High Voltage Direct Current Power Transmission Research Institute

Digital–analog–physical Complex the Unique Test Area of System Operator of the United Power System

Experimental Research Centre
«ELECTRODYNAMICS»

The experimental research centre «Electrodynamics» (ERC) was founded on the basis of JSC «NIIPT» department of power systems research. JSC «NIIPT» is a scientific center of the System Operator of Unified Power System (UPS) of Russia.

The main assignment of ERC «Electrodynamics» is the assistance in the formation and realization of a technical policy of System Operator regarding the maintenance, reliability, and controllability of UPS of Russia.

MAIN DIRECTIONS OF ACTIVITY

1. Complex research of controllability and system reliability of UPS of Russia, organizational and technological development of dispatching and management systems of UPS of Russia.

2. Carrying out experimental and research works using an electrodynamic simulator concerning the application in UPS of Russia of new equipment, including tests, certifications and adjustments «on a turn-key basis» of systems of regulation, automatics, protection and control.

3. Teaching and improvement of professional skills of experts in planning and management of power system modes, including the organization and carrying out experimentally-technological practical works on the basis of an electrodynamic simulator.

Meeting of Power Systems section (ERC «Electrodynamics») of Scientific Council of JSC «NIIPT»

PECULIARITIES OF DIGITAL-ANALOG-PHYSICAL COMPLEX

The Digital-analog-physical complex includes the world's largest electrodynamic simulator (EDS) of electric power systems (more than models of 1000 physical generators, prime movers, transformers, transmission lines, complex load, direct current transmissions, FACTS, etc.).

The analogue part of a complex consists of adjusted semi-conductor models of steam, hydraulic and gas turbines and their regulating systems and various types of models of automatic excitation controllers. The digital part of a complex – system of registration of experiments, representing some modern multichannel digital oscilloscopes and the service programs, allows making the subsequent processing of experimental data. Complex is equipped by devices, allowing representing emergencies in electric power systems and work of devices of the local and centralized emergency control systems, and also with the large number of transducers forming information-measuring system.

Control room of digital-analog-physical complex

Control panels of equipment physical models

Thanks to the large and multifunctional base of the main and accessory equipment, and the flexible system of planning of experiment and registration, complex is able to model electrical modes and electromechanical transients in power pools practically of any complexity **taking into account specific features of real installations**.

The complex is highly efficient, able to make experiments in real time and in conditions as much as possible approaching to operating. The conformity of nominal secondary voltages and currents of EDS instrument transformers to industry standards makes possible, integration of real control devices, regulators, automatics and protection with EDS.

BASIC DIRECTIONS OF DIGITAL-ANALOG-PHYSICAL COMPLEX APPLICATION

Comprehensive tests of new samples of microprocessor devices – allows to proceed complete examination of these devices, to eliminate latent defects in algorithms and software, to prepare basing on results of tests the expert judgment on their conformity to system requirements and the scientific and technical recommendations concerning application on objects in UPS of Russia.

Tests of excitation controllers are held according to the typical «Program of complex system tests of microprocessor automatic excitation controllers of synchronous generators» approved by RAO «UPS of Russia» and agreed with System Operator.

Reception of representatives of «Promindustiya» company together with ALSTOM specialists

Considering the importance of adaptation of AVR of foreign companys to operate in the conditions of the Russian electric power systems, the **carrying out of similar tests for all foreign AVRs is recommended to be obligatory by RAO «UPS of Russia» in case of AVRs application on objects of UPS of Russia** (Circular «About application of automatic excitation controllers for generators with the capacity 63–1200 Ì W»).

The conclusions and recommendation prepared from test results are used by manufacturers for finalization of field systems of generators, and participation in tenders for delivery of these systems in case of building and reconstruction of power stations.

Tests, check on functioning and adjustment «on a turn-key basis» of control devices, automatics and protection systems of a power system, station and power unit levels – provide the increase of system reliability of UPS of Russia;

Adjustment of AVRs «on a turn-key basis» – provides an augmentation of functioning reliability of power installations, decrease of **terms and volume of starting-up and adjustment works , makes their cost lower.**

Such adjustment is especially effective:

– **for hydro power stations** where both the hydrogenerators and their operating conditions have especially individual character;

– **for nuclear stations** where full-scale adjustment of an AVR on on the real object is essentially limited due to the safety reasons;

Development and tests of pre-production models of microprocessor devices, systems, and also new laws of regulation and control;

Complex research of the efficiency of new samples of the electrical equipment application in UPS of Russia;

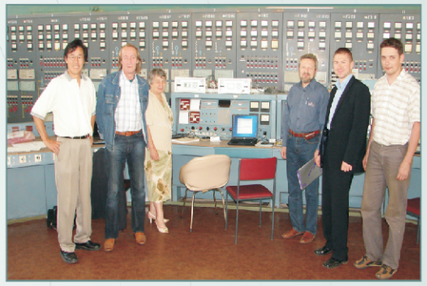
Complex researches of modes, stability, reliability and survivability of electric power systems of all levels of complexity.

