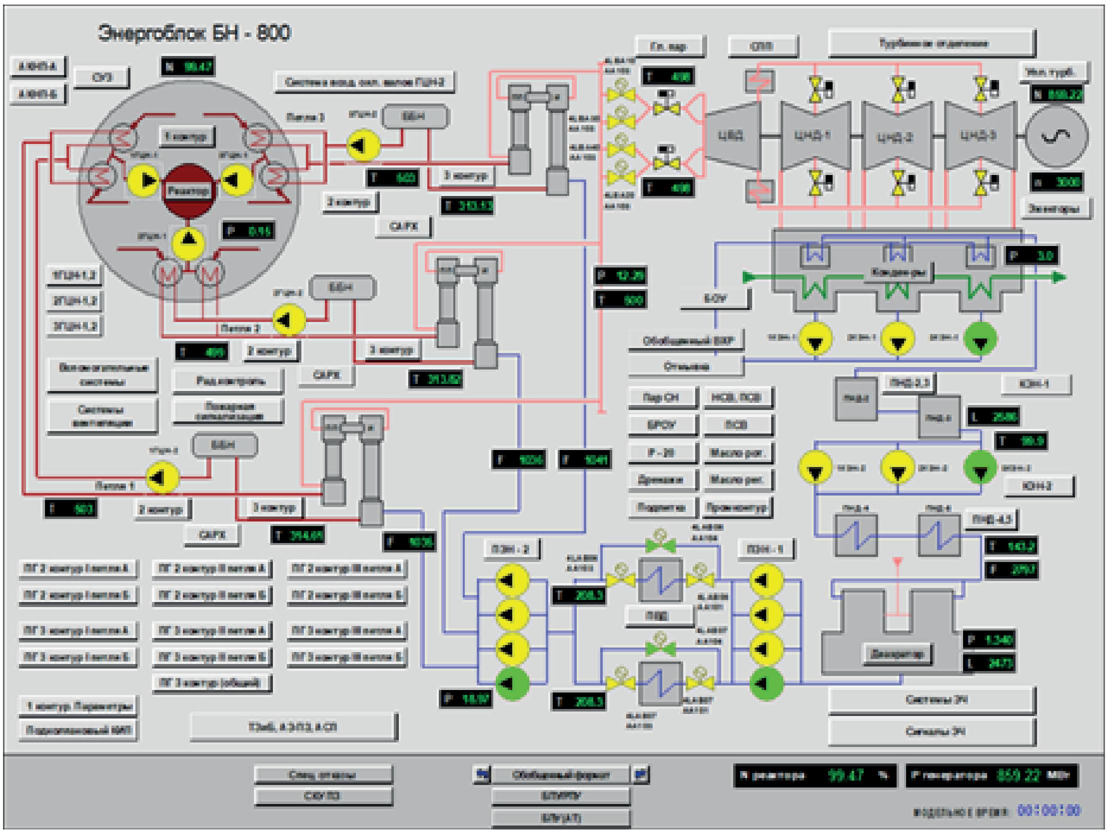

Figure 8: Main format of full sized simulator of Beloyarskaya NPP unit 4.

6. Conclusion

As a result actuality of the report topic is the lack of methods for NPP automatic regulators setting before the adjustment process. In view of the uniqueness of the standard blocks for each unit, it is proposed to set automatic regulators via the corresponding analytical and full sized simulators of the nuclear unit. In further research on the subject of the report, it is proposed to establish a relationship between the parameters of automatic regulators and the parameters of the process equipment being the objects of control, and also to develop adjustment mechanisms and software for their implementation. This approach will allow to adjust the automatic regulators of the nuclear unit without the energy and economic losses that occur during the iterative setting of control devices during the adjustment of the unit.

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