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The Use of Information Systems for Regulation of Gas Engine Operating Parameters

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Abstract. The purpose of the work is to indicate the possibility of using selected IT systems to analyse work and regulate operating parameters of gas engines. An additional task of the work is to indicate new possibilities of using IT systems in power plants. The publication shows the development of industrial information systems in recent years. It is shown how these systems are used for direct control and adjustment of operational parameters of power equipment, ranging from water boilers to steam boilers, turbines and cogeneration aggregates. These systems implement technical safeguards and can be used to analyse work characteristics in an appropriate configuration. The more elaborate energy systems, the wider the scope of use of IT systems. Due to the full automation and control of cogeneration gas-powered power generators, an automatic heating water flow control system through heat exchangers can be used in these installations. This solution requires the expansion of the heating water pumping system with pumping sets with inverters and fittings of the pumping station with remote control.

1. Introduction

Nowadays, as never before, the greatest emphasis is placed on efficiency, from the effective use of working time, through the efficiency of product and goods production to the efficient use of fuels. More specifically, this issue for industry is about the highest possible profit with the least effort while maintaining quality requirements. In the case of power plants, the raw material for the production must be used with the smallest profligacy; the production process must be carried out with the lowest possible consumption of raw material and energy while maintaining certain characteristics and quality requirements of the final product. With the development of technology, you can observe the rapid development of the IT industry. Industry has become a real training ground for using technical innovations in mass production. Engineers have increasingly begun to reach for IT solutions and use them for their purposes. Considering IT systems in the operation of energy devices, we can say that we are talking about a instrumentation and automated control systems most often in a closed system. Closed systems exist as preanalytical, analytical or post-analytical phase of the production cycle [1]. The supplementary hardware and software have been specifically designed to integrate with instrumentation and applications [2]. The control in the case of gas engines is the programmable control in the part covering only the gas engine, while the heat recovery system works in the programmable control mode with some elements operating in the fixed-value and follow-up control mode. The control is carried out in a local and a remote mode [3, 4]. The user decides about the mode control. When analysing the possibilities of using IT systems, it is necessary to take into account:

- the possibilities offered by the IT layer of this system, i.e. the capabilities of the system for entering measurements, connections with actuators, the possibility of modifying and expanding the system with further parts - these possibilities are important for specialists in the I&C industry
- the appearance of the user interface, whether it is readable or easy to learn the knowledge of plant control associated with the system; this is particularly important in the context of people who deal with the operation of installations and not the operation of IT systems
- the IT system should be secured against losing operator control over the technological process in any emergency
- the IT system should facilitate the operator's work.

The quality of an IT solution is a combination of technical, ergonomic and functional quality. The visualizations of the implemented tasks is very important from the point of view of the practical operation of I & C equipment. The publication compares the readability of information obtained in textual form with information resulting from the process of visualization [5, 6]. The aim of the analyses is to point IT solutions that take into account the importance of functional and ergonomic factors. The simplicity of learning, an effortlessness of use, a visual mapping accuracy, shorter system operation training, faster execution of tasks, and a reliability of system use determine the success of control, measuring equipment and automation systems. After analysis of the technical condition of the existing configuration of I & C equipment, a response was prepared that provided a solution to the illegibility of existing solutions. The system was controlled by an automation system controlled by the superior ASIX SCADA system. The presented solutions are intended to show the possible user interface modifications that result in increased readability of the installation's work. The basis of the work is to present the graphic representation of combustion process parameters in the existing gas engine.

2. A gas engine as a high-efficiency cogeneration unit

A heat engine is a machine that converts a heat energy obtained by burning solid, liquid or gaseous fuels into a kinetic energy. The discussed engines are internal combustion engines converting a thermal energy obtained as a result of combustion of gaseous fuels, in which the conversion of the thermal energy into the kinetic energy takes place inside the engine working space (in the cylinder). The engines are made in the technology of vertically arranged cylinders, with a turbocharging (one turbocharger for each cylinder row).

The motivation for achieving high values of fuel utilization factor has led to increased interest in cogeneration applications [7]. The analysed gas engines coupled with electric generators with electric power from 2.0 to 4.3 MWe. These engines produce electricity and the heat from the engine block and the heat contained in the exhaust gas is recovered as waste and utilized in further processes. Thermal energy is transferred to the heating network and used for the production of cold. The first application of the analysed internal combustion engines together with an electric generator was the replacement of previously used gas boilers powered by mine gas, with a capacity of about 5.0 MWt that was used to meet the needs of the mine-heating network. The use of gas engines means that with the same amount of gas fuel consumed, heat energy is obtained and electricity is generated as an additive.