EFFICIENCY OF TESTS USING DIGITAL-ANALOG-PHYSICAL COMPLEX

In particular:

digital excitation controllers of the foreign companies: ABB (Switzerland), Basler Electric (USA) – have been adapted for the working conditions of UPS of Russia. Based on results of tests, the recommendations to their application in UPS of Russia have been issued. As a result of adaptation of regulator DECS-400 the analogue of a relay of excitation boost has been added to its control law. That allowed to increase transient stability limits at normative emergencies approximately by 10 %.

Testing of ST5B AVR and PSS (PSS2B) of UNITROL-5000 excitation system (ABB, Switzerland) To the left – Davor Tomerlin (ABB)



Testing of DECS-400 (Basler Electric, USA). To the left – developer of the AVR Dr. Kim Kiyong, third from the right – head of the laboratory of physical modeling Esipovich A.

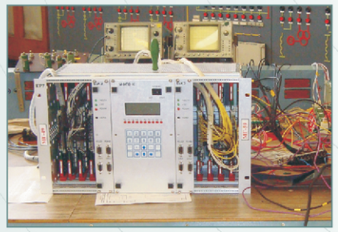
GEOGRAPHY OF WORKS OF ERC «ELECTRODYNAMICS»

THE MOST IMPORTANT WORKS PERFORMED DURING RECENT YEARS USING DIGITAL-ANALOG-PHYSICAL COMPLEX

Functioning tests and scientific and technical recommendations development concerning implementation in UPS of Russia:

– Microprocessor excitation controllers of domestic and foreign manufacture: ARV-M, 2Ì , 3Ì , Ì À (JSC «Power Machines», «Elektrosila»), AVR-2 (SC «Energokomplekt»), UNITROL-5000 (ABB, Switzerland), DECS-400 (Basler Electric, USA), ÀRV-NL (JSC «Elsib»), KOSUR-C (JSC «NIIElektromash»), AVR REM è AVR REM-700 (SC «RUSELPROM-ELECTROMASH»);

Digital excitation controller AVR REM (SC «RUSELPROM-ELECTROMASH»)



Digital excitation controller «KOSUR-C» JSC «NIIElektromash»

Digital excitation controller ARV-NL «ELSIB»

– microprocessor automatics of liquidation of asynchronous modes (ALAR-C (JSC «NIIPT»), ALAR-M (JSC «Energosetproekt»));

ALAR-C (JSC «NIIPT»)

Testing and adjusting:

– microprocessor excitation controllers of generators (Sajano-Shushenskaja HPP, Ust-Ylym HPP, Viljujsky-3 HPP, Zagorsk pumped storage station, Mosenergo cogeneration station ¹ 22, Leningrad NPP, Kola NPP);

– digital systems of group regulation of active power and group regulation of voltage and reactive power (Sajano-Shushenskaja HPP, Nizhniy Novgorod HPP, Zejsky HPP, Novosibirsk HPP);

Development and tests of pre-production models of microprocessor control and protection devices:

– Siemens devices for semi-automatic switching of the generating units of Northwest TPP from an electric power system of Finland to UPS of Russia and back;

– the block of a microprocessor protection of synchronous engines;

– modern converters based turn-off thyristors for creation of flexible connections and devices of compensation of a reactive power (STATCOM);

ARV-3M (JSC «Power Machine») testing for Leningrad NPP. Developer of the AVR Fadeev A.

