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# Computer simulator-analytical complexes of thermal power stations for the training with higher education students

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**Abstract.** The possibilities of using computer simulator-analytical complexes for training and retraining of large thermal power plants personnel are analyzed. Long-term experience of simulators using at the Thermal Power Stations Department (TPP) of Kazan State Power Engineering University (KSPU) is generalized. The requirements for computer simulators for the higher educational process are grounded.

## Introduction

Automation is of particular importance for heat and power facilities. This is due to the high degree of mechanization for electrical and thermal energy production processes, as well as high pressures and temperatures in the steam-water circuits of thermal power plants, which imposes higher requirements on their regulation accuracy.

Expenditures for the fuel and energy complex development constitute a significant share in the state budget. In this regard, one of the urgent problems of the domestic economy is to increase the efficiency of large thermal power plants - thermal and nuclear power stations, powerful boiler houses.

This task solution should be facilitated by the training of highly qualified personnel who possess modern knowledge, skills and skills to work in the energy sector.

A promising area for improving the education quality in technical and technological universities can be the introduction of computer simulators in the educational process. In recent years, significant results have been achieved in the development and improvement of full-scale simulators imitating the technological processes of energy production at thermal power plants [1].

## Requirements for the operational personnel of thermal power stations

The training with the computer simulators using has not yet received wide distribution in the implementation of educational programs in universities. At the same time, the existing requirements for operational personnel of thermal power plants, as required by the professional standard "Employee for the organization of operation of thermal power plant mechanical equipments" [2], provide for the ability to perform, in particular, such labor actions:

- control of operating modes and technical condition of thermal mechanical equipment, detection and recording of faults and defects of components, equipment design, according to instrument readings on the remote control board;
- carrying out emergency drills.

The same standard requires the employee skill:

- work with a personal computer and the software used at TPPs;



– determine the sequence of necessary actions in the operation performance of thermal mechanical equipment.

To train these and other labor actions and skills, it is advisable to use computer simulators, the software of which corresponds to the algorithms of control systems of technological processes on real heat power objects.

### **Experience of computer simulators and computer training-analytic complexes introduction in the educational process at the department of thermal power plants**

At Kazan State Power Engineering University over the past decade, a significant experience has been accumulated in the successful implementation of computer simulators and computer simulators and analytical complexes in the educational process in the profile of "Thermal Power Stations" at the same department.

The first was mastered the all-mode computer simulator of the condensate power unit of supercritical pressure with a capacity of 300 MW, developed at the Ivanovo State Power Engineering University under the direction of Rabenko V.S.

On this simulator, multi-purpose classes are conducted with students studying in the areas of Bachelor's and Master's programs "Heat and power engineering and heat engineering" [3].

First, students receive theoretical knowledge, studying the content of mnemonic diagrams and the simulator management.

The second part of the training is connected with the implementation of practical tasks based on the experience of operating power units of thermal power plants. For example, one of the works is designed to acquire knowledge, skills that prevent automatic power unit shutdown in case of emergency stopping one of the two circulation technical water supply system pumps. Operational personnel must implement the least fuel-intensive transfer of the power unit to about 180 MW capacity, which will avoid an unacceptable vacuum deterioration in the turbine condenser. The power reduction should be smooth, otherwise the heat and power equipment service life is reduced.

The another work subject, also related to ensuring the continuous turbo accessory functioning, is the transfer of the increased pressure deaerator to the atmospheric regime. The main condensate feeder deaerator is characterized by high parameters (pressure 0.6-0.7 MPa and about 160 °C temperature). The transfer to atmospheric mode allows to inspect the deaerator and perform the necessary work without power unit stopping.

Finally, in the magistracy, the methods of main and auxiliary equipment thermal engineering tests can be studied using the simulator.

At present, educational methodological support is developed using the computer simulator-analytical complex of the power unit with a 450 MW combined-cycle plant (CCP-450).

The computer simulator - analytical complex of the 450 MW unit simulates the operation of the main and auxiliary equipment, control and protection algorithms, simulates control from the operator stations, is a training, pre-examination preparation and examination test for the CHP operational personnel [4].

It is designed for personnel training, and testing in the following specialties: Deputy Chief Operations Engineer, Senior Power Change Supervisor, Power Station Manager, Shift Supervisor, Senior Machinist, Power Unit Machinist, auxiliary Machinist, Electrician on duty.

Let's consider its technical characteristics [5, 6]. The CCP -450 power unit consists of two GTE-160 gas turbine units, two heat recovery boilers of type Pr-228 / 47-7.86 / 0.62-515 / 230, one steam turbine T-150-7.4, three turbogenerators, a set of auxiliary equipment (pumps, heaters, coolers, etc.) operating in a single thermodynamically connected technological cycle.

