VOL. 10, NO. 16, SEPTEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

MICROPROCESSOR CONTROL SYSTEM OF TECHNOLOGICAL PROCESS OF STEAM GENERATING INSTALLATION OF OILFIELD

Valery Ivanovich Finaev, Vladimir Vladimirovich Ignatyev, Evgeny Yuryevich Kosenko, Vladimir Vitalyevich Mikhailov and Oleg Borisovich Spiridonov
Southern Federal University, Rostov-on-Don, Bolshaya Sadovaya Str., Russia
E-Mail: iskobersi@gmail.com

ABSTRACT

The aim of the work is to solve the problem of choosing the configuration of microprocessor control systems and software with redundancy (reservation) functions for control of boiler burners of steam generating at the enterprises of oilfield. In article two types of a configuration of a microprocessor control system are offered. In the second type of a configuration reservation happens not only through the main stations, but also via the distributed modules. Application of the second type allows increasing reliability and non-failure operation of a control system. The structure of a microprocessor control system is defined. The program for the second configuration of a control system of steam generating installation is created. Setup of parameters of a control system and parameters of PID-regulators are carried out in SCADA system. Control and display of results of control are carried out also in SCADA system. The description of work with SCADA system is provided in article. A work example is reviewed, windows of displays, adjusting data, setup of automatic regulators are shown.

Keywords: oilfield, industrial controllers, control system, steam generator, programming, software redundancy, SCADA-system, setup, regulator.

1. INTRODUCTION

Introduction of new technologies in the problems of oil production and refining is associated with the use of modern technologies, and the development of automatic control systems on the basis of industrial controllers. The use of industrial controllers provides the necessary and sufficient level of automation [1-5]. Efficiency of use of industrial controllers is defined by their ample opportunities and multifunctionality [6-8]. Steam generating installations are applied in oil refining at the oil industry [9, 10].

The boiler is a part of steam generating installation. The furnace mode and quality of burning of fuel in a boiler are provided by supply of gas and air in a fire chamber and timely removal from a fire chamber of products of combustion. A control system of steam generating installation includes large number of different actuating mechanisms: flue-gas pumps, fans, flow-control valves and other devices and mechanisms.

Quality of work of all these components of a control system influences the general productivity of a boiler. Creating effective in several indicators (criteria) configuration microprocessor control system is an actual task in the development of control system of steam generating installation. The microprocessor control system must meet to the following criteria: safety, multifunctionality, universality at configuring of hardware and software, interchangeability of components («modularity») of system, abilities of system to expansion, abilities of system to connection to the Internet and other.

Universality at configuring hardware and software is connected with possibility of modification of algorithms of functioning, step-by-step debugging of work of a control system. The control system is realized on industrial Siemens microcontrollers [11, 12] with function of full reservation of control of all parameters of boiler burner of steam generating installation. Own reservation of controllers is also provided.

2. DEVELOPMENT OF A CONFIGURATION OF A CONTROL SYSTEM

There is a problem with providing increased reliability microprocessor control system in the development of its configuration. Requirements of high reliability are defined by rules of arranging and safety of operation steam and water-heating boilers [13], systems of distribution and gas consumption [14]. This problem can be solved by programming the controller - software redundancy in compliance with the requirements for software and hardware complexes for automated process control systems of thermal energy systems [15].

In the process of software redundancy the part of the program is loaded in the main controller and a backup controller. If the processor (CPU) of the main controller processes this part of the program, CPU of the reserve controller it passes. This approach prevents a divergence between two program parts, for example, because of interruptions, different cycle times, etc. [16-19].

For a control system of steam generating installation two options of a configuration of a

VOL. 10, NO. 16, SEPTEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

microprocessor control system with hardware and software redundancy are offered. These configurations allow eliminating errors a component in the central processor, software errors, break of the processor bus, etc.

Redundant system software includes two central processor blocks which are connected through bus system (MPI, PROFIBUS, or Ethernet), and a redundant user program. The user program is loaded into both processors. A controller equipment is completely duplicated on all data inputs-outputs and power key elements that control mechanisms and regulators.

The highly reliable model of the Siemens controller with the high speed of information processing expanded with the working range of climatic conditions is chosen as a core of a control system. This model allows to work with distributed periphery remote control cabinets, directly located at the burners (control cabinets burners - CCB).The first type of a configuration is shown in Figure-1.