Effectiveness testing of group regulation of voltage and reactive power device for Novosibirsk HPP

ARV-2M (JSC «Power Machine») testing for Zagorsk pumped storage station

Tests of new control laws for controlling the excitation of asynchronized synchronous generators (ASG) and electromechanical frequency converters on the basis of ASG:

– tests of the sample of the AVR for ASG 110 MW Mosenergo cogeneration station ¹ 22;

– tests using the control law of electromechanical frequency converter on a model of a digital regulator for a variant of nonsynchronous connection of IPS of Siberia and IPS of East;

Researches of variants of the Transbaikalian converting complex on substation Mogocha (classical DC transmission, DC transmission based on turn-off thyristors, electromechanical frequency converter);

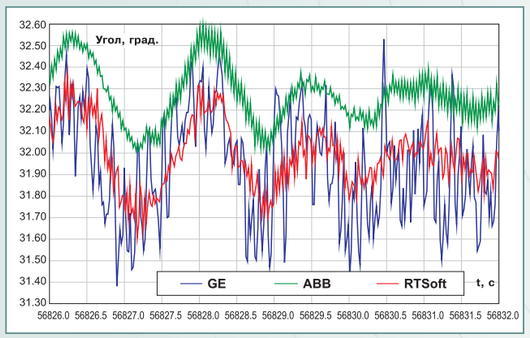
Scientific and technical support of WAMS implementation in UPS of Russia;

Comparative tests of digital registrars SMART-WAMS (RTSoft), RES-521 (ABB), terminals N60 (GE Multilin) and the Arbiter 1133A (Arbiter Systems);

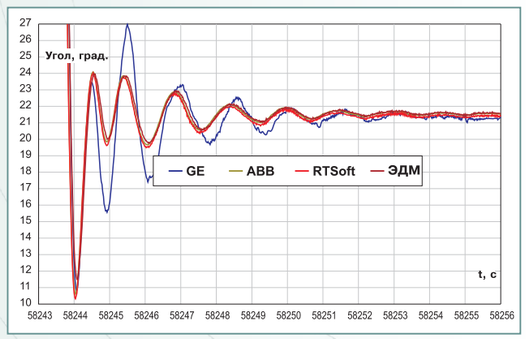
Comparative tests of various digital WAMS registrars

Chief engineer of General Electric Multilin Infante Otamendi Francisco

Results are considered by research supervisor of JSC «NIIPT» Koshcheev L. A.



Measurements results with large distortions of the voltage curve



Closing of the chain scheme

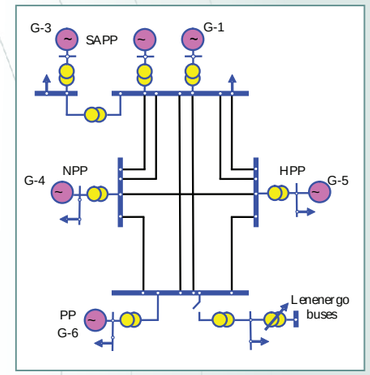
Complex researches of modes, stability, reliability and survivability of electric power systems:

- an electric power system «Three gorges», the Chinese National Republic;
- perspective schemes of interconnection of UES of Russia with UCTE.

TESTING OF PROTOTYPE MODELS OF MICROPROCESSOR AVR ON PROPER FUNCTIONING AND PROVIDING RELIABILITY AND STABILITY OF ELECTRIC POWER STATION DURING PARALLEL OPERATION WITH AN ELECTRIC POWER SYSTEM

The examinations of Russian and foreign AVR are implemented using a test scheme of complicated electric power system. An adequate picture of multifrequent motion in various scheme-regime and emergency conditions is obtained. The test scheme is developed in NIIPT and is included in the Digital-Analog-Physical Complex.

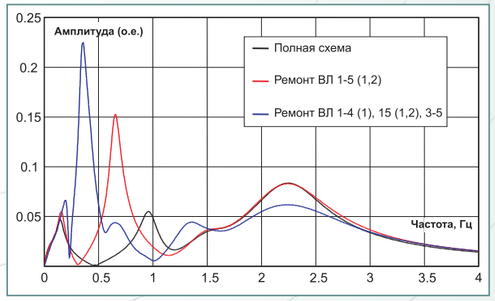
The scheme includes 6 synchronous power generators with their block power transformers, 5 complex load nodes, interconnecting autotransformer and 9 lines. Generators 1–3 represent the model of the heat station (state area power plant), equipped with three similar blocks operating with two bus systems of different voltage. Generators 1 and 2 are connected to the 500 kV bus system, generator 3 to the 220 kV bus system. Generators 4 and 5 represent the model of Nuclear power plant and Hydroelectric station, the 6th generator is an equivalent of concentrated power system. For the AVR examinations in the scheme of enlarged block a capability of scheme transformation is foreseen.



