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TRAINING SYSTEM FOR POWER PLANT OPERATORS CONTROLLING THE ELECTRICAL PART OF A POWER GENERATING UNIT

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Abstract. The expediency of the development of local training systems for power plant operators is considered.

Principles of creating a training system for control operators of the electrical part of the power generating unit of the thermal power station have been developed. This system consists of two subsystems: a model of the electrical part of the power unit and a training subsystem. The model of the electrical part of the power unit includes models of a power system, generator, facilities, turbines, excitation systems, etc. The training subsystem allows the staff to cope with a learning process and acquire the skills necessary for control operators.

The developed training system allows the staff to learn how to control the electrical part of the power generating unit during normal, special and emergency modes, such as: synchronization of the generator with the system (manual, automatic), transferring the excitation of the generator from the working excitation system to the standby excitation system and vice versa, synchronous oscillations of the system, load asymmetry, etc.

The training system provides the opportunity of staff self-training, as well as objectively evaluates their knowledge of the operational control of the power unit. Its use allows the increase in the training quality of control operators of thermal and nuclear power plants.

Key words: local training system, training quality, control operators, full-scale simulator, electrical part of the power unit, training subsystem.

1. Introduction

The training of control operators at power plants usually is carried out in special training centers (STC). At these centers the general theory, maintenance instructions, technical specifications of the equipment of power units, directive materials, features of operational control etc. are studied. Training of control operators in STC is fulfilled by carrying out the tasks of operational control of the power unit on the full-scale simulator. The full-scale simulator is a simulation model of a control operator's workplace consisting of simulators of control systems, monitoring and the alarm systems of the unit control desk (UCD) and model of the power generating unit of power plant [1]. In modern full-scale simulators the model of the power generating unit of power plant is realized with the use of powerful servers. The costs of the development, creation and operation of such full-scale simulators can reach 3–4 million dollars [1].

It is possible to increase training quality of control operators of power plants due to the application of specialized (local) training systems [2]. These systems provide acquiring skills in the operational control of the separate systems of the power unit, for example, of a steam generator (or its separate components), nuclear reactor, turbine, generator, boiler, auxiliaries, etc. [3], [4].

The purpose of the work is the development of the principles of creating the training system for control operators of the electrical part of the power unit of power plants.

2. Research results

The training system of operational control of the electrical part of the power unit is developed for training the control operators of both thermal, and nuclear power plants [5].

The control operators can study the principles of operational control of the electrical part of the power unit during such normal modes: synchronization of the generator with the system (manual, automatic), transfer of excitation of the generator from the working excitation system to the standby excitation system and vice versa, the transfer of power supply of auxiliaries sections from the working transformer to the standby transformer and vice versa, planned disconnections of the generator from the grid, excitement of the generator by the working or standby exciter. It is also possible to learn how to control the power unit in these modes in the case of equipment malfunctions, for example, the malfunction of the automatic field regulator of the generator, malfunction of the working or standby exciter, malfunction of the automatic startup device of working or standby excitation system and so forth. The training system also allows acquiring the skills in power unit control in special and emergency modes, such as: partial and complete loss of the generator excitation, asynchronous mode of the generator with total loss of excitation, breakage of the switch circuits, load asymmetry, internal damage of the power unit, etc. [6].

The training system consists of two subsystems: the model of the electrical part of the power unit (EPPU) and the training subsystem. The model of the electrical part of the power unit simulates processes occurring in this part, the systems of its control, monitoring, relay protection, technological and emergency alarm. The training subsystem directly conducts the training process and evaluates the knowledge of the operating staff about the control of the above mentioned EPPU [7].

For the operation of the training system the only used device is a personal computer (PC) which significantly reduces its cost. The fragment of the UCD of the EPPU and the fragment of UCD of the EPPU facilities displayed on the PC monitor are shown in Fig. 1 and Fig. 2 respectively [7].

