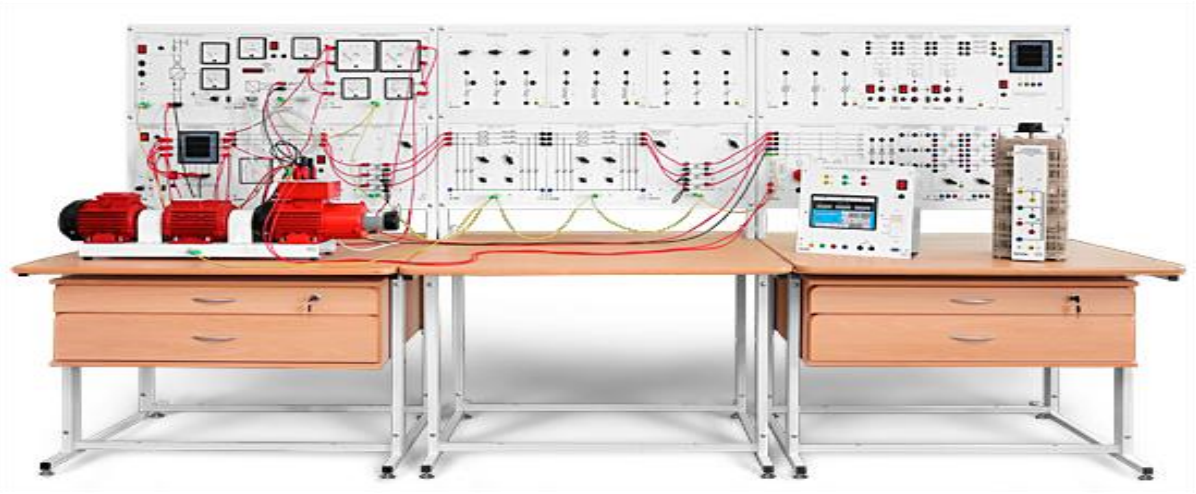
MINISTRY OF EDUCATION AND SCIENCE
OF THE REPUBLIC OF KAZAKHSTAN
Rudny Industrial Institute

KHABDULLIN A.B.

EDUCATIONAL HANDBOOK



"INTRODUCTION OF THE ELECTRIC SYSTEM MODEL IN THE EDUCATIONAL PROCESS OF THE SPECIALTY "POWER ENGINEERING "

Rudny, 2018

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The manual reflects innovative technologies introduced in the educational process in the specialty "Power Engineering".

The first chapter provides information on the role and importance of innovative technologies in the educational process of the electric power professions. The theoretical material is given and the procedure for introducing innovations is shown.

The second chapter gives information on the technical description of the laboratory stand "Model of the electrical system". The role of each module on the stand is described.

The third chapter outlines the practical application of the laboratory stand in the educational process in the discipline "Electrical networks and systems". Implemented in the educational process is a real laboratory bench, the management of which is carried out using a software package

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CONTENTS

INTRODUCTION

Modern requirements of science and technology require the preparation of highly qualified engineering personnel. The problem of improving the quality of education is the most important and discussed topic. The quality of education is determined not only by the level of knowledge and skills of the teachers of the department, but also by the intellectual, strong-willed abilities of the students themselves.

We, the teachers, have to answer questions like how to work on the technology of teaching at the level of modern development of science and technology, what forms of the educational process, methods and means of teaching, how to ensure the formation of elements of professional competencies in accordance with the State Standard and Standard Programs.

Technical discipline includes theoretical, practical and laboratory studies aimed at acquiring students with necessary knowledge, the formation of appropriate general cultural and professional competencies. The latter in the basic, refers to the ability to apply theoretical positions (knowledge) to the solution of practical problems. The degree of mastering the material by students depends on the following factors: the level of students' preparation, the qualifications of the teachers themselves, the material base of the department, the methodological support of the discipline, the content of the teaching and methodological complexes of the discipline being read.

It is difficult to influence all factors at the same time, but every teacher should strive to improve the quality of students' education. To solve this problem, new organizational and methodical approaches are required, innovative modern equipment.

The issue of training technical personnel has close interaction with the process of industrial modernization. There are three types of barriers to modernization within enterprises. First, these are barriers in specific technical tasks. This barrier is removed by the purchase of new innovative technical equipment. Secondly, barriers in business processes. To do this, it is necessary to create conditions for the enterprise to be effective. Third, cultural barriers. The issue of training highly qualified personnel refers to the third type of barriers.

Industrial enterprises and social facilities need new personnel that have knowledge in accordance with the needs of enterprises and modern realities. At present, for industry, the system of training scientific and engineering personnel requires in-depth analysis and an early resolution of this issue. The industrial push in the Republic of Kazakhstan is based on a fundamental education and a unique engineering school.

Therefore, in order to adapt students' preparation to the specific requests of our partners, we develop and implement new curricula and programs that are coordinated with the management of industrial enterprises. The innovations introduced by us, although having their own zest, remain in line with traditional approaches to the training of modern specialists. At the same time, we proceed from the fact that the learning process can be improved. At the Department of Power Engineering and Heat Power Engineering, we closely monitor the quality of our graduates' preparation, their employment, and observe the graduate's career growth.

The modern educational process in higher education is characterized by intensive use and introduction of new innovative and information technologies.

The use in the educational process of new innovative and information technologies poses the task of their optimal combination with traditional methods of teaching.

Chapter 1. Modern trends of preparing high qualified personnel

1.1 The role of innovative development in the training of personnel in the energy sector

Many university professors, leading special disciplines ask the question, what should be the occupation for mastering by students the maximum of what is given to them.

At present, training of a specialist of a new quality is required. The society needs not just a literate worker, but a specialist capable of self-education, oriented to a creative approach to business, possessing a high culture of thinking, and a multi-faceted person.

It is necessary to teach the graduate the ability to learn all his life, and for this the teacher needs to be able to constantly update the techniques, collaborate with the new generation, fit into the ever-changing environment, encourage students in their creative attitude to the subject, using various non-traditional forms and methods of teaching, innovative technologies.

Innovation is a theoretically grounded, purposeful and practical-oriented innovation.

The purpose of innovative education:

- ensuring a high level of intellectual, personal and spiritual development of the student;
- creating conditions for mastering the skills of presenting the material;
- training methodology of innovations in socio-economic and professional spheres.

Traditional educational process in universities gives students academic knowledge, but the binding of this knowledge to a specific professional activity occurs sporadically, when doing a course work, when passing pre-diploma or production practices. It is difficult to equip a student with real professional knowledge and qualities. Innovative education is focused on the formation of professional knowledge and qualities in the process of mastering innovation dynamics. The concept of professionalism becomes an integral quality of the graduate, which he synthesized himself in the process of studying at the university choosing his own trajectory of training. The student's awareness of himself as a professional influences the outcome of the educational process, as it activates the motivation for self-development, transforms the learning process into a source of satisfying the needs of the developing personality. As a result, the student realizes a real transition from a formal legal to a state of actual anthropocentrism.

Emphasis is placed on personal-oriented technologies - training in cooperation with the enterprise, the method of projects, technologies of individualization and differentiation, different level training.

The technology of individualization finds wide application in conducting classes of disciplines with the course project, diploma design. The successes of the graduate of the university in the protection of course or diploma projects indicate the effectiveness of the work.

The technology of collective learning is widely used in conducting classes in the form of seminars, talks, discussions, dialogues as a result of which there is a solution of the problem situation posed to the student.

Training in cooperation in the university is carried out when conducting laboratory and practical work on the disciplines of a special cycle by the dual training method. The stimulation of interest in the subject, the activation of the student's creative activity, the formation of skills for independent cognitive activity in them is achieved when conducting classes in an unconventional form-discussions, seminars, a round table.

The binary form of structure training and character differs substantially from other types of training, from traditional theoretical and production occupations. It provides not only a holistic connection between theory and practice, but also unites the themes of basic knowledge of several special disciplines that have a common technological nature.

The basis of binary training is the step-by-step organization of cognitive and practical activities of students. Such classes are held lively, emotionally, in the atmosphere of high activity of students and cover the material of several disciplines.

The system was the holding of conferences during the specialty weeks of the specialization following the results of students passing industrial practices (technological and pre-graduate), in which students from third and fourth years of the specialty take part. At the conference, students share their impressions received in practice, confirm that the practice is aimed at mastering professional work in the specialty; consolidation, expansion, deepening and systematization of knowledge gained in studying the special cycle disciplines, acquiring initial practical experience, developing professional thinking, testing professional readiness for independent work activity, studying work to ensure traffic safety and labor protection in enterprises. Students had to use their theoretical knowledge in carrying out specific assignments of enterprise specialists.

Innovative technology means a system of checking students in the knowledge of special disciplines. Modern methods of measuring the level of student preparation, focused on the use of computer technology (computer testing) and fully responding to the realities of the present, provide fundamentally new opportunities, improve the effectiveness of any teacher of the university. The advantage of these technologies is that they provide new opportunities for the student. A student from an object of learning turns into a subject of learning, consciously participating in the learning process and independently making decisions. With traditional control of information on the level of preparation of students, the teacher was fully in command and fully disposed. With the use of new computer methods of collecting and analyzing information, it is accessible to students. Allows you to consciously make decisions related to the course of the educational process, to make students and teachers associates in school. The strength of computer test knowledge control is the ability to cover a large amount of material during the testing process and gain a broad view of the student's knowledge, which makes it possible to significantly increase the objectivity, detail and accuracy of the evaluation of learning process results.