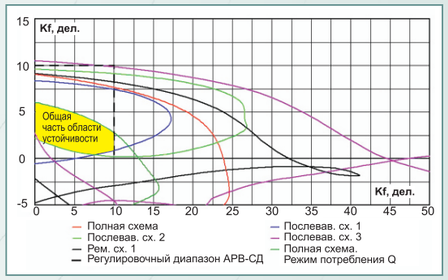
Test scheme of electric power system

Tested ARVs are installed on the 1st and the 2nd generators. In case of network transformation (disconnection of lines) the test scheme of the power system can be transformed from full polygon schemes to various chain-structured schemes, this provides wide ranged changes in carrying capacity of the network. That curcamstance allows to examine AVR systems during the rated and extreme dynamic disturbances, including the actions of counter-emergency automation.

Test scheme of Electrodynamics' simulator (EDS)



Operating conditions' frequency characteristics



The area of oscillatory stability of the equivalent generator of state area power plant, connected to the 500 kV bus system

Complex system tests of AVR REM and AVR REM-700. On the right there are scientist Sorokin D. V. and senior scientist of ZAO NPP «RUSELPROM-ELECTRONMASH» Bogachkov M. L.

The test scheme is equipped with regulators of basic EDS – automatic voltage, speed, frequency and power regulators, automation (modeling normative emergency disturbances and actions of counter-emergency automation), regime parameters' sensors and the system of digital oscillographing.

The typical program of AVR complex system tests, approved by RAO «UES of Russia» is implemented using the test scheme of the electrodynamical simulator. Detailed examination of voltage regulators is provided.

Typical program of complex system tests of microprocessor AVR includes:

– Implementation of standards' requirements on static stability and quality of electromechanical oscillations damping in normal, remedial or post-emergency regimes;

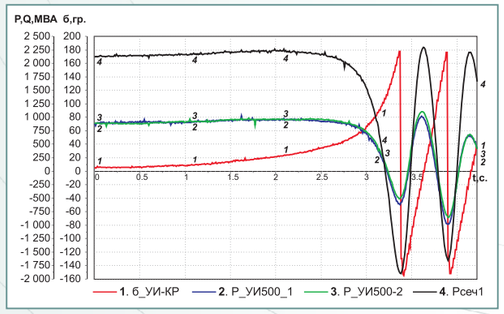
– Providing stability factor during the normative emergency disturbances in power systems, including parallel operating with emergency automation complexes;

– Control of full usage of rated capabilities of AVR power part;

– Proper functioning control of field current limiter and minimum excitation limiter during the dynamic disturbances;

– Examination of reactive power control stability and the quality of regime stabilization during parallel operation of two AVR in enlarged block of generators.

The area of static oscillatory stability



The character of stability violation at the selected tuning of system stabilizers AVR-M in test scheme

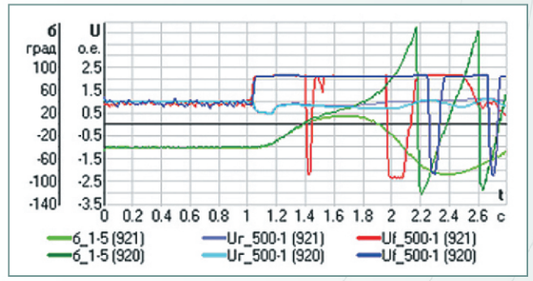
Stages of stabilization structure's efficiency tests (providing the static oscillatory stability and high quality of electromechanical oscillations damping in normal, remedial or postemergency conditions):

– Determination of generator static oscillatory stability areas. The areas are plotted in the axes of multiplication factors of stabilization channels for the group of typical regimes and selection of the common setting for regulator's stabilization channels;

– Damping quality estimation for the predetermined settings in the circumstances of various operation conditions of generator and power station during the small signal test disturbances;

– For the regimes limited by the terms of static oscillatory stability, with the predetermined setting tuned, stability violation character is detected.

The damping quality of large postemergency oscillations with the selected AVR setting tuned is verified during the normative emergency disturbances in the power system. There are three groups of disturbances provided by «Operating instructions for power system stability»: the emergencies with/without power and frequency balance variation (disconnections of divergent lines; single-phase, two-phase short circuits to earth, triphase shorts circuits on the divergent lines with their disconnection; sucsessfull SPAR (single-phase automatic reclosing) and TPAR of lines; disconnection of loads and generators in the recieving part of power system; short circuits with disconnection of two-chain transmission lines and with the failure of phase of curcuit breaker and operating breaker fail protection).