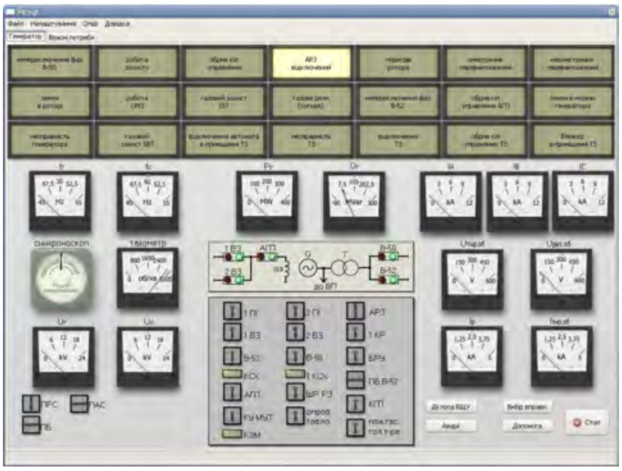

Fig. 1. Window displaying the UCD fragment of the EPPU.

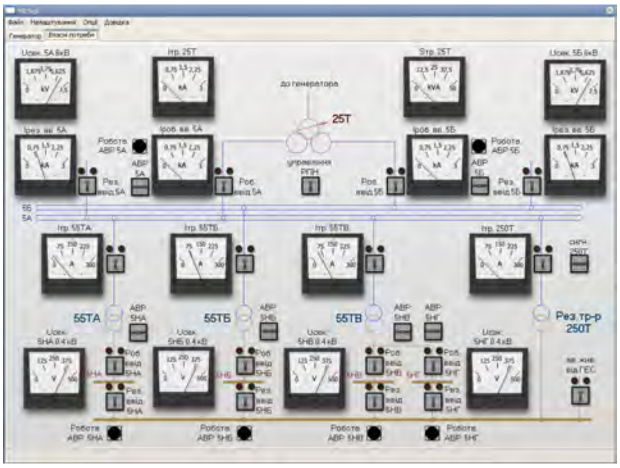

Fig. 2. Window displaying the UCD fragment of the EPPU facilities.

The training system, unlike the full-scale simulator, does not use real technical units (i. e., control switches, selector switches, measuring instruments, etc.) which reproduce the work of control systems, monitoring and alarm systems of the UCD. The absence of traditional control and monitoring systems in the described training system is not a significant disadvantage. Since recently PCs are increasingly used in the UCDs of the power plants displaying on their monitors separate fragments of power unit layouts, their control and monitoring systems.

The block diagram of the EPPU model is shown in Fig. 3.

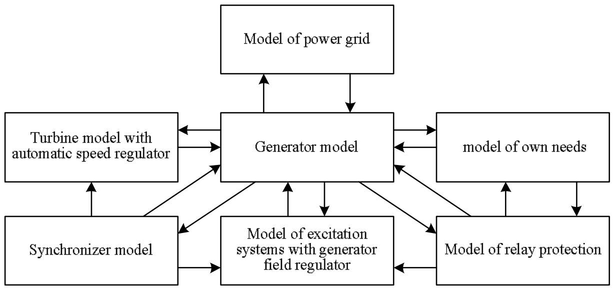

Fig. 3. Block diagram of the model of the EPPU.

The mathematical model of the EPPU and its digital implementation must meet the requirements imposed on the training systems for the control operators of the power plants which are as follows:

– main coordinates of the mode on models of measuring instruments should be simulated with accuracy up to 2 %, minor coordinates with accuracy up to 10 % [8]. Practically all coordinates of the mode of an electric part of the power unit are considered to be the main;

– the model must adequately respond to any actions performed by operating staff with the help of imitators of control systems of the EPPU;

– the model should be stable during significant time intervals (up to several hours);

– modeling of processes in the EPPU should be performed in real time.

The block diagram of the model of a separate component of the EPPU is shown in Fig. 4.

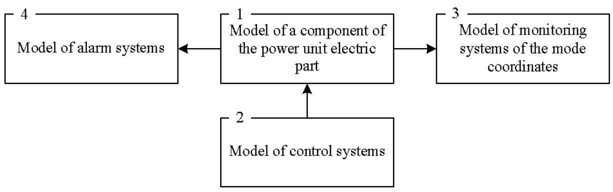

Fig. 4. Block diagram of the model of a separate component of the EPPU.