As an object of innovative technologies in the teaching of special disciplines, an enormous role is played by the teaching and research activity of the process of joint work of students and teachers, consisting of the main stages characteristic of research: the formulation of the problem; studying theory on this topic; selection of research methods and practical mastery of them; collection, analysis and generalization; drawing conclusions. Educational and research activities are of a scientific nature. Scientific research activity is a concrete form of scientific work. Comprehensive, reliable study of the object, process, phenomenon, their structure, relationships and relationships on the basis of principles and methods of cognition developed in science with the aim of obtaining not known knowledge of them and using this knowledge in their practical activities.

In the process of carrying out research projects and assignments, the student takes on certain research skills: to work with scientific literature, to select and analyze the necessary information, to see the problem of research, to develop a hypothesis, to define concepts, to reason and logically express thoughts in written and oral form, algorithms of activity, provide detailed evidence; objectively assess their achievements.

Conducting classes of special disciplines using video material, computer presentations is a powerful stimulus in teaching. The mental processes of students are activated: perception, attention, memory, thinking; much more active and faster is the excitement of cognitive interest. Information technologies present information in various forms and make the learning process more effective. Saving the time required to study a particular material is 30%, and the acquired knowledge is saved in memory for significantly longer. The use of ICT in conjunction with properly selected teaching technologies creates the necessary level of quality of instruction, variation, differentiation and individualization of instruction.

Based on the above material, it is necessary to concretize the following conclusions:

- the mastering of new material improves, students easily perceive the information provided;
- in the course of work students develop spatial and logical thinking;
- the optimization of the pace of work of students is naturally achieved;
- there is an opportunity to create a problem situation with the help of computer animation, the students are motivated by learning activity.

Occupation using computer presentations has a higher efficiency compared to the usual occupation.

The main task of the teachers of the Department of Power Engineering and Heat Power Engineering is the preparation of students for the forthcoming work activity, the middle manager and the top level of enterprises. In turn, preparation for work includes:

- Arming with the basics of knowledge;
- the formation of professional skills.

The future specialist should be able to plan his work, make an operative decision on the basis of an analysis of the situation, make calculations, monitor the progress and results of his work.

Skills are formed in the course of work. To develop the skill, it is necessary to repeat the actions, exercise, training. The formation of skills occurs in the process of repeated fulfillment by students of the corresponding tasks: tasks, training tested tasks, various calculations, analysis of situations, real practical laboratory work.

The essence of innovative technologies aimed at developing skills is to ensure that students fulfill tasks in the process of solving which they would master the methods of activity.

Consequently, the leading functions of modern innovative education include:

- intensive development of the personality of the student and teacher;
- democratization of their joint activities and communication;
- Humanization of the educational process;
- orientation to creative teaching and active learning, the student's initiative in shaping himself as a future professional;
- modernization of the means, methods, technologies and material base of training that contribute to the formation of innovative thinking of the future professional.

1.2 The main priorities for the training of highly qualified personnel in the specialty "Power Engineering" at the Rudny Industrial Institute

The Rudny Industrial Institute is a regional technical university that provides personnel with the needs of the economy of the region and the Republic of Kazakhstan. The history of the Rudny Industrial Institute is closely intertwined with the history of the region's largest ore mining and processing enterprise - Sokolovsko-Sarbaiskoye Mining and Processing Association (formerly Sokolovsko-Sarbaisky Ore Mining and Processing Enterprise). In the late 1970s, the Rudny Industrial Institute was, practically, the only technical university in the entire northwestern region of the KazSSR, which determined it as the main base for the training of engineering and technical personnel for the mining, construction and energy industries. In the difficult years of the emergence of independent Kazakhstan, when the demand for engineering personnel was reduced, it was possible to maintain the basic personnel potential and the material base of RII. At present, the Rudny Industrial Institute is a modern scientific and educational complex in the field of technical sciences with a developed infrastructure.

In the structure of the Institute there are 3 faculties (Mining and Metallurgical Faculty, Faculty of Energy and Information Systems, Faculty of Economics and Construction), 7 departments. Students are trained in 18 bachelor's specialties in the state and Russian languages in full-time, evening and correspondence forms of study on the basis of general secondary, technical and vocational, higher education.

Over the years, more than 25,000 specialists with higher education have been trained at the Rudny Industrial Institute, many of whom have become major managers, businessmen, civil servants and outstanding scientists.

The students of the specialty "Power Engineering" are taught at the Department of "Power Engineering and Heat Power Engineering" of the Faculty of "Power Engineering and Information Systems" since 1995.

Specialty "Power" according to the results of the independent rating of universities of the Republic of Kazakhstan in the areas of training specialists of 2016 conducted by an independent agency of accreditation and rating takes the 5th place out of 10 universities of participants.

In recent years, the university has been actively updating the educational and laboratory facilities. The use of various technologies for promoting educational services at the department is of a systemic nature:

– the specialty "Power engineering" is significant for the region and for the Republic of Kazakhstan;

– the specialty is updating the educational and laboratory base for special disciplines;

– there is a close relationship with the industry of the region and the RK;

– there is a demand for graduates in the labor market, a high percentage of graduates' employment - 95%;

– modular structure of training, evenly distributes the load and provides constant monitoring of the student's work;

– the academic mobility of students in Kazakh and foreign universities is applied to the specialty;

– the specialty "Power Engineering" passed international specialized accreditation in December 2016;

– on a specialty the system of dual training is intensively developing;

– information-switching technology is being introduced into the educational activity of the specialty;

– the model of 3 languages is being introduced.

Priority directions of the development of the specialty "Power engineering" are:

1. Ensuring the quality training of competitive personnel:

– the opening of postgraduate education programs for magistracy in the specialty "Power Engineering" in 2017-2018 academic year

- during the period 2017-2021. a set of works will be carried out aimed at preparing modern training courses, creating a new competence model for a graduate of the specialty "Power Engineering";

- participation of students in the specialty in the implementation of the social project "Mangylik ezh zhastary - industriya!";

- From 2017 it is planned to introduce the elements of the dual system of training and personnel training in the educational process with specialists of the Sarbaisk Interconnystem Electric Grids Branch of KEGOC JSC, SSGPO JSC, Saryarka Avtoprom and TOO Ardzhan Firms, Rudnensky Branch ". It is planned to conduct joint training sessions, defend diploma projects, pass educational, industrial pre-diploma practices by students;

- Strengthening of the personnel potential by inviting graduates of the master's degree, Ph PhD in the specialty "Power Engineering" with teaching in Russian, state and English;

- Inviting practitioners to conduct classes in the disciplines of the specialty in the framework of dual training;

- invitation of leading teachers of Russian and foreign universities for lecturing in English;

- participation of teachers and graduates of the department in the international program "Bolashak";

- introduction of anti-corruption technologies to the specialty, by improving the admission of examinations, credits, course and diploma projects;
- replenishment of the library fund with educational literature and literature of foreign and domestic authors on the educational program in the state and English languages.

2. Modernization of the content of educational programs in the context of global trends.

- development of 3 language education in the specialty;
- the introduction of information and communication technologies in the educational activities of the specialty in order to improve the quality of educational services, increase the level of specialists, the development of distance education, the introduction of the educational program "Electric Power Engineering" software ElectronicsWorkbench, VisSim, MathCad, MATLAB, licensed versions of which are available at the department AISiBpo to the disciplines:
- "Industrial Electronics"
- "Mathematical problems and computer modeling in the electric power industry"
- "Computer-Aided Design Systems in the Electric Power Industry"
- "Transient processes in the electric power industry"
- "CAD in the Electric Power Industry"
- "Theoretical Foundations of Electrical Engineering"
- to attract teachers with knowledge of the English language and to prepare training and methodological support in the disciplines of the specialty in English:
- "Electrical networks and systems - 2017;
- Renewable energy sources - 2018;
- CAD in the electric power industry - 2019.
- creation and acquisition of virtual laboratory complexes for the following disciplines:
- "Mathematical problems and computer modeling in the electric power industry";
- "CAD in the electric power industry";
- "Industrial electronics";
- Theoretical Foundations of Electrical Engineering.
- acquisition of complexes of laboratory equipment for the following disciplines:
- "Electrical networks and systems"
- "Electric stations and substations"
- "Technical means used in EE"
- "ACS and reliability"

- "Electrotechnical Materials Science"
- "Electrical apparatus"
- «Industrial electronics»,
- "Theoretical Foundations of Electrical Engineering".
- development of the specialty of external and internal academic mobility:
- training in the far and near abroad;
- training in universities of the Republic of Kazakhstan;
- the passage of production practices in the IASTE program in the far and near abroad;

- development of entrepreneurship skills among students of the specialty by involving them in seminars, advanced training courses, conferences, participation in scientific circles of the Department of Economics and Management.