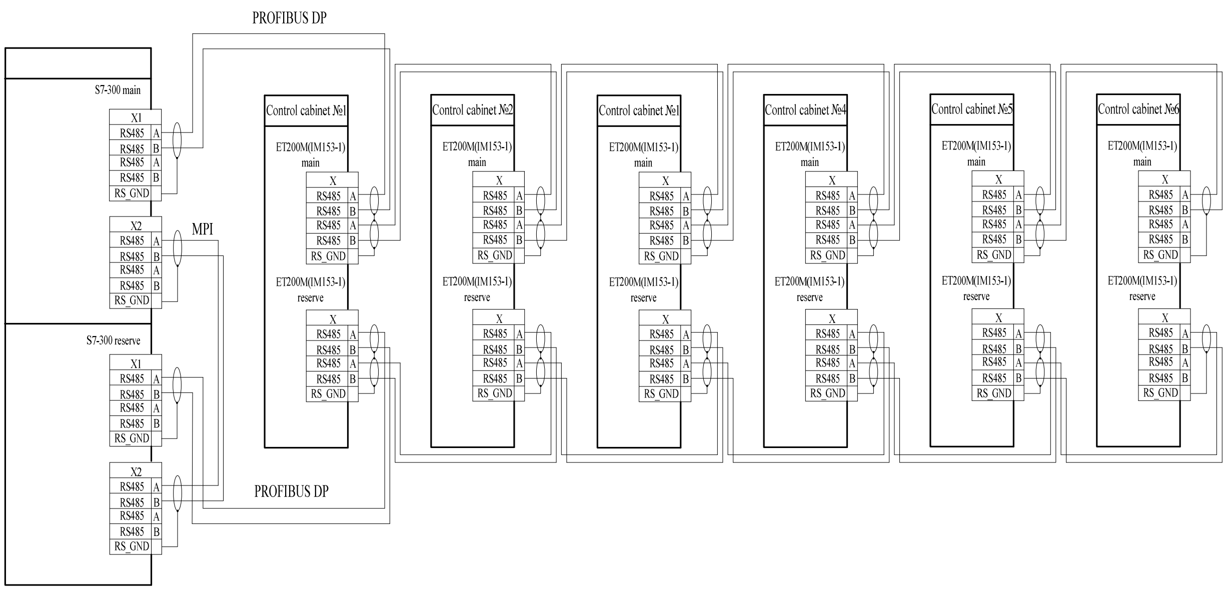

Figure-1. Configuration № 1.