After these positive experiences with replacing small water boilers with gas engines equipped with generators, it was decided to use the heat generated by gas engines to generate cooling energy from this heat. Due to these investments, installations containing gas engines began to be increasingly perceived as modern and energy-saving energy installations. Small gas boilers were simple installations and required only a few basic parameters to be monitored:

- a water flow through the boiler
- temperatures before and after the boiler
- a pressure in the combustion chamber
- a gas pressure
- a gas flow to the boiler.

Supervision over these parameters was carried out by observing the indications of instruments installed on control boards. The boiler protection was carried out by electrical systems, control and measuring instruments and mechanically executed. However, small gas boilers were fairly simple installations and required only a few basic parameters to be controlled, it became necessary to develop automation, control, and measurement when used for large power installations with gas engines. Matching tables with control and measuring instruments became larger and with many different indicators. Installations with the production of cooling energy from heat energy have become technically predominantly advanced. The control of aggregates with gas engines is a closed-loop control system with electric actuators. By requesting engine start, the engine operator starts the programmed engine start sequence, meeting all conditions causes the engine to start. When the engine is running, the operator sets the value of the engine load, and the system controls the engine cooling system so that the oil and cooling water temperature parameters are optimal [8]. Installations that support various functionality of gas engines have become almost ideal for setting up the new design of computer systems. Because these installations cooperate with various types of other external entities, it became necessary to connect various types of computer systems with various functionalities. Some systems control, supervise and implement security, others only visualize parameters, and others collect data and present them in the form of reports. It is a training ground for testing and development of systems that can integrate all functions [9].

3. A control of the gas engine system

3.1. Selected problems of the gas engine operation

Optimizing the operation of a gas engine, especially of high power, is an extremely important concern. The control system for the integration of automation and information systems, as well as production should be responsible for:

- an engine management
- an adjusting the engine cooling system on the coolant side
- an engine lubrication control.

Controlling engine operation results from the need to obtain the assumed system efficiency. The use of this system functionality eliminates the risk of starting the engine with out of order engine systems. When starting the engine, the operator triggers a programmed start sequence during which many systems are tested:

- a throttle (the system checks whether it moves in the full range of operation - in the event of non-compliance interrupts the start procedure)
- a bypass valve of the turbocharger (in the same range as the throttle)
- the system checks if there are adequate pressures in individual elements of the cooling system
- after the start-up, the system ensures the correct ignition setting of the engine, as well as the right mixture temperature.

In addition, the system causes the engine to be shut down if the limit parameters are exceeded.
Adjustment of the engine cooling system on the coolant side is the use of an IT system that facilitates the operation of the engine, the operator corrects only to a small extent the settings of the engine cooling system, the system reacts to any changes in the temperature of the coolant in accordance with programmed algorithms. In the event of a sudden increase in the temperature of the coolant due to the deactivation of a heat exchanger, the emergency coolers are started in the correct order at the appropriate speed of the cooling fans until the load on the engine is reduced or it is taken out of service. The system prevents unnecessary engine starts, and thus increases the reliability and efficiency of production.

Adjustment of the engine lubrication system is a system that decides whether in the event of an oil level dropping in the oil pan top up its level by automatically pumping from the fresh oil tank. The oil temperature is one of the basic parameters necessary for the trouble-free operation of the gas engine and this parameter is also one of the most closely monitored parameters. The computer system immediately responds to any temperature changes by continuous analysis of the thermal state of the engine. It does faster than the operator by reacting at many points in the installation simultaneously, which is not possible with manual adjustment of the system by the operator.

3.2. The gas engine control solutions

The first and the basic IT system is the gas engine control system. This system allows the gas engine and the generator to be operated safely and reliably. To supervise and control the operation of gas engines, it uses an IT system that provides the ability to control the engine from the place of engine installation locally as well as remotely.

Figure 1 presents a simplified diagram of connections and cooperation of computer systems of the cogeneration aggregate and connections with external measuring elements. The basic system collects data from the gas engine measuring points:

- a coolant temperature
- an oil temperature
- a lubricating oil pressure
- pressure measurements in the cooling system
- a combustion temperature and an ignition energy in cylinders.