Efficiency evaluation of AVR-2 during the control of the excitator's power part in limit conditions

Discussion of the test results of AVR-NL developed by SPA «Elsib»

AVR tests are carried out in the conditions of heaviest emergency disturbances in the regimes, limited by the ranges of dynamic stability. This makes possible to evaluate the degree of excitation system rated capabilities usage and examine if the relay's boost works properly.

The tests are completed by issuing the scientific and technical recomendations for using the regulator on the objects of Russian UPS during the upgrade and new constructions.

ADJUSTMENTS OF MICROPROCESSOR AUTOMATIC VOLTAGE REGULATORS FOR CONCRETE POWER INSTALLATIONS «ON A TURN-KEY BASIS»

Tests, adjustments and tuning of KOSUR-C on the Kolskaya Nuclear power plant's generators. Senior staff scientist Kirienko G. V.

Executed according to the specially developed technology, which helps to:

– determine the settings of AVR and PSS commercial prototypes, according to the conditions of providing high quality damping during the low-disturbant motion in the circumstances of the scheme-regime peculiarities of the concrete station operation;

– test AVR and PSS during all rated emergency disturbances in the power system in the circumstances of counter-automation complexes actions.

Technology includes:

– Creation of the physical model on the basis of Digital-Analog-Physical Complex;

– Test program development;

– Testing the regulators and the tuning of their regulation and stabilization channels according to the test program.

Creation of the physical model includes following stages:

– Development of the etalon digital model of the power system, transient implementation and stability analysis;

– Creation of the equivalent of the power system and its relationship to the etalon model check;

– Physical model of the electrical scheme development;

– Selection of the equipment, tuning and assembly of the scheme, basic electrical regimes setting and test emergencies simulation, measurement and registration systems preparation.

The etalon digital model of the power system is created on the bases of scheme parameters initial data, information about scheme structure, current and perspective regimes.

ERC «Electrodynamics» has reliable digital models of power systems, including adequate models of system regulation of aggregate, station and system level. The verification of AVR and PSS digital models is implemented by comparing the frequency characteristics of the models and natural regulators. Verification of the turbine speed regulators models and other regulation devices of aggregate, station and system level is implemented by comparing their behavior in digital model with the data registered in the real power system.

Digital models of power systems are verified by the comparison with WAMS digital registrators data, recorded during various technology violations. Digital models of the power systems are developed on «SO UPS» demand for all the IPS (interconnected power systems). These models are used by appropriate IDO (interconnected dispatcher's office) for executing operational calculations and periodically are actualized by ERC «Electrodynamics».

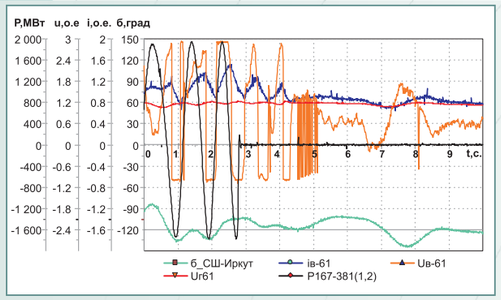
Electromechanical transients, regime's static aperiodic and oscillatory stability limits are estimated with the implementation of that model. This reveals scheme-regime peculiarities of operation of concerned power object (station, generator) in a power system and takes them into account at the creation of an equivalent scheme. Creation of an equivalent of etalon electric scheme is implemented with the special software complex developed in NIIPT, which provides an identical coincidence of operation parameters in full scheme and in the saved part of the equivalent scheme and saves the dynamical properties of the etalon digital model. The level of power system detail (size of the saved part) is estimated by the comparative calculations held in the etalon and equivalent schemes. A specified permissible error of equivocation, which as usual doesn't exceed the permissible error of the source information (approximately 5%), becomes the criterion.

On the basis of the rated researches the physical model of power system is created. Its size doesn't depend much on the dimension of etalon scheme, but on the scheme-regime conditions of the operating station's generators in electric power system. The level of station detailing depends on the main scheme, equipment configuration and current tasks.

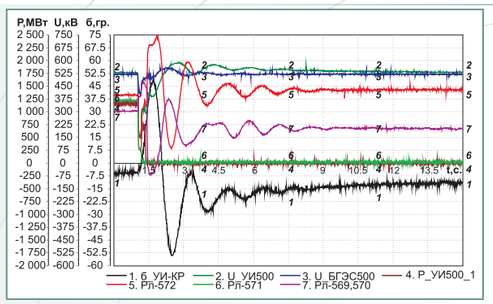
The program of system examinations for voltage regulators adjustment and tuning is formed on the basis of typical program described above, taking into account the peculiarities of the station, its power system contiguity scheme and the concrete tasks being solved.