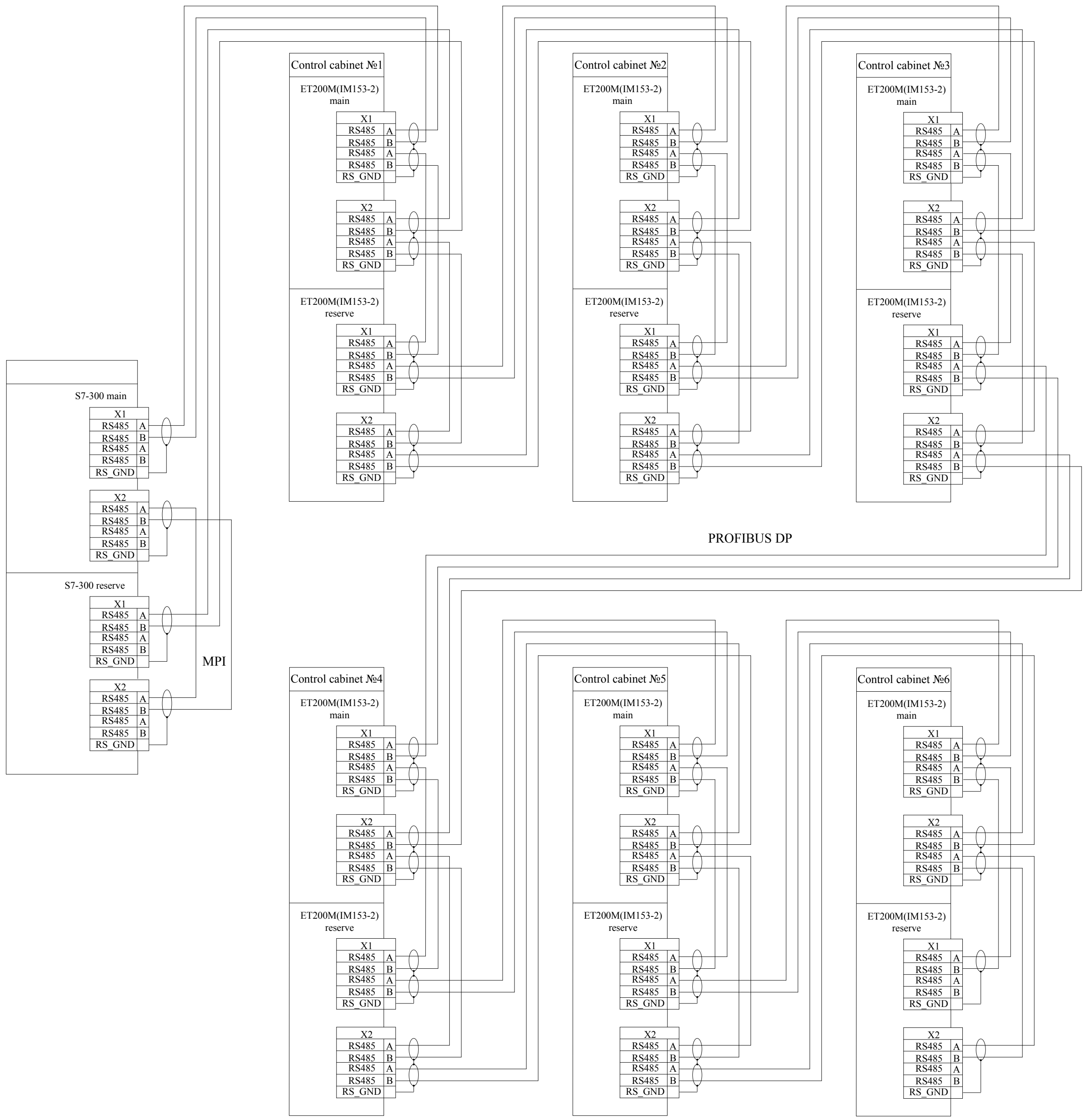

Figure-2. Configuration № 2.

In such configuration the redundancy of the distributed periphery is carried out through redundancy of the main stations.

The second type of a configuration is shown in Figure-2.

In this configuration, a redundancy is made not only through the main station, but also through the modules distributed periphery.

This type of redundancy allows to greatly improve reliability and non-failure operation of a control system in case of failure of separate modules. Stations of the distributed periphery have completely redundant channels of collection of information and control of mechanisms according to the specified algorithms.

With redundancy software the following errors can be fixed: component failure in the central device (power supply, bus, DP-Master), CPU failure because of hardware or software errors, break of a bus cable of redundant connection or redundant connection of DP-Slave, PROFIBUS-module defect in redundant connection of DP-

VOL. 10, NO. 16, SEPTEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Slave [7]. The main elements are two stations S7-300. In each station there is one CPU with the socket for connection of DP-Master system. Both stations are connected via a bus through which data is exchanged.

Connection to the periphery is carried out through two DP-Master systems: one DP-Master system in station «S7-300 main», other DP-Master system in station «S7-300 reserve». Devices distributed periphery ET 200 M are connected to both systems DP-Master through the redundant module DP-Slave. DP-Slave module allows to switch from one interface to another in case of error. Such switching allows one and the other DP-Master systems to monitor the status of the technological process.

The program of control of steam generating installation is created with the help of industrial programming languages (SCL, STL) [18]. The program of control is made on the basis of the second configuration of a microprocessor control system, is processed and displayed by SCADA-system. The main functions of the developed SCADA system are: display system parameters; viewing of archive of system parameters, setup of PID-regulators with a setting PID-coefficients with their display in SCADA-system, display of temporary graphs of parameters on demand, setting of emergency borders of the measured parameters with their display in SCADA-system, setting of warning borders of the measured parameters with their display in SCADA-system.

The terminal of a microprocessor control system of steam generating installation consists of two displays. The window of the display № 1 is shown in Figure-3.