- regularly adjust educational programs in accordance with the requirements of Industry 4.0

- modernization of the educational program including the introduction of the specialization "Energy Saving and Energy Resources" in accordance with the requirements of JSC "KEGOC", JSC "SSGPO" and LLP "Saryarka Avtoprom"

3 Development of the infrastructure of the department:

- giving an attractive appearance to the chair "Power and Heat Power Engineering";

- creation of an innovative laboratory of "Energy-saving technologies";

- development and equipping of the appearance of all laboratories of the specialty "Power Engineering";

- additional certification of graduates of the specialty within the framework of the work center training center (qualification of Electrician for repair of electrical equipment of power plants "," Electrician for power networks and electrical equipment "," Electrician (of all names) ";

- development of information structure of the department;

- introduction of the system for supporting the development of the specialty "Electric Power" by attracting the branches of the department, the base for the passage of all types of practices;

- Acquisition of a set of devices for energy audit of tasks and facilities: power quality analyzer, current clamp, luxmeter, laser rangefinder, pyrometer, diagnostic instrument for measuring insulation 10kV.

- Conducting refresher courses for employees of enterprises of the Northern region in the amount of 96 hours in the direction "Electricity supply of industrial enterprises"

- newly acquired new innovative equipment to adapt:

- to the educational process;

- to perform contractual works;
- used in scientific research and scientific circles
- to attract school leavers to the specialty "Power Engineering" by participating with reports at the sectional units held in the regional student conferences of the faculty, university.

4 Ensuring the effectiveness of research and their contribution to the industrial and innovative development of Kazakhstan:

- Strengthening the scientific potential of the department by training teachers in PhD, and graduates of the Bachelor's program in the Master's program;
- Preparation of a package of documents for the opening of postgraduate education in the specialty;
- publication of articles by faculty members in journals with high ratings (impact factor);
- participation of teachers and students in international republican conferences;
- submission of applications by teachers of the department and obtaining an author's certificate;
- implement a pilot project to conduct energy audit of the buildings of the university;
- develop a comprehensive energy-saving plan with the extension of this experience to other industrial objects.

5 Education in the student youth of new Kazakhstan patriotism, strengthening of spiritual and moral values; the national idea of "Mongilik El" and the culture of a healthy lifestyle:

- to carry out various measures to develop patriotism and a healthy lifestyle for students.

The implementation of the above measures will allow:

- to improve the quality of the specialty educational process;
- Develop new training programs using modern equipment;
- on the basis of application in the educational process of progressive training systems to increase the competitiveness of graduates;
- the use of modern equipment in the educational process will raise the contingent of students in the specialty;
- Increase the publishing activity of teachers and students.

1.3 Conclusions on the chapter

In the presented chapter the materials of a modern tendency of preparation of highly skilled staff on chair of Power industry and теплоэнергетики are stated. The materials are presented in the following sequence:

- the role of innovative development in the training of personnel in the energy sector;
- the main priorities of the training of personnel in the specialty "Power Engineering" at the Rudnensk Industrial Institute;
- Five main priorities are shown, which include the solution of the following issues:
- ensuring the quality training of competitive personnel;
- modernization of the content of educational programs in the context of global trends;
- development of the infrastructure of the department;
- ensuring the effectiveness of research and their contribution to the industrial and innovative development of Kazakhstan;
- education in the student youth of new Kazakhstan patriotism, strengthening of the spiritual and moral values of the national idea "Mengeik EL" culture of a healthy lifestyle.

The implementation of the proposed activities for the EEETE Chair will:

- to improve the quality of the educational process of the specialty Power Utilities;
- Develop new training programs using modern equipment;
- on the basis of application in the educational process of progressive training systems to increase the competitiveness of graduates;
- the use of modern equipment in the educational process will raise the contingent of students in the specialty;
- Increase the publishing activity of teachers and students.

Chapter 2. Technical description of the stand "Model of the electrical system"

2.1 The purpose and design of the stand

"Model of the electrical system" is intended for conducting laboratory and practical works on the courses: "Transient processes in the electric power industry", "Relay protection and automation", "Automatic design in the electric power industry" "Electrical networks and systems".

The stand allows to qualitatively simulate the established operating modes of electric power systems, electromagnetic and electromechanical transient processes with various kinds of short circuits, to investigate the factors influencing the static and dynamic stability of the parallel operation of synchronous generators, to investigate relay protection and automation devices. A feature of the stand is its modularity. The stand consists of two laboratory tables, in frames of which separate modules are fixed, also the stand includes a personal computer located on a special table and a bedside-stand for the electric machine unit.

A personal computer is one of the components of a laboratory stand. With the help of specialized software included in the stand, it is used for oscillography, data visualization, as a multichannel oscilloscope and recorder, as well as for controlling and protecting electric power objects in real time.

The stand includes the following modules: Electromachine unit; Stand power module; Three-phase network module; Power meter module; Excitation module; Module "Frequency converter"; Measuring module; I / O module with I / O board; Module "Speed Meter"; Module "Inductive load"; Module "Capacitive load"; Module "Active load"; Module of the unit; Synchronization module; Personal Computer; Bedside-stand for electric machine; Table under the personal computer; A set of connecting wires and power cables; CD with software;

All modules are in the same quantity except: Module of single-phase transformers; Switch module; Power line module; Table with a frame in an amount of 2 pcs.

The main view of the stand is shown in Figure 2.1. In the frames of the laboratory stand tables, separate modules are placed in two rows. All modules of the stand have the same overall size of the front part: 200x248 mm. The stand modules can be installed in any order, however, the following arrangement of modules and supports in accordance with Figure 2.1 is preferable.

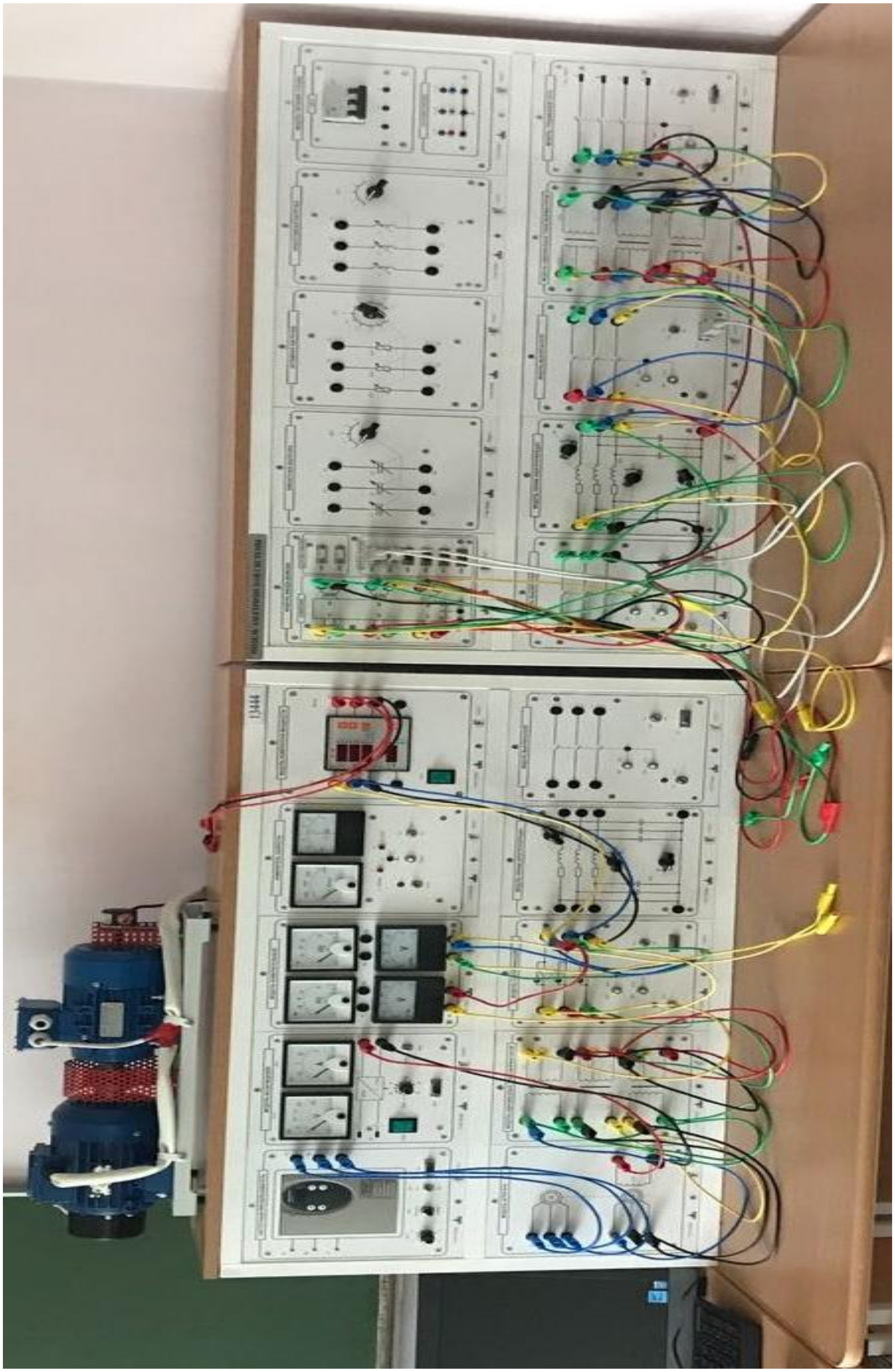


Figure 2.1 - General view of the laboratory stand

Two laboratory tables are placed side by side. In the upper row from the left to the right are placed measuring modules, load modules and the power module of the stand and are arranged in the following sequence:

- excitation module;
- module "Frequency converter";
- power meter module;
- measuring module;
- input-output module;
- Module "Speed Meter";
- Modules of inductive, capacitive and active loads, respectively;
- stand power module.