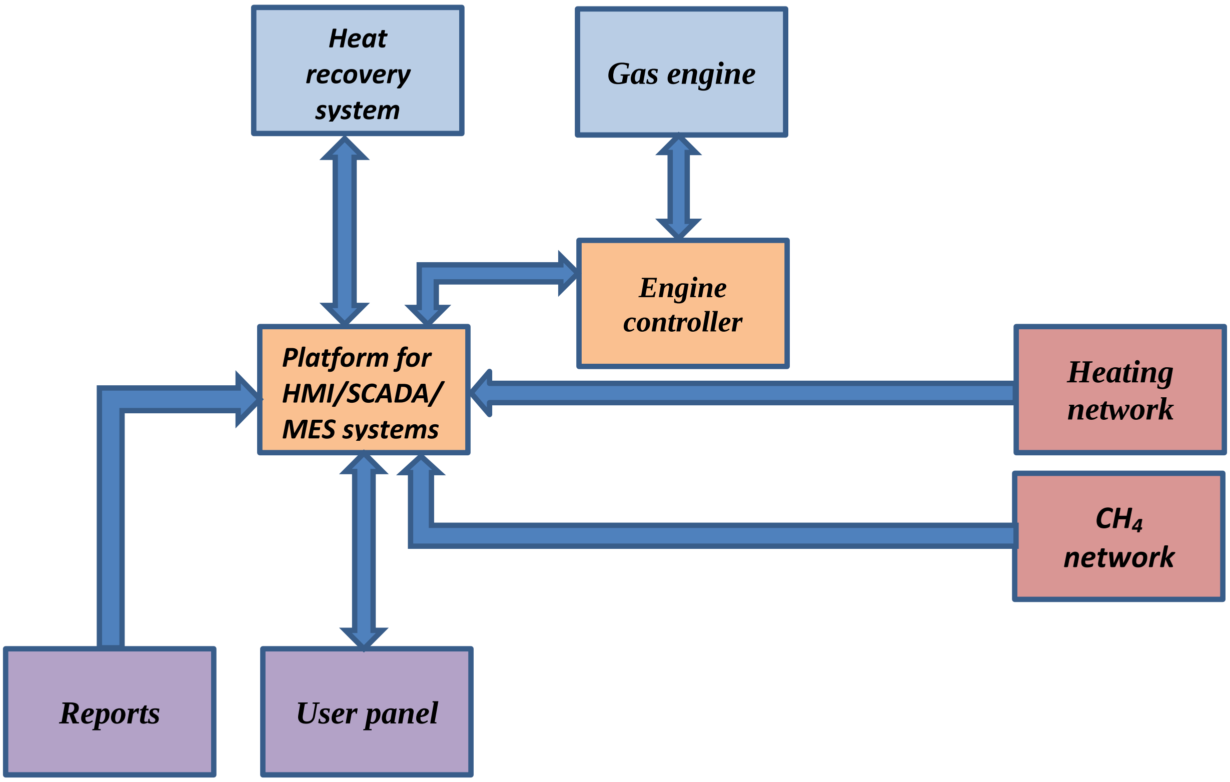

Figure 1. The trigeneration installation diagram.

Control of gas engines is carried out individually for each of the engines. Each engine is located in an individual building. In the building of each of the engines on the control cabinet there is a tactile control panel of the TEM Evo system and a synchronoscope ignition. In the room of the block control room of the CHP plant, there are computers with an access application to the TEM Evo system installed - the access management to the TEM Evo system is carried out from these computers. In the place of the block heat and power plant control room there are computers with ASIX application with full access to control and regulation of gas engines, as well. In the engineering and technical service rooms there are computers with ASIX application installed, but only with the possibility of viewing operating parameters. The SCADA system is the master system is ASIX system of ASKOM Gliwice. To control the processes in gas engines, SIMATIC controllers from Siemens are used:

- SIMATIC S7-300 for TCG 2032 V16 engine
- SIMATIC ET 200S for CG 260 16V engine

The standard SIMATIC controllers consist of:

- Central Unit - CPU
- Expansion modules - with a central cassette (CC) with a capacity of up to 8 modules, in the case of more modules, expansion cassettes (EU) are used. A maximum of 32 modules can be supported (4 cassettes of 8 modules each)
- Interface modules - responsible for communication between individual cassettes
- Function modules - have processors and work independently of the controller's main processor. They are used when technological tasks require high computing speeds and high control dynamics
- Communication modules - allow the controller to be connected to a network such as PROFIBUS.