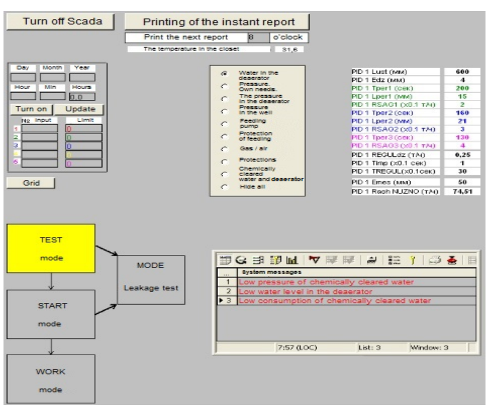

Figure-3. The window display № 1.

The window of the display № 2 is shown in Figure-4.

The first display displays only working information and is not intended for correction the setting data or input of the current data. On the second display the setting data, time of the printing of the following report, an installation working mode, system alarms, protection and blocking signals, control modes and other information are displayed. Setting data of protections are grouped in four groups on the following categories: feeding pump (FP), gas and air, steam, chemically cleared water (CCW), deaeration.

To modify the values of the initial data from group it is necessary to activate the group by corresponding switch. Correction of values of setting data is made by click of the left button of a mouse on the corresponding numerical value

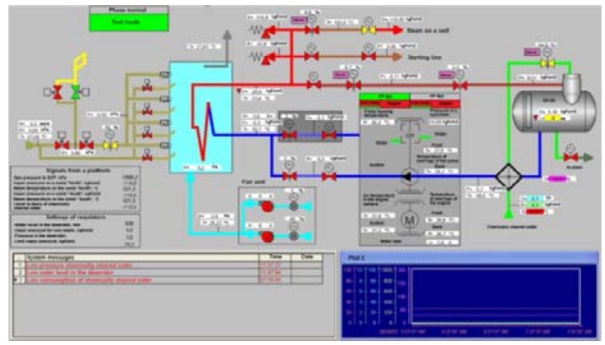

Figure-4. The window display № 2.

The grouped setting data of protections are shown in Figure-5.

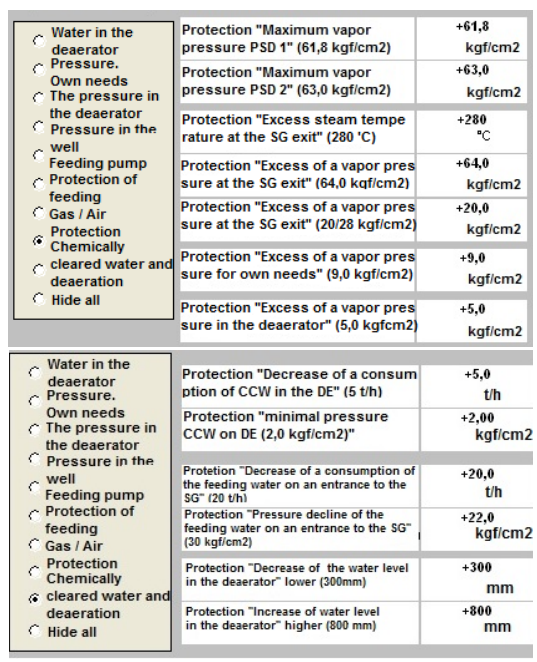

Figure-5. The grouped setting data of protections.

Access rights management is carried out in the application «User Administrator». Running of this application is carried out from the WinCC Explorer program (a package for development of SCADA-systems), located on the taskbar. There are two groups of users with

VOL. 10, NO. 16, SEPTEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

different priorities: «Administrator group» and «Operators». Operators are added to «Operators» by pressing of the right button of a mouse on the name of group and a choice of the Add user point.

For each new operator it is necessary to enter his login, the password and verify password. Access rights of each operator are changed as follows: it is necessary to allocate the corrected operator and in the right part of a window to note available options of authorization (red LED indicates the permitted authorization). Operator access to the system can be limited in time. To limit the access time of any operator it is necessary to set non-zero value «Automatic Logout after». Time of permitted access is set in minutes.

3. SETUP OF AUTOMATIC REGULATORS

View of window Automatic regulator «Transient mode FP»» is shown in Figure-6. This automatic regulator has three setting parameters.

Settings at the transitional mode FP		
FP 1-2 TRANSFER TO	Edz (t/h)	1,5
FP 1-2 TRANSFER TO	Timp (x0.1S)	5
FP 1-2 TRANSFER TO	Tper1 (x0.1S)	20

Figure-6. Automatic regulator «Transient mode FP».