In the lower row from left to right are the modules of laboratory works:

- module of the unit;
- Modules of single-phase transformers;
- synchronization module;
- switch modules;
- power line modules;
- Three-phase network module.

To the left of the laboratory tables is a nightstand with an electric machine, the cables of which are connected to the unit module, to the right of the laboratory tables there is a table with a personal computer.

The technical characteristics include the following

- Power supply from a three-phase network with line voltage . 3x380 / 220 V
- Supply voltage frequency 50 Hz
- Power consumption, not more than 1000 V A
- Overall dimensions 3200x1350x650 mm
- Weight, no more than 300 kg
- Operating range temperatures +10 ... 35 ° C
- Humidity up to 80%

2.2 Scheme of the stand connection

The power supply of the stand is provided from a three-phase five- or four-wire network (depending on the type of power supply network) with a rated line voltage of 380V, a power cable K1 having an 11-pin connector type RP-10-11 at one end. The options for connecting the stand to the network are shown in Figures (2.2 - 2.4). Diagrams of interconnections are given in Figures (2.5-2.7).

The stand provides protection from electric shock by grounding the metal parts of the modules and frame housings. The presence of protective earthing is mandatory! For earthing the stand on the frames, as well as the power module, grounding bolts are provided, a protective PE conductor is provided in the power cable. There are several options for connecting the stand depending on the type of electrical network system in the place of operation of the stand. The TN-C-S system. It is necessary to combine the PE and N power cables of the stand when the stand is connected to the mains. And also connect the earthing bolts on the power module and the frame of the stand in accordance with Figure 2.2.

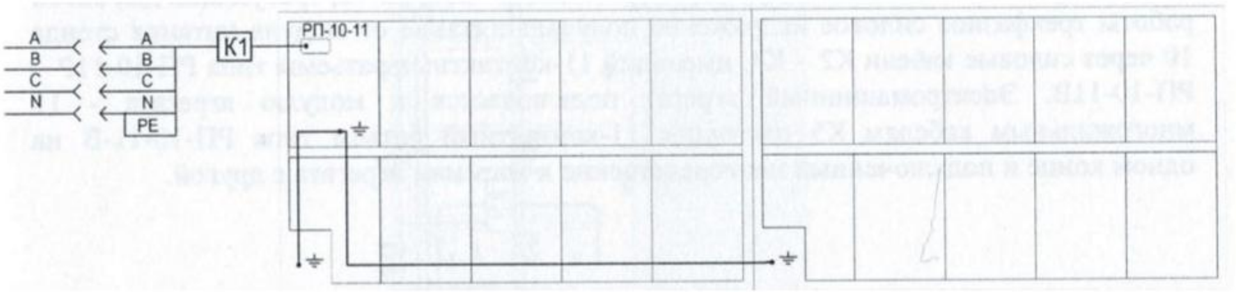


Figure 2.2 - Grounding scheme TN-C-S

TT system with PE conductor in the socket. Grounding is done by using the PE conductor in the power cable. The grounding bolts on the frames and the power module must be connected in accordance with Figure 2.3.

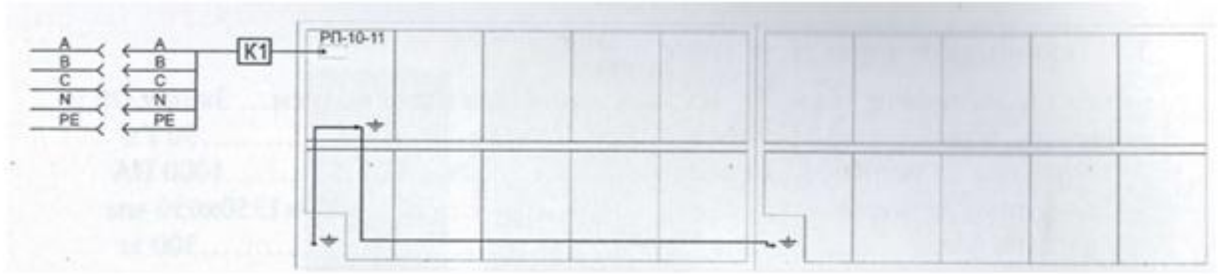


Figure 2.3 - Earthing scheme of TTs

The TT system when there is a grounding bus in the room. Grounding is carried out by direct connection of grounding bolts to the frames and the power module of the stand with the grounding bus. PE conductor in the power cable is isolated in accordance with Figure 2.4.

The connection diagram of the inter-unit three-phase power supply voltage of the modules is shown in Figure 2.5. The three-phase network module - 20, the power meter module - 3 and the frequency converter module - 2, requiring for its operation three-phase power voltage receives power from the power supply module of the stand 10 through power cables K2-K4, having 11-contact connectors type RP-10-11R - RP-10-11V. The electric machine is connected to the unit module - 11 multi-conductor cables K5 with a 11-pin connector type RP-10-11-B at one end and connected directly to the terminals of the unit on the other.

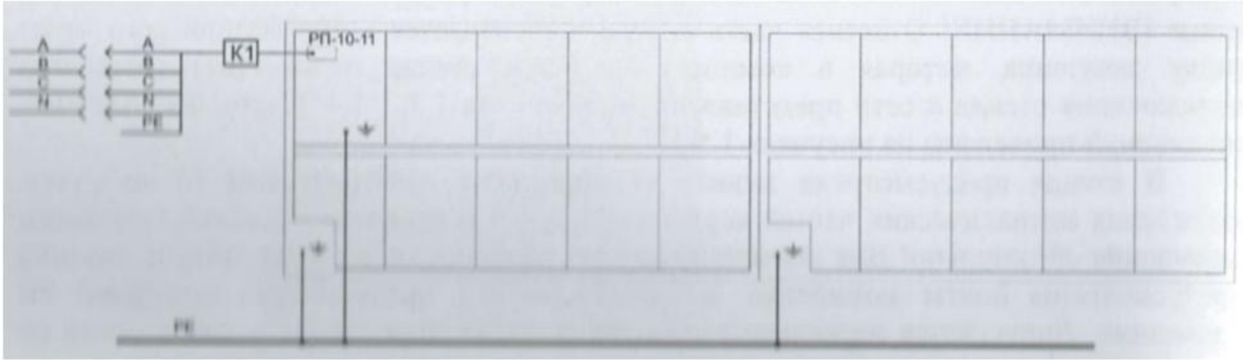


Figure 2.4 - TT grounding scheme (if grounding bar is present)

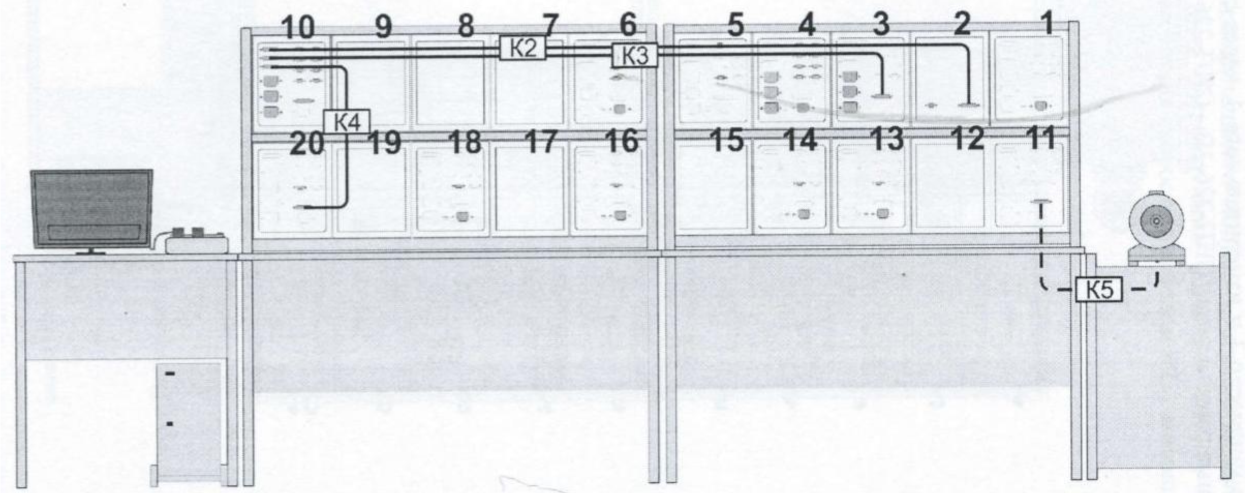


Figure 2.5 - Wiring diagram of the inter-unit three-phase supply voltage

The connection diagram for the inter-unit single-phase power supply voltage of the modules is shown in Figure 2.6. Switch modules 14, 16, 18 excitation module 1, angle and speed meter 6, and synchronization 13, as well as a mains filter (pilot-splitter), requiring for their work single-phase power voltage are supplied from the power module of the stand 10, power splitters on modules of the power meter 3 and measuring 4, through power cables Кб ... K13, having 3-contact connectors of the SNP-226-3B-SNP-226-P type.