The WOODWARD GW4 controller is responsible for the process of automatic synchronization with the power network in both motors. The SCADA system collects data from the SIMATIC controller of the relevant engine, using these data it partially realizes control algorithms, on the basis of available data it calculates other data which are not measured. The system issues alarm and warning messages, archives data, gives the possibility to create archive charts from any time horizon.

Figure 2. The real cogeneration aggregate control display.

The Figure 2 shows the previously used by the authors and the currently existing user interface fully functional but not very legible. The figure shows the TEM Evo system user interface, the basic hood from which the engine starts and stops, as well as its synchronisation with the power grid and the possibility to change load. Moreover, this display selects the engine control method - manual or automatic, additional basic information related to the gas engine operation is provided on this display. It is a fully functional display, however, it is not very readable, which causes some difficulties for people operating the installations, additionally it has very limited functions of analysing the operating parameters of the archives. This causes some difficulties for people who operate installations.

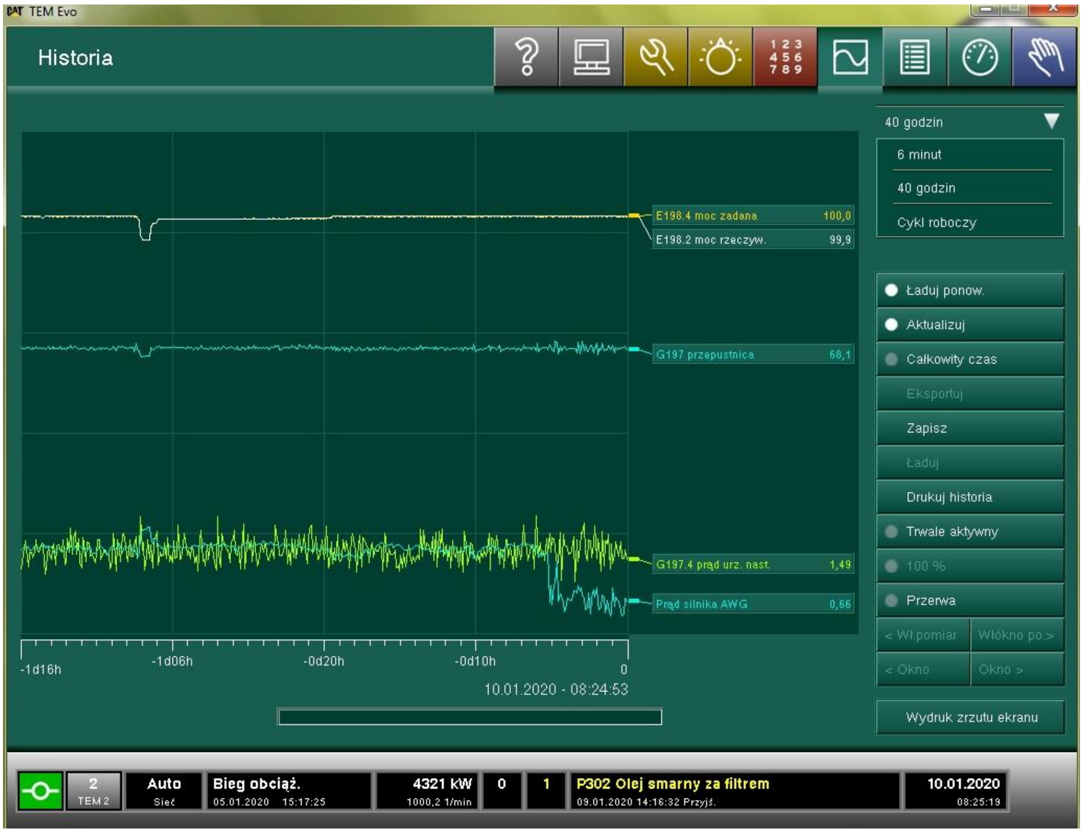

Figure 3. The real analogue measurements and trend display.

The presented interface has limited functions of analysing archive operational parameters, as shown in the Figure 3. The function that draws archival charts allows you to generate charts n 6 minute or 40 hours back, but without the ability to save charts, except for the option to save to external media. In addition, the number of parameters that can be placed on one chart at the same time is limited. The 6-minute time horizon can be selected on this figure. It is not possible to stop it - only a screenshot to *.pdf format can be taken. The chart can display up to 20 parameters simultaneously, but then the chart becomes unreadable. The attached graph shows the parameters of engine operation allowing to check its load capacity: actual load, set load and throttle opening degree together with the current of throttle flap control. As for the opportunity of interfering with the engine operation via the interface, it is possible to select the operating mode (automatic or manual), start and stop the engine, synchronize and unsynchronize the engine with the power grid, as well as increase and decrease the engine load.