The GTE-160 gas turbine unit is a single-shaft four-stage turbo unit operating in a simple thermodynamic cycle, with an initial gas temperature of about 1060 °C and a gas temperature at the output from the turbine of 537 °C.

Electric power GTU at the calculated external conditions in accordance with GOST 20440 (outdoor air temperature 15 °C, pressure 0.1013 MPa, humidity 60%, resistance to output inlet to the

compressor 1 kPa, resistance at the gases output from the gas turbine 3.3 kPa) is 155.3 MW with a efficiency coefficient of 34.12%.

Combustion products after each gas turbine are delivered to their recovery boiler. The recovery boiler has a tower layout, two high-pressure (HP) and low (LP) pressure steam pipelines with steam drums and forced and natural circulation in evaporation circuits. There is no fuel burning in the boiler, passing the exhaust gas of the gas turbine through the non-working boiler is not allowed. In the course of the gases in the boiler, the HP superheater, HP evaporator, HP economizer, LP superheater, LP evaporator and gas condensate heater are located in the boiler. Steam after superheaters of high and low pressures enters the high-pressure cylinder (into the chamber between 16 and 17 stages) of the steam turbine. Steam pressure and temperature regulation in the recovery boiler in the operating range of loads is not provided, it is designed to work with steam sliding parameters of determined by the temperature and gases flow entering the recovery boiler from the gas turbine, as well as the steam turbine operating mode.

The steam turbine T-150-7.4, with two adjustable steam samplings for heating the network water, with a nominal capacity of 161 MW at the nominal condensing mode and 129 MW at the nominal heating mode, with a rotation speed of 3000 rpm, is intended for direct drive generator, mounted on a common foundation with a turbine, and tempering to 358 MW at an estimated outside air temperature of -2 ° C. The turbine is a single-shaft two-cylinder unit.

Another simulator installed at the TPP department is simulator of the combined-cycle power unit 410 MW of Nyagan power station, which was commissioned in 2013. It has one of the highest efficiency achievable in the steam-gas cycle with condensation power generation - 58% [7].

The prototype of the CCP-410 simulator includes [4]: one gas turbine Siemens SGT5-4000F, one steam turbine SST5-3000, a heat recovery boiler Ep-270/316/46-12.5/3.06/0.46-560/560/237, SGen5-2000H turbo-generator, power unit accessories; remote objects controlled from the block control panel, including: circulating pump station, shore pump station, cooling tower with natural circulation, block gas preparation station; automated control and monitoring system SPPA-T3000 (Siemens).

Also at the department of TPP KGEU there was installed a "Plant simulator with cross-link connections for the CHPP", simulating the operation of the AMAKS software package installed on the TP-80 boiler to control the fuel supply [4].

The structure of the cross-link simulator include:

- two boiler units of TP-80 type;
- turbine unit type PT-60-130/13 with generator TV-60-2;
- turbo-unit of T-100/120-130 type with generator TVF-120-2;
- the boiler installation of the turbine PT-60;
- the heating system of the turbine T-100/120-130;
- system of main steam pipelines;
- nutrient-deaeration plant with four deaerators 0.6 MPa;
- plant circulation system;
- atmospheric deaerators 0.12 MPa for make-up.

To train students and conduct classes to improve skills and retrain workers in the energy industry a series of practical classes were developed. They provide for the fulfillment of tasks for the preparation for the start-up and start-up of individual units and aggregates, as well as for the CCP unit as a whole from the hot state and on sliding parameters from the cold state. Several lessons are associated with stop equipment.

## Conclusion

The network of computer simulator classes created in recent years [3, 6, 8, 9] and the accumulated experience of conducting training sessions allows us to draw some conclusions regarding the requirements for the learning process simulators.

First of all, its maximum possible approximation to the real operating conditions of equipment in various modes is necessary. There the opportunity should be of time scaling (especially for many

hours of starting and stopping operations), suspending a job, recording the current state, going back to any stage of work, having immediate messages about student mistakes made, and so on. Presence of all these simulator functions promotes increase of a degree of student independence at practical employment carrying out.

The combination of theoretical training, laboratory classes on the thermal power plant operating equipment and the practical tasks using a computer simulator implementation is necessary for the comprehensive training of future specialists to work at large thermal power plants.

Developed and successfully tested educational technologies with thermal power station computer simulators using can be used for retraining and further training of large thermal power plant workers.

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