The connection diagram for the inter-unit low-voltage supply voltage of the modules is shown in Figure 2.7. Modules of switches 14, 16, 18, frequency converter 2, angle and speed meter 6, input-output 5, three-phase network 20, synchronization 13, requiring for their work low-voltage supply voltage + 5V / -

H2V / -12V receive power from the power module stand 10 and low-voltage feeder of the measuring module 4, through standard K14 ... K23 cables having 9-pin DB-9M-DB-9F connectors. The motor encoder is connected to the speed meter module 6 by cable K23, which has a DB-9M connector.

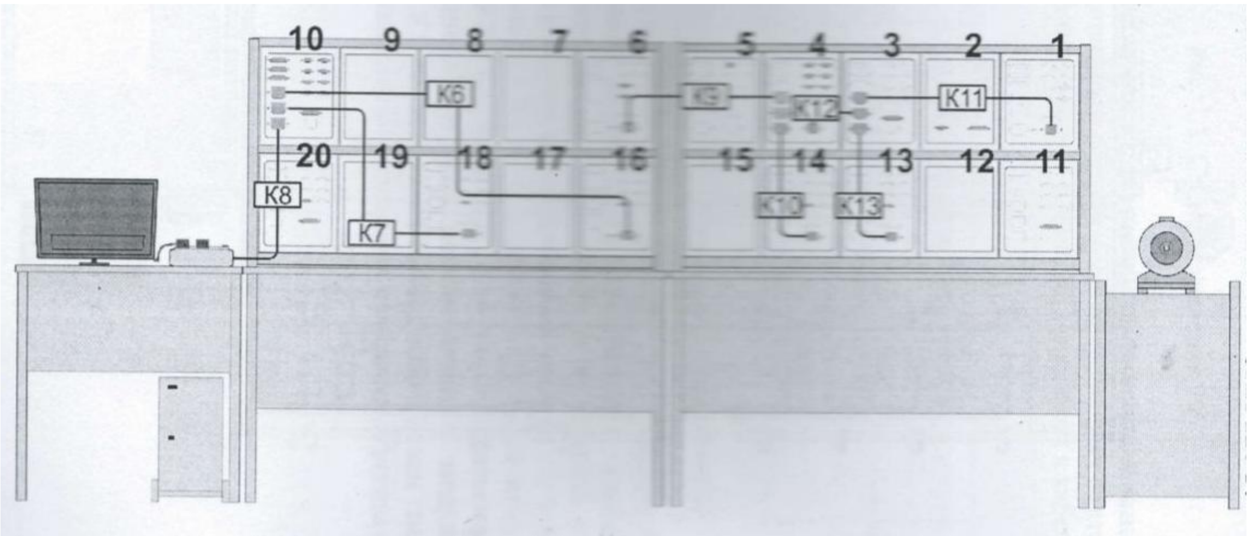


Figure 2.6 - Wiring diagram of inter-unit single-phase supply voltage

Figure 2.7 - Wiring diagram of inter-unit low-voltage supply voltage (DB9 connectors)

Figures (2.2 - 2.7) show the stand type from the back side, while the stand modules are indicated as follows: 10), I / O module (place 5), power meter module, (place 3), excitation module (place 1), frequency converter module (place 2), three-phase network module (location 20), speed measuring module (place 6), the module of the switch (places 14, 16, 18), mo (place 4), modules of single-phase transformers (places 12, 19), power transmission module (places 15,17), synchronization module (location 13), unit module (location 11).

The connection diagrams do not include the computer power cables and the USB cable.

The list of used cables in the laboratory stand is given in Table 2.1.

Table 2.1 - List of laboratory stand cables

№ Cable	Cable designation	(module, connector) from where goes	Connector (in cable) Type	(module, connector) Where does	Connector (in cable) Type	Cable assignment
1	К1	net	Customer plug	10:X1	РП-10-11В	Supply of three-phase supply voltage to the laboratory stand
2	К2	10:X2	РП-10-11В	2:X2	РП-10-11Р	Supply of a three-phase power supply voltage to the frequency converter module
3	К3	10:X3	РП-10-11В	3:X1	РП-10-11Р	Supply of three-phase power supply voltage to the power meter module
4	К4	10:X4	РП-10-11В	20:X1	РП-10-11Р	Supply of three-phase power supply voltage to the three-phase network module
5	К5	Electro-engine aggregate	-	11 :X1	РП10-11В	Connection of the electric machine to the module of the electric machine unit
6	Кб	10:X5	СНП-226-В	16X1	СНП-226-Р	Supply of single-phase power supply voltage to the breaker module
7	К7	10:X6	СНП-226-В	18:X1	СНП-226-Р	Supply of single-phase power supply voltage to the breaker module
8	К8	10.X7	СНП-226-В	Network filter	Rosette type F	Supply of single-phase power supply voltage of the PC through the mains filter

Continuation of table 2.1

1	2	3	4	5	6	7
9	К9	4X2	СНП-226-В	6:X1	СНП-226-Р	Supply of single-phase power supply voltage to the speed meter module
10	К10	4:X4	СНП-226-В	14:X1	СНП-226-Р	Supply of single-phase power supply voltage to the breaker module
11	К11	3:X2	СНП-226-В	1:X1	СНП-226-Р	Supply of single-phase power supply voltage to the excitation module
12	К12	3:X3	СНП-226-В	4:X1	СНП-226-Р	Supply of single-phase power supply voltage to the power supply splitter of the measuring module
13	К13	3:X4	СНП-226-В	13:X1	СНП-226-Р	Supply of a single-phase power synchronization module.
14	К14	10:X11	DB-9M	4:X5	DB-9F	Supply of low-voltage supply voltage to the power supply module of the measuring module
15	К15	10:X12	DB-9M	20:X2	DB-9F	Supply of low-voltage supply voltage to the three-phase network module.
16	К16	10:X13	DB-9M	6:X2	DB-9F	Supply of low-voltage supply voltage to the speed meter module

Continuation of Table 2.1

1	2	3	4	5	6	7
17	K17	10:X14	DB-9M	18:X2	DB-9F	Supply of low-voltage supply voltage to the breaker module
18	K18	10:X15	DB-9M	16:X2	DB-9F	Supply of low-voltage supply voltage to the breaker module.
19	K19	4:X12	DB-9M	5:X1	DB-9F	Supply of low-voltage supply voltage to the module input-output
20	K20	4:X9	DB-9M	2:X2	DB-9F	Supply of low-voltage supply voltage to the drive module
21	K21	4:X 11	DB-9M	14:X2	DB-9F	Supply of low-voltage supply voltage to the circuit-breaker module
22	K22	4:X10	DB-9M	13:X2	DB-9F	Supply of low-voltage supply voltage to the synchronization module
23	K23	Electro-engine aggregate	-	6.X3	DB-9M	Pulse signals feeding to the speed meter module from the motor encoder
24	K24	Computer	USB-A	5;X2	USB-B	Communication of the input-output module to the personal computer (not indicated on the diagrams)

The feeding stand is made from a three-phase network with a nominal voltage U=380/220B. Pin contacts cable connector three-phase power supply is presented in table 2.2.

Table 2.2 - Splitting the network cable of the laboratory stand

Connector terminal RP10-11	B1	A1	A2	A3	A4
Cable outlet	protective ground (PE)	neutral (N)	phase «A»	phase«B»	phase«C»

2.3 Structure and general principles of the stand operation

By its designation, the stand contains the main electromechanical units, power converters, measuring elements intended for performing laboratory works in the sections "Transient processes in the electric power industry", "Relay protection and automation", "CAD in the electric power industry" "Electrical networks and systems". For this purpose, the following elements are included in the laboratory stand:

1. Electro-machine unit and unit module. The unit contains a drive motor (asynchronous machine), a synchronous generator and a pulse speed sensor. The unit module simplifies the connection of the power circuits of the motors and the speed sensor.

The use of a pulse speed sensor and a frequency-to-voltage converter unit located in the speed meter module allows the circuit to be assembled with both analog speed feedback and load angle 5 of a synchronous machine.

2. Power modules (stand power module, three-phase network module), protecting the stand in the short-circuit mode and providing three-phase voltage 380V, single-phase voltage 220V and low-voltage supply voltages ± 12V, + 5V. The three-phase network module operates in manual and automatic modes.