For example, during researches on AVR-M for Ust'-Ilimskaya hydroelectric station generators, stagial upgrade of excitation system was taken into account. Wherefor, joint operation of this regulators and the unmounted AVR+PSS was researched. The research concluded with the correction of the AVR-M regulation law (according to the circuimstences of the joint operation with AVR+PSS), this provided the possibility of upgrading the station generators' exitation systems in any sequence. Besides, during the tests **the possibility of generator excitation voltage boost ration significant reduction** without changing the setting of central emergency automation complex of Bratskaya hydroelectric station, was confirmed.

During the tests of voltage regulators on Sayano-Shushenskaya HPP the efficiency of the selected setting was examined by modeling the system failure which entailed stability violation of parallel operation of Siberian IPS on the cut set Krasnoyarsk, Hakassiya-West.



Estimation of AVR efficiency at the liquidation of system failures' consequences



Two-phase short to earth at the Ust'-Ilimskaya HES 500 kV bus system with the disconnection of line 571 at the breaker's phase fault and operation of breaker fail protection with taking into account the operation of CCEA complex of Bratskaya HES

DIGITAL-ANALOG-PHYSICAL COMPLEX COMPOSITION AND KEY SPECIFICATIONS

The Digital-analog-physical complex is allocated in a separate laboratory-technological building of NIIPT with a total area of 2,700 square metres occupying three main floors and two cable semi-floors. The ground floor is a machine hall housing simulators of synchronous machines with driving movers simulating primary ones: asynchronous motors simulating power system dynamic load and resistances simulating resistive load.

Laboratory-technological complex

Generators and loads panels

The first floor is occupied by simulators of transformer substations, transmission lines, infinite buses. The second floor houses a control room.

SYNCHRONOUS MACHINE SIMULATORS

66 synchronous machine simulators with 1.5, 2, 3, 5, 10, 15 and 30 kV A power ratings are available. The rated stator voltage is 230 V, the rated rotation speed is 1,000–3,000 RPM.

The machine simulator differs from a standard low capacity machine by its special desing of stator and rotor cores, as well as by its overall capacity exceeding that of real machines by several times.

This allows it to withstand long overcurrents and overvoltages without any damage to the equipment and facilitates the adjustment of parameters (x_d, x_d', x_d'', T_{d_0} ,magnetization curve) providing for their conformity to real ones.

The possibility of simulating different generator types (hydro and turbine) and synchronous compensators is provided by the necessary supply of accessory rotors and the ongoing adjustment of unit mechanic inertia by selecting and installing the accessory discs on a rotor shaft.

Generators and primary motors

Especially convenient for simulation purposes are the developed in the NIIPT modified machine simulator units with the three phase network winding on the rotor and the field winding on the stator.

In these units the parameters to be simulated are adjusted by a variety of techniques: changing the air gap between rotor and poles, selecting and fitting accessory spacers between yoke and pole, changing the position of steel rods in the holes of pole yokes, and using special magnetic shunts in damper winding slots on the stator.

Conformity of the most important for proper simulation parameters (field circuit time constant (T_{d_0}),boosting and deboosting factors) to real ones, makes possible to model a great variety of synchronous machine excitation systems.

In order to adjust the T_{d_0} values of synchronous machine simulator units, the NIIPT systems of utilizes excessive winding resistances. The effect is achieved by adding into the field circuit an additional EMF proportional to excitation current and inverse to the voltage drop in the resistance of the loop.

Various types of automatic excitation regulators are simulated by means of a universal analog unit specially developed and manufactured in NIIPT. The unit permits using several regulation channels with variable (controlled by an external signal) gain coefficients: for proportional control systems by stator voltage deviation; for system stabilizers additionally by a stator voltage derivative, deviation and first derivative of voltage frequency on the output terminals and a rotor current derivative. The regulator comprises a boosting and deboosting device operating when stator voltage reaches assigned minimum and maximum values, as well as additional inputs for implementing various programmed effects from protection and emergency control devices.

As mentioned above, Digital-analog-physical complex enables the connection of real devices, in particular, industrial system stabilizers of different types.

PRIME MOVER SIMULATORS

For adequate representation of long transients (1 s and longer) it is essential to provide in the Digital-analog-physical complex the identity of prime mover simulator characteristics to real ones for a prime mover with all automatic regulation systems. In some cases the transients in steam generators and their automatic regulation systems (ARS) should be accounted for.