The FP 1-2 TRANSITION *Edz* (t/h) parameter adjusts a dead zone of an automatic regulator regarding the measured size of adjustable parameter. Adjustable parameter is the water consumption on the steam generator. In Figure-6 parameter has value ±1,5t/h.

The FP 1-2 TRANSITION *Timp* (×0,1s) parameter adjusts duration of the impulse acting on the rotary mechanism (ESTM) according to the necessary direction of rotation. Parameter is set by an integer with a step 0,1s. In Figure-6 parameter has value 0,5s.

The FP 1-2 TRANSITION T_{per1} (×0,1s) parameter adjusts the frequency of the pulse repetition acting on ESTM. Parameter is set by an integer with a step 0,1s. In Figure-6 parameter has value 2,0s.

The automatic regulator gives impulses of control with duration T_{imp} and with the set frequency (T_{per1} parameter) on ESTM.

The automatic regulator keeps the «Water consumption on the steam generator» parameter to constants in size, with an accuracy of the measured parameter ±*Edz*. This automatic regulator works only during the mode of switching between the feeding pumps when both feeding pump are switched on at the same time. Consumption value is given by indication of the measured consumption of value when the second pump is switched on, i.e. at the beginning of the transitional mode of the FP. The automatic regulator influences upon control pulses the ESTM of the FP which is not in manual mode. Thus, the automatic regulator influences the FP opposite chosen for manual control.

View of window Automatic regulator « Water level in the deaerator (DE)» is shown in Figure-7. The automatic regulator has two-level structure. Figure-8 shows that the settings are given separately for each stage. The automatic regulator has fourteen parameters of settings and one information parameter.

PID 1 Lust (мм)	600
PID 1 Edz (мм)	4
PID 1 Tper1 (сек)	200
PID 1 Lper1 (мм)	15
PID 1 RSAG1 (x0.1 т/ч)	2
PID 1 Tper2 (сек)	160
PID 1 Lper2 (мм)	21
PID 1 RSAG2 (x0.1 т/ч)	3
PID 1 Tper3 (сек)	130
PID 1 RSAG3 (x0.1 т/ч)	4
PID 1 REGULdz (т/ч)	0,25
PID 1 Timp (x0.1 сек)	1
PID 1 TREGUL(x0.1сек)	30
PID 1 Emes (мм)	50
PID 1 Rash NUZNO (т/ч)	74,51

Figure-7. Automatic regulator «Water level in the deaerator».

This parameter sets the setpoint of required level of water in the deaerator, which the automatic regulator strives to keep, changing consumption of chemically cleared water. In Figure-7 parameter has value 600mm of water.

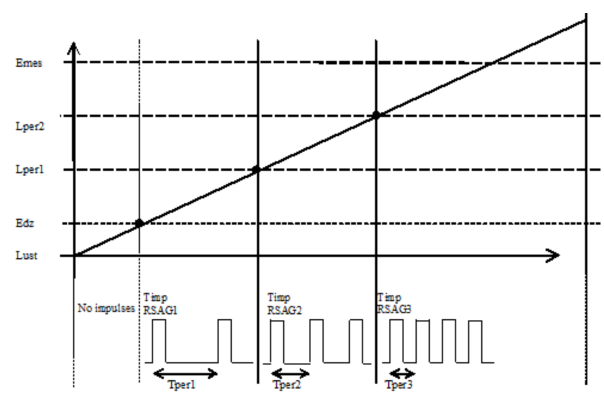

Figure-8. The work of an automatic regulator «Water level in the deaerator».

The *Edz* (mm) parameter adjusts the dead zone of an automatic regulator regarding the measured value of the adjustable parameter. In Figure-7 parameter has value ±4,0mm of water. The T_{per1} (s) parameter adjusts frequency of the repeated analysis of size of adjustable parameter (water level in the deaerator) and correction of the parameter (the required consumption of CCW on the DE) influencing water level in the DE. The step of the period is set by the RSAG1 parameter (×0,1t/h). Parameter T_{per1} is set by an integer with a step 1,0s. In Figure-7 parameter has value 200s.