3. Power modules (Frequency converter and excitation module) are intended for supplying voltages to the electric machine unit: the frequency converter provides the supply of power adjustable alternating current voltages to the motor (3 x 0 ... 380 V), speed control, maintaining constant torque values; the excitation module provides for supplying the winding of excitation of the synchronous generator with a controlled DC voltage 0 ... 100 V, 0 ... 2A. Both modules work in manual and automatic modes.

4. Load modules (inductive, capacitive and active) provide the introduction of additional adjustable inductances, capacitors and resistors in the three-phase circuits under study.

5. Measuring modules (power meter, measuring, speed meter) allow you to perform:

- measurement by the digital device of the parameters of alternating current (U, I, f, P, cos ф);
- measurement of speed n (rotational speed of electric machines) and load angle 6;
- measurement of variable voltages and frequencies by panel devices.

6. Modules of laboratory works (single-phase transformers, synchronization, power lines, switches) allow you to simulate and explore the electrical system. The synchronization module and the switch modules operate in manual and automatic modes.

7. A personal computer and an input / output module are used to measure, register and oscillate signals, implement remote and automatic control functions using specialized DeltaProfi software.

The input-output module is designed for input and output of analog and discrete signals to a personal computer via current and voltage sensors and DeltaProfi mod.5.4.3 input / output board with the purpose of oscillating transient processes and controlling stand modules in an automatic mode.

2.4 Technical description of the stand elements

Electro-machine unit

The electric machine unit is three electric machines connected on one shaft in accordance with Fig. 2.8:

- drive motor (asynchronous machine) (Ml);
- synchronous generator (M2);
- pulse speed sensor (DS).

Electric machines are installed on the basis of the Axis, the drive motor, the synchronous generator are connected to each other with the help of the clutch C\.

The speed sensor is connected to an asynchronous machine by means of a coupling mounted on the shaft of the machine. The power cable K5 of the electric machine unit is connected to the connector XI of the unit module, the cable of the speed sensor K23 - to the connector X2 of the speed meter module.

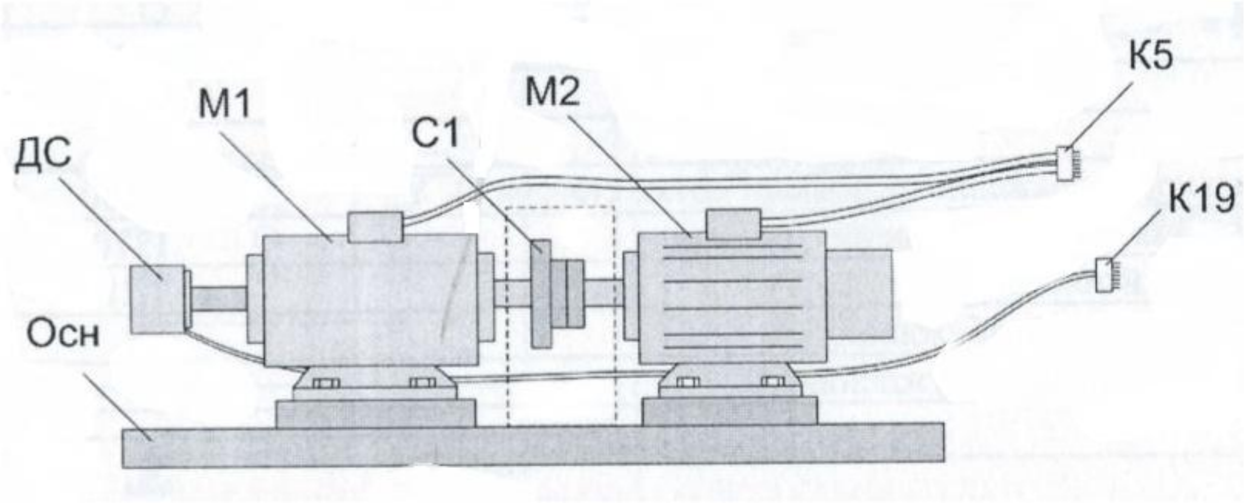


Figure 2.8 - Electromachine aggregate in the speed sensor

The pulse sensor allows you to monitor the current speed of the motors. If you need to enter an analog signal in the laboratory that is proportional to the rotational speed of the motors in the complex, you can obtain it using a frequency-voltage converter (TCTN) installed in the speed meter module.

The electromachine unit is installed on the bedside table located on the left of the laboratory tables and connected with the harnesses to the unit modules and the speed meter on the back of the stand in accordance with Figure 2.7. This makes it possible to use only the front panel of the unit module for the required connections of electric machines.

Passport and calculated data of the asynchronous motor are presented in Table 2.3, the synchronous generator in Table 2.4, and the speed sensor in Table 2.5.

Table 2.3 - Passport and calculated data of an induction motor (drive)

Parameter Name	Meaning
Type	АИС71В4УЗ
Power W	370
Nominal supply voltage of the stator winding, V. Y	3x380
Nominal speed, rpm	1370
Rated current of the stator phase, A	1,18
cos c	0,7
Nominal torque. H m	1.4
Active stator resistance rt 2 mc, Oh	19
Mechanical stains, Stroke Hell, W	11

Table 2.4- Passport and calculation data of the synchronous machine

Parameter Name	Meaning
Type	AIS71BY3
Power, W	370
Nominal supply voltage of the stator winding, V. Y	3x380
Nominal speed, rpm	1370
Rated current of the stator phase, A	1,18
Nominal excitation current , A	1
Maximal excitation current, A	2

Table 2.5 - Nameplate data of a pulse speed sensor

Parameter Name	Meaning
Type	TRD-S500VD
Supply voltage, B	=5
Resolution, imp / rev	500 —

The power module of the stand (MPS) is designed for inputting three-phase voltage from the network to the laboratory stand, protecting the stand from short-circuit currents and supplying power and low-voltage supply voltages to the stand modules. The appearance of the module is shown in Figure 2.9.

On the front panel of the module there are:

- circuit breaker QF1 type iEK BA47-29 SJU at 10A / 400V;

- a secondary power source of the type PT45V, which provides power to the stand components with a voltage of ± 12 V, + 5 V;

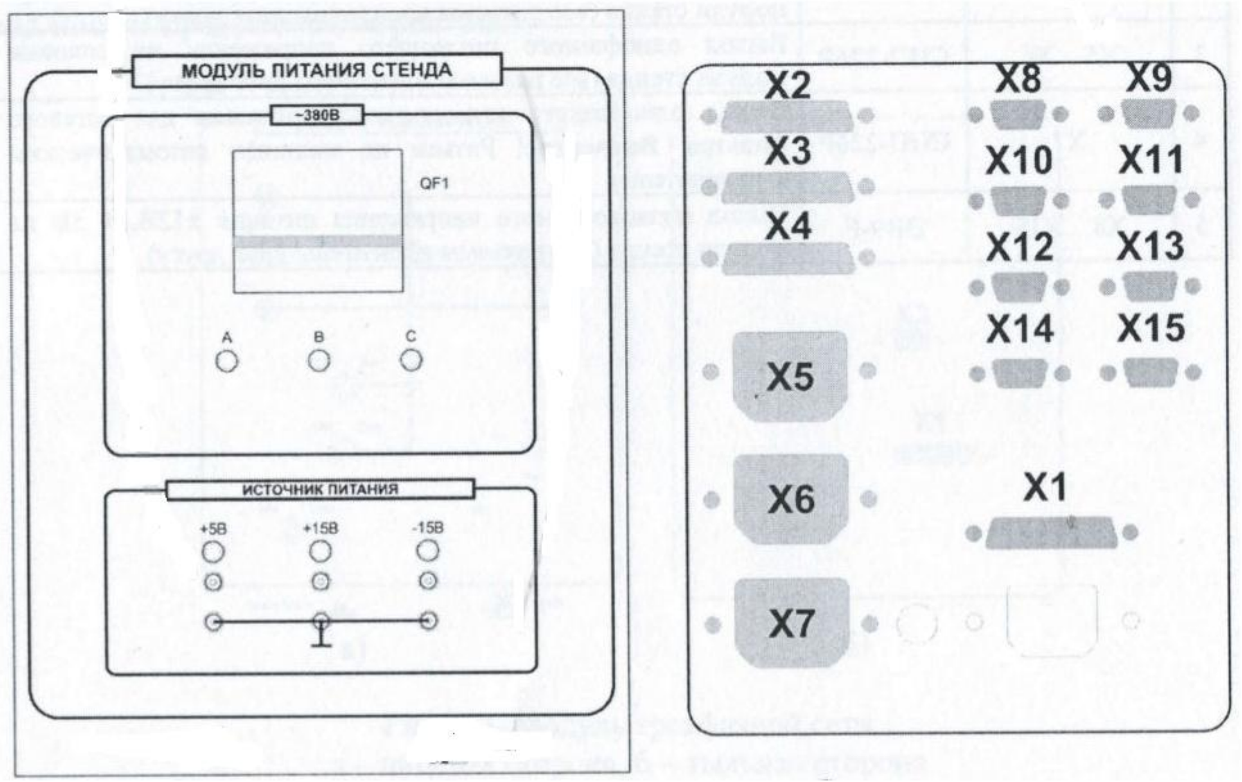
- indicating and monitoring elements (LEDs and terminals) for indicating the power supply, low voltage presence and monitoring with the voltage level meter of the VIP level.