Generators and primary motors

Hydraulic and steam turbines, boilers and their regulation systems are simulated in the Digital-analog-physical complex by DC motors fed by controllable thyristor convertors with control systems which are in fact analog simulators of a boiler, a turbine and their ARS.

Developed in NIIPT and installed in Digital-analog-physical complex are universal analog devices – «Power unit simulator» – in three modifications – from the most comprehensive to the most simplified ones. The comrehensive power unit simulator is described by a system of 12-th order non-linear differential equations and provides adequate representation of:

– all the basic time constants of turbine, boiler and their ARS;

– turbine and its ARS non-linearities including valve stroke asymmetry, as well as valve stroke characteristics of high and medium pressure parts depending on control signals;

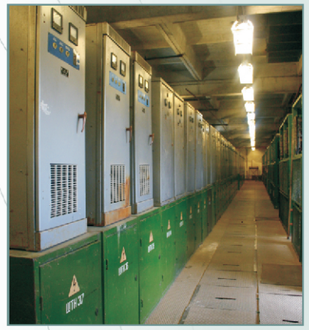
– ARS insensitivity area to frequency (rotation speed) change;

– power reserve value (constraints);

– power ratio of high, medium and low pressure parts;

– intermediate steam overheating;

– possibility of effecting the power unit by various channels from protection and emergency control automatic devices.



Thyristor converters

Also available in Digital-analog-physical complex is an analog unit simulating a hydro turbine.

A comprehensive hydro turbine simulator described by a system of 8-th order non-linear differential equations reproduces the torque-speed characteristic of a turbine, speed regulation characteristics and even accounts for the transients in a pipeline (a hydraulic shock).

POWER TRANSFORMER SIMULATORS

150 power transformer simulators available within the Digital-analog-physical complex provide the representation of any assigned characteristics of step-up and step-down transformer substations. Practically all transformer simulators are embodied as single-phase, two-core, two-winding, open or air-cooled. Transformer inductive impedance is changed either by using asymmetrically allocated windings or a special magnetic shunt.

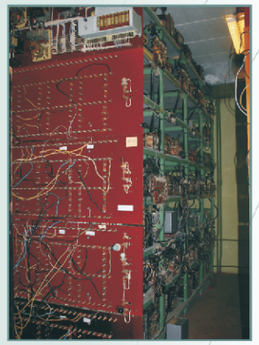
Three-phase groups of most of transformer simulators have rated capacity of 6 kV A and 20 kV A. The first group transformers are intended for 3–5 kV A synchronous machines, and the second group ones for 10 kVA and larger synchronous machines. All the transformers have equal rated voltages – 220–127/1024 V.

High voltage windings have 36 taps, low-voltage ones have 8 taps. This permits to vary the transformer turn-ratio within a wide range. The transformer design provides for reduced losses in steel and decreasing no-load current. The total amount of active power losses in the nominal conditions of transformer operation does not exceed 2%.

AC TRANSMISSION LINE SIMULATORS

Each phase of a three-phase transmission line is simulated by one or several cells, which are Pi-type equivalent circuits, comprising self-induction coils and capacitors having the necessary Q-factor. There are 700 Pi-cells in Digital-analog-physical complex which provide the representation of high-voltage and distribution networks of high degree of complexity.

While studying electromechanic transients in a 50 Hz network the required accuracy is provided by simulating transmission line sections up to 250 km with one cell.



Power transmission lines

The rated voltage of transmission line simulator is determined by selecting the corresponding scale. For high voltage line simulation, 1 V of the simulator corresponds approximately to 1 kV of the real system. In NIIPT the experiments in the Digital-analog-physical complex are carried out for high voltage networks up to 1150 kV with adequate representation of normal and emergency (symmetrical and non-symmetrical) operating modes of various transmission line types: one-circuit, two-circuit with a ground wire and without it, higher transfer capability, compact, adjusted, etc.