The L_{per1} (mm) parameter adjusts the range of the values T_{per1}. This module is the deviation of the measured parameter «The water level in the DE» from the specified setpoint *Lust*. At this deviation, the frequency of repeat analysis of the size of adjustable parameter (the water level in the DE) is T_{per1} (seconds). The «The required consumption of CCW on the DE» parameter is corrected with the step set by the RSAG1 parameter. In Figure-7 L_{per1} parameter has value 15mm.

The RSAG1(×0, 1t/h) parameter sets a step of correction of the «The required consumption of CCW on the DE» parameter with frequency of T_{per1} (seconds) at the level of a deviation of L_{per1} of the current water level in the deaerator from the level set by the *Lust* parameter. In Figure-7 RSAG1 parameter equal 0, 2t/h.

At a mismatch of the set level in DE and the measured water level in DE more L_{per1} but less L_{per2} the automatic regulator is guided by adjusting T_{per2} and RSAG2 values. In Figure-7 these parameters are, respectively, 160cm and 0,3t/h.

At a mismatch of the set level in DE and the measured water level in DE on value, more L_{per2} the automatic regulator is guided by T_{per3} and RSAG3 setting data. In Figure-7 these parameters are, respectively, 130s and 0,4t/h.

The E_{mes} parameter (mm) sets mismatch module size between the required water level and the measured water level in the DE. In this case on the screen of an operator console the warning informational message about need of manual correction of water level for the DE is appeared.

The first step of an automatic regulator strives to keep the required water level in DE (it is set by the *Lust* parameter) through periodic (with T_{per} period) correction (with RSAG step) the «The required consumption of CCW on the DE» parameter, reflected by the Rash NUZNO parameter (t/h).

Parameters of the second step.

The REGULdz parameter (t/h) adjusts the dead zone of the second step of an automatic regulator regarding the measured value of the adjustable «The required consumption of CCW on the DE» parameter.

«The setting parameter» is the «The required consumption of CCW on the DE» parameter which is corrected by the first step of an automatic regulator. In Figure-7 parameter has value ±0,25t/h. Parameter is set by number to within 1 sign after a comma.

The *Timp* (×0,1s) parameter adjusts duration of the impulse acting on ESTM «The water level in the DE» according to the necessary direction of rotation. Parameter is set by an integer with a step 0,1s. In Figure-7 parameter has value 0,1s.

The TREGUL (×0,1s) parameter adjusts the frequency of the *Timp* pulse repetition acting on ESTM. Parameter is set by an integer with a step 0,1s. In Figure-7 parameter has value 3,0s.

The second step of an automatic regulator strives to keep a constants the «The consumption of CCW on the DE» parameter with an accuracy of the measured parameter ±REGULdz. The automatic regulator gives control impulses by *Timp* duration and with the frequency set by the TREGUL parameter on ESTM. The setting (basic) value of consumption size is value of an output variable from the first step of an automatic regulator «The required consumption of CCW on the DE» the Rash NUZNO parameter (t/h). The Rash NUZNO parameter (t/h) is a service parameter and can be changed by automatic regulator automatically in the regulation process. Parameter will be displayed as information, but if necessary, the manual adjustment of this parameter is also provided.

In the beginning the automatic regulator compares the previous value of the mismatch module of adjustable parameter (water level in DE) and the current value, and then gives out output action. If the current value is more previous (i.e. there is a tendency to increase the size of a mismatch of adjustable parameter), output impact is given on the «The required consumption of CCW on the DE» parameter also through the second step of an automatic regulator on the «Measured consumption of CCW on the DE» parameter. If there is a tendency to reduce a size of a mismatch, the automatic regulator continues the analysis of adjustable parameter, but output impacts on ESTM aren't given.

View of window Automatic regulator «Vapor pressure for own needs» is shown in Figure-9. This and other automatic regulator has one-stage structure, i.e. output influence of an automatic regulator is given directly for the ESTM mechanical regulator.

PID 2 Pust (кгс/см2)	5,0
PID 2 Edz (кгс/см2)	0,1
PID 2 Timp (x0.1 сек)	4
PID 2 Tper1 (сек)	8
PID 2 Pper1 (x0.1 кгс/см	2
PID 2 Tper2 (сек)	6
PID 2 Pper2 (x0.1 кгс/см	3
PID 2 Tper3 (сек)	3
PID 2 Emes (x0.1 кгс/см2	7

Figure-9. Automatic regulator «Vapor pressure for own needs».