On the back side of the module there are connectors for connecting the supply voltage and stand modules. The purpose of the connectors is given in Table 2.6. The three-phase network module is designed to supply three-phase supply voltage from the mains and is used in laboratory circuits as a source of almost infinite capacity. The module contains a three-phase contactor with two-channel manual control, used as a model of a three-phase circuit-breaker. The appearance of the module is shown in Figure 2.10.

On the front panel of the module there are:

- toggle switch SA1 "Network", which provides power on / off of the module and its corresponding LED indicating the presence of power;

- terminals L1 ... L3, which are outputs of alternating voltage 380V phases A, B and C and are buses of almost infinite power.

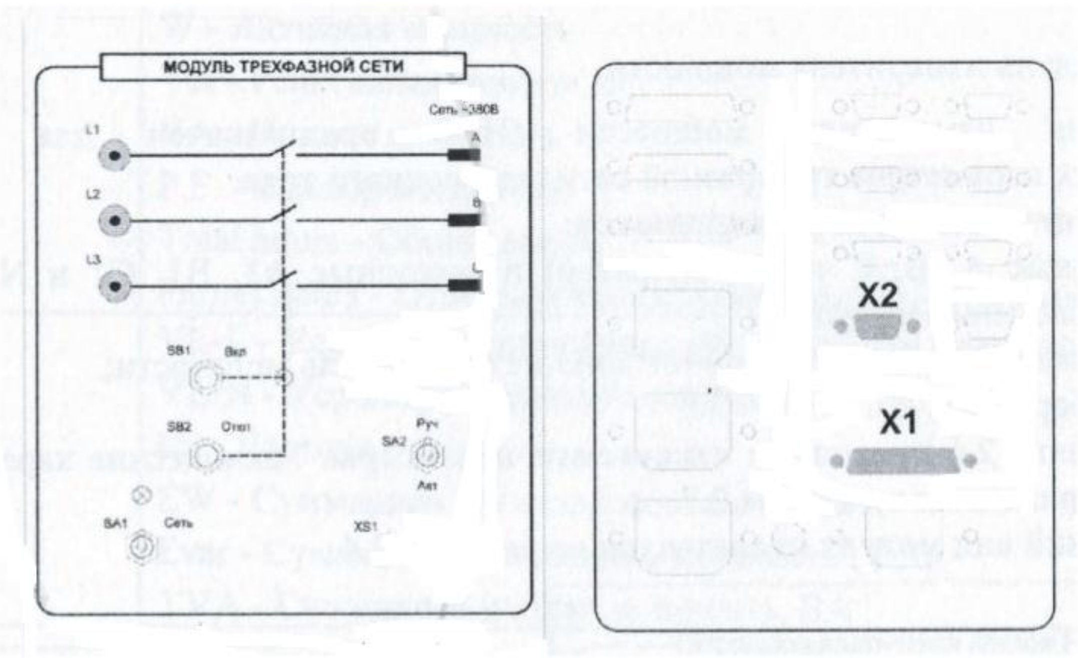


a - front side, b - back side

Figure 2.9 - Stand power module

Table 2.6 - Purpose and types of connectors of the stand power module

№	Connector identification	Connector type	Purpose of the connector
1	XI	РП10-11В	Entrance of three-phase feed-in tensions stand (three phases And, B. C. нейтраль of N, grounding of RE)
2	X2...X4	РП10-11Р	Exit three-phase feed-in tensions on the power modules of stand (all sockets are identical to each other)
3	X5...X6	СНП-226Р	Exit of monophase feed-in tension on the power modules of stand (all sockets are identical to each other)
4	X7	СНП-226Р	Exit of monophase feed-in tension for a network filter. Attention! A socket is not protected by a circuit breaker.
5	X8...X15	DB9-F	Exit of low-voltage tension of feed ±of 12B, 5B on the modules of stand (all sockets are identical to each other)



a - the front side, b - the back side

Figure 2.10 - Three-phase network module

- SB1 "On" and SB2 "Off" buttons for controlling (on / off) the switch of the three-phase network module and its corresponding LED indicating the current state of the switch (on / disabled);
- Toggle switch SA2, which selects the mode of operation of the module, in the "Manual" position, the control of the switch is done manually, with the buttons SB1 and SB2, in the "Auto" position, the switch is controlled via the XS1 connector located on the front panel of the module;
- connector XS1 type DB9, providing the possibility of remote control of the switch in case when the toggle switch SA2 is in the "AUT" position. On the back of the module, the connectors are used to connect the supply voltage. The purpose of the connectors is given in Table 2.7.

The Power Meter Module (MI) is designed to measure the electrical parameters of a three-phase AC power system.

The front panel houses

: - input A, B, C and N (generator) and output Al, Bl, C1 and N (load) of the module connection terminal;

- the "Network" button to power the power meter;
- device DM K 20.

Table 2.8 shows the measured parameters. Technical characteristics of the meter are given in Table 2.9.

Table 2.7 - Purpose and types of connectors of the three-phase network module

№	Denotation of socket	Type of socket	Setting of socket
1	XI	РПКМ1В	Entrance of three-phase feed-in tension -380В from the module of feed of stand (sockets of X2...X4 module of feed of stand)
2	X2	DB9-M	Entrance of low-voltage tension of feed ±of 12В. SB

Table 2.8 - Table of measured parameters for group LEDs LED01 and LED03

LED01	VL-L - Linear (межфазное) tension of VL - N is Phase tension And - Current of W is an active-power of Var - a reactive-power of VA is Complete power of P.F. it is Factor of power of Total hours is Common time of Partial hours is the Separately fixed time (Separate time)
LED03	VL-L - Linear tension of VL - N is Phase tension And - Current of W is an active-power of Var - a reactive-power of VA is Complete power of P.F. it is Factor of power of Total hours is Common time of Partial hours is the Separately fixed time (Separate time)

Table 2.9 - Meter Specifications

Parameter	measurement range	Error
Linear voltage, V	60-830	±0.35%
Phase voltage, V	30-480	±0.35%
Current, A	0,05-6	±0.5%
frequency Hz	45-65	±0.1 Гц
Active power, W (cosφ 0.7-l) / (cosφ 0.3-0.7)		±1% / ±1.25%
Full power, VA	-	±0.5%
Reactive power, VAR (cosφ 0.7-l) / (cosφ 0.3-0.7)	-	±1%/ ±1.25%

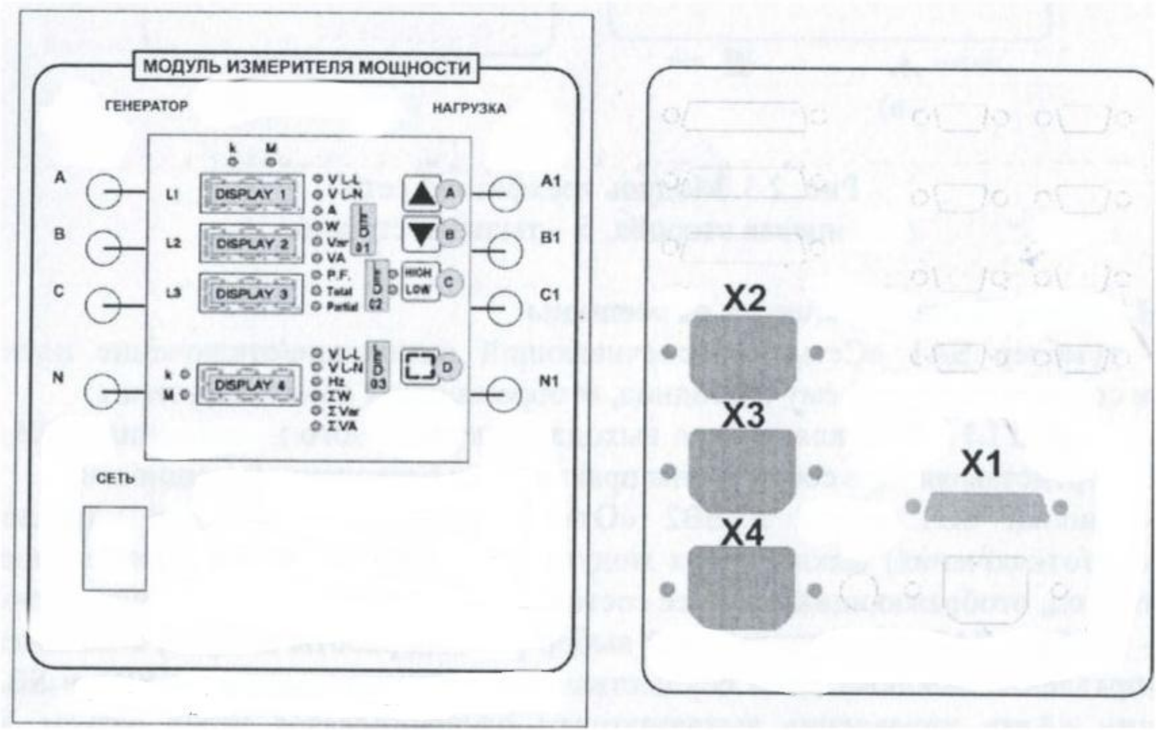
The appearance of the module is shown in Figure 2.11.