DC SIMULATOR

The simulator of DC transmission lines and convertor substations comprises the following components:

– 20 two-bridge 12-phase thyristor convertors;

– maximum rectified voltage of a convertor pole is 2,5 kV, maximum operating current is 10 A;

– 20 groups of power transformers with sectioned windings;

– nominal transformer capacity is 6,67 kV A, nominal voltage of a network windings is 500 V, nominal voltage of the winding feeding a bridge is 720 V;

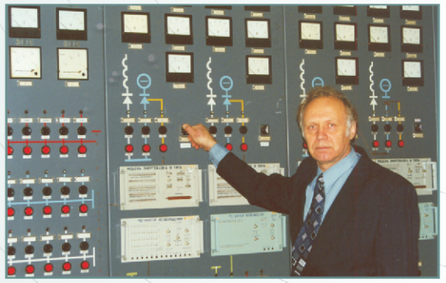
– 20 bar-type linear reactors with an accessory yoke used for simulating five cells of a DC line simulator;

– a set of reactors and capacitors providing the simulation of pole and «ground» inductances, mutual and intrinsic conductor capacitances;

– 20 sets of three-phase 5, 11, 13-th harmonic and wide-band filters;

– 20 fast response regulators of thyristor convertors. Each of the regulators includes the regulation subsystems of rectified current, minimum current and margin angles of invertor unit automatic and protection system, central power regulators (when simulating a DC network) and measuring systems on DC and AC sides;

DC power transmission, SR, Series capacity device, STC, STATCOM



The manager of experimental-research sector Michurin N. A.

– 40 sets of executive devices converting the output control impulses of regulators into the signals controlling bridge thyristors.

SIMULATORS OF ELECTRIC LOAD NODES

The Digital-analog-physical complex comprises 166 electric load nodes formed by the combination of asynchronous-motor, shunt and convertor loads. This combination permits to reproduce any specified static and dynamic load characteristics.

The power part of load simulator units has two embodiments:

– 20, 14, 10, 7, 4.5 kW asynchronous motors (30 units) have on their shafts DC generators supplying power into the network across a thyristor invertor (recuperation) or through the switcher of the single phase resistors. Adjustment of thyristor invertor ARS specifies characteristics of an electric load.

Loads models

– Motors of lower than 4.5 kW (50 units) capacity also operate in combination with DC generators which supply power to resistors.

When comprehensive simulation of load synchronous motors is needed, generator simulator units are used.

Load nodes have additional power commutators intended for selecting the shunts connected to the given load node.

SWITCH BOARDS

The power circuit of a power system simulator is assembled on switch boards having the cable outputs of generator node transformer, transmission line and load node simulators. The number of power connections from transmission line simulators varies with the network simulator.

Switch boards and cable connections equipped with joints (connectors) facilitate the assembling of power circuits, since no temporary jumper cables are needed.

DIGITAL-ANALOG-PHYSICAL COMPLEX CONTROL SYSTEM

The control board comprises control and supervision devices enabling a researcher to set the design operating mode of a considered power pool, to change it in the desierd direction, to arrange a design emergency situation, to provide a definite sequence of actions of automatic devices aimed at clearing the emergency situation, as well as devices simulating the actions of system automatic devices operating in post-emergency operating mode.

Digital-Analog Physical Complex control room

The Digital-analog-physical complex control system has two-levels. The power plant (substation) level is formed by generator and load control boards which provide triggering of all units, synchronization of generators and synchronous compensators, connection of loads.

Initial regime controlling.
Senior staff scientist Guschina T. A.

The adjustment of a design operating mode is done at system control level from special panels having excitation and generator speed control devices, as well as laboratory instruments for measuring rotation speed, phase angle of generator rotors, voltage at their terminals and at substation buses, real and reactive power generated by power plants, and power flows in transmission lines.

For the sake of convenience, control bodies and control devices of each power plant simulator are allocated on separate standard units (developed in NIIPT) which are connected to the circuit by flexible jointed cables, and are installed on laboratory tables, which form the Digital-analog-physical complex system control board.

In order to control commutation apparatus according to a predetermined time program (short circuit, automatic reclosure, etc.) electronic computer programmed devices provide the possibility of executing a large number of commands with accurate time settings in 0.01 s steps.

SYSTEM OF EXPERIMENTS REGISTRATION

Implemented for electrical signals recording and analysis of that data using a PC.

Includes an input unit, PC with D to A and A to D converters and software for digital oscillographing.

Digital oscillograph.
Tests are performed by engeneers
Kuzminova A. A.and Kabanov D. A.

Provides:

Input signals are recorded simultaneously using 32 analog channels. Signals are galvanic isolated from the PC and each other. Relative error of measuring constant and variable signals by each of the channels doesn't exceed 1%;

Period and duration of input signals scan (over 0.125 ms) can be defined;

Synchronization of scan frequency with the frequency of the investigated scheme;

Overview and analysis of the process in general or by separated parts is available, using specially developed software.

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