The *Pust* parameter (kgf/cm^2) sets adjusting data of the required vapor pressure for own needs. The automatic

VOL. 10, NO. 16, SEPTEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

regulator strives to support adjusting data, giving on the ESTM mechanical regulator single impulses duration of *Timp* and with frequency of *Tper*. In Figure-9 parameter has value 5,0kgf/cm^2.

The *Edz* parameter (kgf/cm^2) adjusts a dead zone of an automatic regulator regarding the measured size of adjustable parameter. In Figure-9 parameter has value ±0,1kgf/cm^2.

The *Timp* (×0,1s) parameter adjusts duration of the impulse acting on ESTM «The water level in the DE» according to the necessary direction of rotation. Parameter is set by an integer with a step 0,1s. In Figure 9 parameter has value 4,0s.

The T_{per1} (s) parameter adjusts the frequency of repetition of the size analysis of adjustable parameter (vapor pressure for own needs) and correction of position of regulator of ESTM by giving of an impulse *Timp* duration. Parameter is set by an integer with a step 0,1s. In Figure-7 parameter has value 3,0s. The T_{per1} parameter is set by an integer with a step 1,0s. In Figure-9 parameter has value 8,0s. The P_{per1} parameter (×0, kgf/cm^2) adjusts the range of the setting data T_{per1}.

It is the module of a deviation size of the measured the «Vapor pressure for own needs» parameter from the set adjusting size Pust. Frequency of repeat analysis of the value of the control parameter is T_{p1} seconds. In Figure-9 P_{per1} parameter has value 0,2kgf/cm^2.

In a case a mismatch of the set vapor pressure for own needs and the measured vapor pressure for own needs more Pper1, but less P_{per2}, an automatic regulator is guided by T_{per2} setting. In Figure-9 these parameters are, respectively, 0, 2kgf/cm^2, 0, 3kgf/cm^2 and 6,0s. In case of a mismatch of the set water level in the DE and the measured water level in the DE more P_{per2}, the automatic regulator is guided by T_{per3} setting. In Figure-9 these parameters are, respectively, 0, 3kgf/cm^2 and 3,0s.

The *Emes* parameter (×0,1kgf/cm^2) sets mismatch module size between the required vapor pressure for own needs and the measured value at which the screen displays warning information message about need of manual correction of a vapor pressure for own needs. This automatic regulator analyzes the previous and current size of a mismatch between the set and measured adjustable parameters. Output impact on the MEO mechanical regulator is given only if there is a tendency to increase of indicator module of a mismatch between set and measured size of adjustable parameter. View of window Automatic regulator « Vapor pressure in the DE» is shown in Figure-10.

PID 3 Pust (кгс/см2)	3,0
PID 3 Edz (кгс/см2)	0,1
PID 3 Timp (x0.1 сек)	4
PID 3 Tper1 (сек)	15
PID 3 Pper1 (x0.1 кгс/см	2
PID 3 Tper2 (сек)	10
PID 3 Pper2 (x0.1 кгс/см	3
PID 3 Tper3 (сек)	5
PID 3 Emes (x0.1 кгс/см2	5

Figure-10. Automatic regulator «Vapor pressure in the DE».

This automatic regulator is similar to an automatic regulator «A vapor pressure for own needs», but the *Pust* parameter (kgf/cm^2) sets the required value of a vapor pressure directly at the outlet from the steam generator. The principle of regulation and the meaning of the indicators presented in Figure-10 are similar to the parameters given in Figure-9.

View of window Automatic regulator «Vapor pressure on a well» is shown in Figure-11. The principle of regulation and the meaning of the indicators presented in Figure-11 are similar to the parameters given in Figure-10 and described previously.

PID 4 Pust (кгс/см2)	55,3
PID 4 Edz (кгс/см2)	1,5
PID 4 Timp (x0.1 сек)	5
PID 4 Tper1 (сек)	30
PID 4 Pper1 (x0.1 кгс/см	20
PID 4 Tper2 (сек)	25
PID 4 Pper2 (x0.1 кгс/см	25
PID 4 Tper3 (сек)	15
PID 4 Emes (x0.1 кгс/см2	30

Figure-11. Automatic regulator «Vapor pressure on a well».