The model of technological equipment of the particular component of the EPPU, namely, a generator, receiving system, facilities, relay protection, turbine is implemented in Block 1. This model takes into account the state and position of control systems, namely, models of control switches, mode switches, strips. As a result of solving the systems of equations describing processes in technological equipment, mode coordinates are determined which are then reflected in models of measuring instruments used for monitoring of mode coordinates (Block 3) and in models of technological and emergency alarms, including sound alarm (Block 4) which indicates the position of switching devices, the condition of alarm boards, indicator lights, blinkers etc.

A special feature of the model of the EPPU is the simulation of technological processes in real time at significant time intervals and an adequate response to all actions of control operators. This requires the use of special tools and methods to create mathematical models of separate components of the EPPU [9]. Therefore, the implicit Euler method is used to solve differential equations. This made it possible to obtain stable solutions during modeling of processes in the EPPU in the case of significant disturbances, such as disconnection of the generator from the grid, loss of the generator excitation, various damages in the components of the power unit and so forth. This method is also sustainable while integrating the system of differential equations over long time intervals (training can be conducted continuously for up to several hours) with time integration step of 0,1 seconds. [7].

Being based on the mathematical models of the components of the EPPU with the use of object-oriented programming, a digital model of the EPPU was created [7].

The application of modern technologies of object-oriented programming made it possible to create objects reflecting separate components of the EPPU (turbine, excitation systems, generator, receiving system, facilities, relay protection, etc.) and control, monitoring and alarm systems of the UCD (control switches, selector switches, measuring instruments, annunciator panels, synchronoscope, etc.) with parameters corresponding to technological characteristics of real equipment. On the basis of these objects it is possible to create EPPU models of various types and capacity for both thermal and nuclear power plants.

4. Conclusions

To improve the quality of training the control operators of power plants, it is necessary to apply local training systems that imitate the technological processes in separate functional subsystems of the power unit.

The developed training system allows the control operators to acquire necessary skills in the operational control of the EPPU of both the thermal and nuclear power plants.

The training system is made using only PC tools which significantly reduces the cost of its development. It is easily adaptable for specific power units of power stations.

State-of-the-art development of computer software enabled creating more complex models of elements of the EPPU. These models allow real-time simulation of technological processes in the EPPU during normal, special and emergency modes with the required accuracy.

The training subsystem allows control operators' self-training while they are being taught the principles of operational control of the EPPU, as well as carrying out objective monitoring while checking their knowledge. Moreover, the direct influence of the instructor on the process of training is practically eliminated.

The training system for control operators teaching the operational control of the EPPU can be used both in training centers for operational staff of power plants and in the training process of students of electric power specialties.

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НАВЧАЛЬНА СИСТЕМА ДЛЯ ОПЕРАТИВНОГО ПЕРСОНАЛУ УПРАВЛІННЯ ЕЛЕКТРИЧНОЮ ЧАСТИНОЮ ЕНЕРГОБЛОКА

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Розглянуто доцільність розробки локальних навчальних систем для підготовки оперативного персоналу електростанцій.

Розроблено принципи побудови навчальної системи для підготовки оперативного персоналу з управління

електричною частиною енергоблока теплової електричної станції. Згадана система складається з двох підсистем: моделі електричної частини енергоблока та навчальної підсистеми. Модель електричної частини енергоблока включає моделі: енергосистеми, генератора, власних потреб, турбіни, систем збудження тощо. Навчальна підсистема дає змогу управляти процесом навчання та здійснювати контроль знань оперативного персоналу.

Розроблена навчальна система дозволяє персоналу навчатись оперативного управління електричною частиною енергоблока під час нормальних, особливих та аварійних режимів таких як: синхронізація генератора з системою (ручна, автоматична), перевід збудження генератора з робочої системи збудження на резервну та навпаки, синхронні хитання системи, несиметрія навантаження тощо тощо.

Навчальна система забезпечує самопідготовку персоналу під час навчання, а також об'єктивно оцінює його знання з оперативного управління енергоблоком. Її використання дозволяє підвищити якість підготовки оперативного персоналу теплових і атомних електростанцій.

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