The Figure 4 presents a text system informing the operator about changes occurring at a given moment. The basic operating parameters of a gas engine are shown only in the form of numbers. It is not possible to view changes, trends or select individual parameters for analysis.

The Figure 5 graphically illustrates the basic operating parameters of a gas engine. This shows a typical control display, which was created in cooperation between operators and designers. The aim of this cooperation was to create such a display of the technological system that would transmit the necessary information while remaining as legible as possible - this task was fully achieved. This is the extended equivalent of the display shown in Figure 4, which uses the available data acquisition and interpretation possibilities. This display in a simple and legible way shows individual parameters with the possibility of viewing graphical charts of changes of individual parameters, this functionality allows for thorough analysis of the installation's operation and interpretation of changes in its parameters.

The discussed graphic representation of combustion process parameters in the engine informs and controls the operation of the gas engine and supervises the basic parameters of its operation.

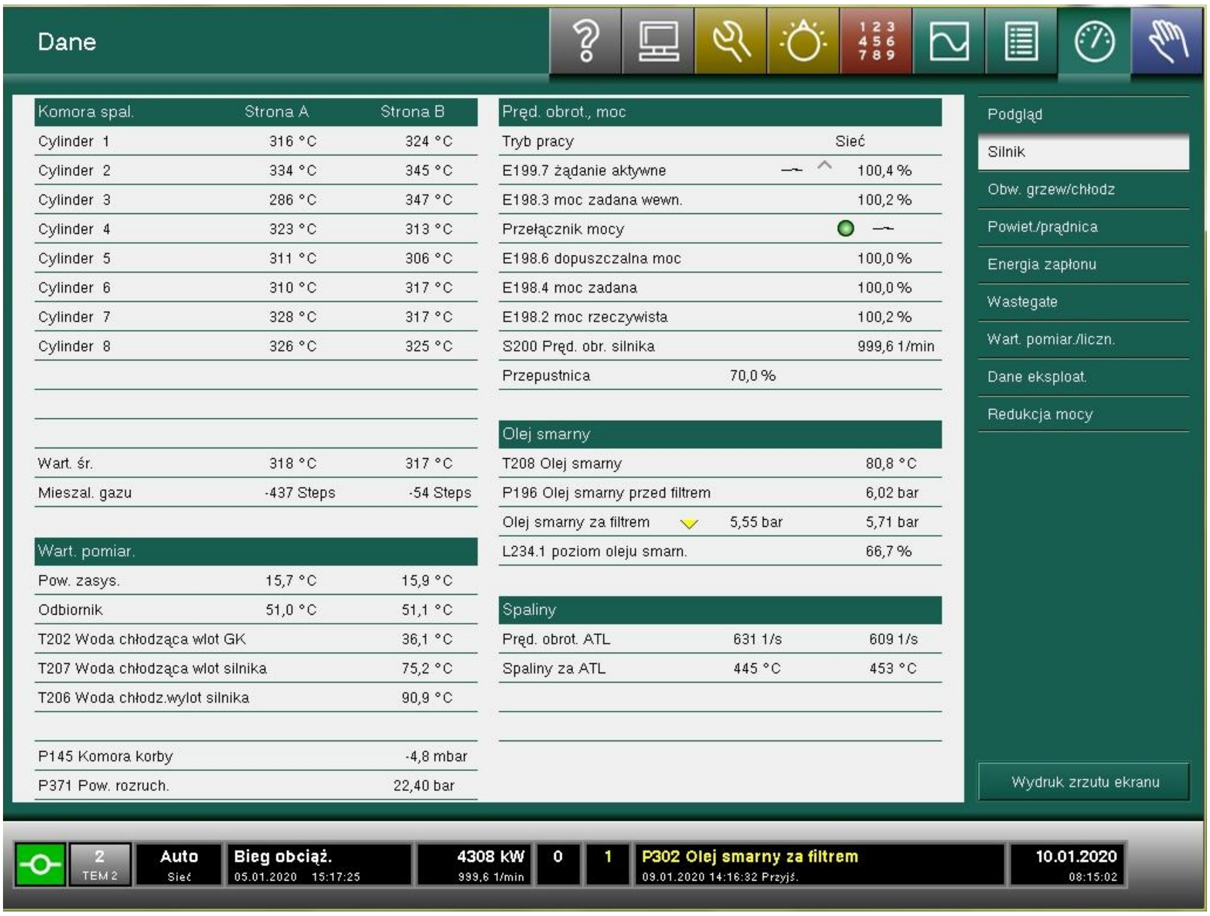

Figure 4. The real text presentation of the combustion process parameters in the engine display.