4. CONCLUSIONS

In materials of this article it is shown that use of industrial controlers for the solution of problems of control of technological processes is connected with a choice of structure of a control system and development of the special software. Difference of the received results from the earlier known [1 - 5, 9, 10] consists that for controlling of steam generating installation for the enterprises of production and oil refining, two options of a configuration of a microprocessor control system are offered.

The control system configuration choice with software redundancy that allowed to greatly improving reliability and non-failure operation of a control system in case of failure of separate modules is justified. SCADA

ARPN Journal of Engineering and Applied Sciences

system for the solution of task of control of steam generating installation is developed. The example of setup of automatic regulators is given.

REFERENCES

[1] Persin S., Tovornik B. 2005. Real-time implementation of fault diagnosis to a heat exchanger. Control Engineering Practice. 13(8): 1061-1069.

[2] HongboZou , Li H. 2015. Tuning of PI-PD controller using extended non-minimal state space model predictive control for the stabilized gasoline vapor pressure in a stabilized tower. Chemometrics and Intelligent Laboratory Systems. 142: 1-8.

[3] Zhou P., Yue, H., Zheng X.-P., Chai T.-Y. 2008. Multivariable fuzzy supervisory control for mineral grinding process. Kongzhi yu Juece/Control and Decision. 23(6): 685-688.

[4] Han Q., Wu H., Ye J., Mao Z., Kang Z., Fan Y. 2010. Monitoring and controlling system of temperature and humidity for tunnel-type dryer. Nongye Jixie Xuebao/Transactions of the Chinese Society of Agricultural Machinery. 41(4): 119-123.

[5] Abdel-Geliel M., Qaud F., Ashour H.A. 2014. Realization of adaptable PID controller within an industrial automated system. EEE International Conference on Control and Automation. ICCA2014, Article number 6871052, pp. 965-970.

[6] Parr E.A. 2007. Programmable Controllers: an engineer's guide; third edition. Publishing House. - M: BINOM Knowledge Laboratory. p. 516.

[7] Vladimir Bobala, Marek Kubalcikb, Petr Dostala, Jakub Matejiceka. 2013. Adaptive predictive control of time-delay systems. Computers and Mathematics with Applications. 66(2): 165-176.

[8] Ibrahimkadić S., Kreso S. 2011. Characteristics of modern industrial control systems. MIPRO 2011-34th International Convention on Information and Communication Technology, Electronics and Microelectronics - Proceedings. pp. 845-849.

[9] Equipment for thermal impact on layer. http://www.studopedia.org/1-25641.

[10] Equipment for thermal impact on layer. http://www.info-net.ru/index.php?action=full_acticle&id=420.

[11] Programmable Controller Simantic S7-300/400. http://www.samselepls.ru.

[12] Simatic/ Totally Integrated Automation. http://www.ste.ru/siemens/pdf/rus/05_S7-300_r.pdf.

[13] Rules of arranging and safety of operation steam and water-heating boilers. SR 10-574-03, 2003.

[14] Safety rules of systems of gas distribution and gas consumption. SF-12-529-03.

[15] The general technical requirements to software and hardware complexes for automated control systems of technological process of thermal power plants. GD 153-34.1-35.127-2002.

[16] Ignatyev V.V. 2008. Automated control system for ignition of burners during the work of a boiler on natural gas / Actual problems of production and electricity consumption: thematic issue // proceedings of SFEDU. Technical science. - Taganrog: Publishing House TTI SFEDU. № 7 (84). pp. 128-136.

[17] Software redundancy for SIMATIC S7-300 и S7-400. http://www.siemens.com/answers/ru/ru/#.

[18] Finaev Valery I., Beloglazov Denis A., Shapovalov Igor O., Kosenko Evgeny Y.a and Kobersy Iskandar S. 2015 Evolutionary algorithm for intelligent hybrid system training . ARPN Journal of Engineering and Applied Sciences. 10(6): 2386-2391.

[19] Beloglazov Denis A., Finaev Valery I., Zargarjan Jury A., Soloviev Victor V., Kosenko Evgeny Y., Kobersy Iskandar S. 2015. Efficiency of genetic algorithms in intelligent hybrid control systems. ARPN Journal of Engineering and Applied Sciences. 10(6): 2488-2495.