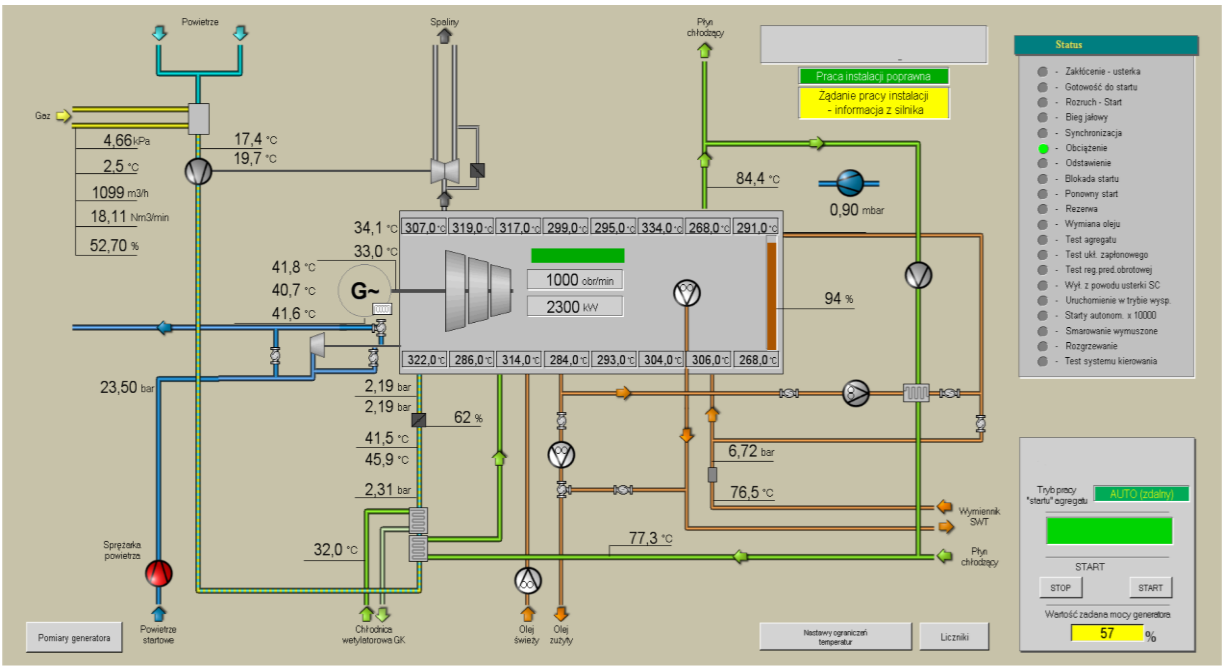

Figure 5. The real graphic representation of combustion process parameters in the engine display.

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Conclusions

This article presents solutions using IT systems for the purposes of supervision and control of exploitation, as well as technical analysis of high-efficiency cogeneration aggregates using gas as the fuel. Analysing the project of processes visualization it can be argued that the legitimate goal has been achieved, but the process of operating cogeneration aggregates can be even more automated.

Even the simplest energy installations currently use support from computer measurement and automation systems. The use of the computer systems allows a very sensitive industrial user to change parameters to ensure the safe operation of these installations, and gives the possibility of remote control of power station installations. In the location of the computer station with the appropriate control software installed, it is possible to select the place of the installation control interface. The use of IT systems in the power industry enables ongoing detailed supervision over the operation of devices. Computer systems support the operator in conducting operations that implement many adjustment processes outside the operator. This approach protects devices and installations against damage.

Unwanted consequences of such a solution can certainly include the need to have highly specialized knowledge among those involved in servicing the control system of these installations. It happens in practise that exceeding a certain parameter will cause the installation to be shut down, and the reason is not a physical exceeding of the measured value, but a defect of the measuring instrument or the measuring path. In such cases, it is necessary to have knowledge of how the control cycle is implemented and what are the relationships between the individual measurement parameters. Implementation of the control system allows achieving effects in the form of improved system efficiency and more efficient system management. Prepared visualization contributes to the identification of the system failure and provides all necessary information about the system operation. The system of visualisation need to be expanded, so this is not a final solution.

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