To the right of the display are the control buttons:

Buttons A and B are used to select the type of measurements that are output to the LED indicators of the LED01 group.

- Measurements relating to the phases LI, L2, L3 are displayed on the displays, respectively, 1,2,3.

- LED indicators "to" and "M" (at the top) show that the measurement result is expressed in thousands or millions;



a - the front side; b - back side

Figure 2.11 - Power Meter Module

Button C is used to activate one of the LED function indicators from the LED 02 group, or to cancel all functions.

With the help of button D, you can make a choice among the three functions of the LED group LED03 and output them to DISPLAY 4.

These modes are intended for averaging the measurements of three-phase components. To indicate the unit of measurement, DISPLAY 4 (on the left) has its own multiplier "k" and "M".

On the back of the module there are connectors for connecting the supply voltage and connecting the stand modules. The purpose of the connectors is given in Table 2.10

Table 2.10 - Purpose and types of connectors of the power meter module

X*	Connector designation	Connector type	Connector assignment
1	XI	РП10-11-В	Input of three-phase supply voltage ~ 3x380 / 220В from the power module of the stand (connectors X2 ... X4 of the power module of the stand
2	X2...X4	СНП-226-Р	The output (splitter) of single-phase supply voltage -220V on the stand modules (all connectors are identical to each other).

The excitation module is intended for supplying the field winding of a synchronous machine.

On the front panel are located:

- the "Network" button to power the MV;

-tumbler SA1 selection of control mode "Hand" / "Auto". In the "Auto" position, the control is performed from an external input signal;

- Potentiometer RP1 providing the setpoint of the task;

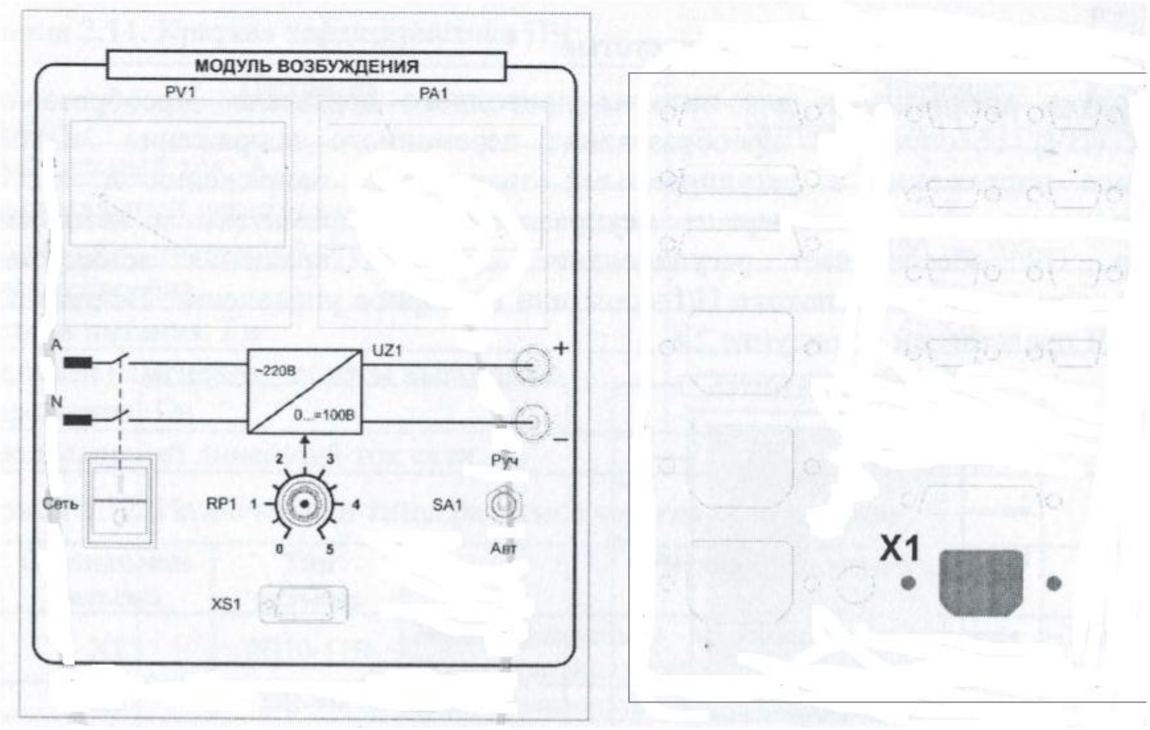
- connector XS1 serves for setting external signals;

- devices PV1 and PA1 for monitoring output values of voltage and current. Appearance of the module is shown in Figure 2.12. Technical characteristics are given in Table 2.11.

On the back of the module connectors for connecting the supply voltage are located. The purpose and types of connectors are given in Table 2.12.

Table 2.11 - Specifications of the excitation module

Specifications:	
supply voltage maximum output current external control signal	-220В
rated output current	0,8 A
maximum output current	2 A
external control signal	=0...10В.



a - the front side; b - rear side
Figure 2.12 - Excitation module

The excitation module can not be turned on without connecting to the load. Use of the module at a current higher than rated is allowed in a short-time mode.

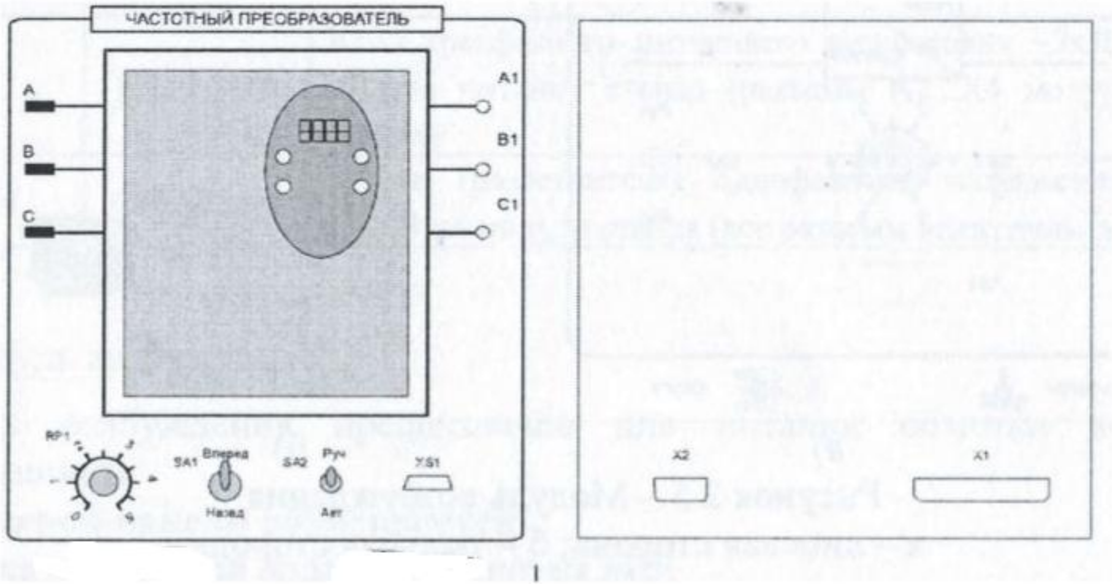
Table 2.12 - Purpose and types of connectors of the field module

№	Connector designation	Connector type	Connector assignment
1	XI	СНП-226-В	Input single-phase supply voltage ~ 220V from the power module stand.

The module "frequency Converter" is intended to power the drive motor. Frequency Converter (VFD) converts the AC voltage 80V 3x3 in the three-phase voltage with adjustable voltage and frequency. The frequency Converter includes uncontrolled rectifier and the Autonomous inverter. The drive provides speed control of the induction motor at a constant flow U/f=const, or vector control. The appearance of the module is presented in figure 2.13.

On the front panel are placed:

- the frequency Converter Altivar-31 with a display and input buttons settings;
- power terminals of three-phase output voltage Al, B1 and C1;



a - the front side; b - the back side

Figure 2.13. Module "Frequency converter"

- potentiometer RP1 of the analogue reference signal;
- switch SA1 for selecting the direction of rotation of the synchronous motor (in this modification of the module SA1, in any position only one direction of rotation of the motor is set);
- SA2 switch for selecting the operating mode;
- connector XS1 (PC) for connecting a personal computer and control the inverter in automatic mode. The module operates in manual and automatic modes, the mode is selected with the SA2 switch. In manual mode, the control signal is set by the potentiometer RP1.

A brief description of the frequency converter is presented in Table 2.13.

Table 2.13 - Short characteristic of the IF

Parameter	Value
Model	Altivar-31 ATV31H075N4
Rated current, A	2,3
Maximum transient current, A	2,3
Supply mains voltage, V	от 380 до 500
Number of phases	3
Power frequency, Hz	50/60
Frequency range of output voltage, Hz	0...400
The maximum line current of the network, A	2,7...3,6

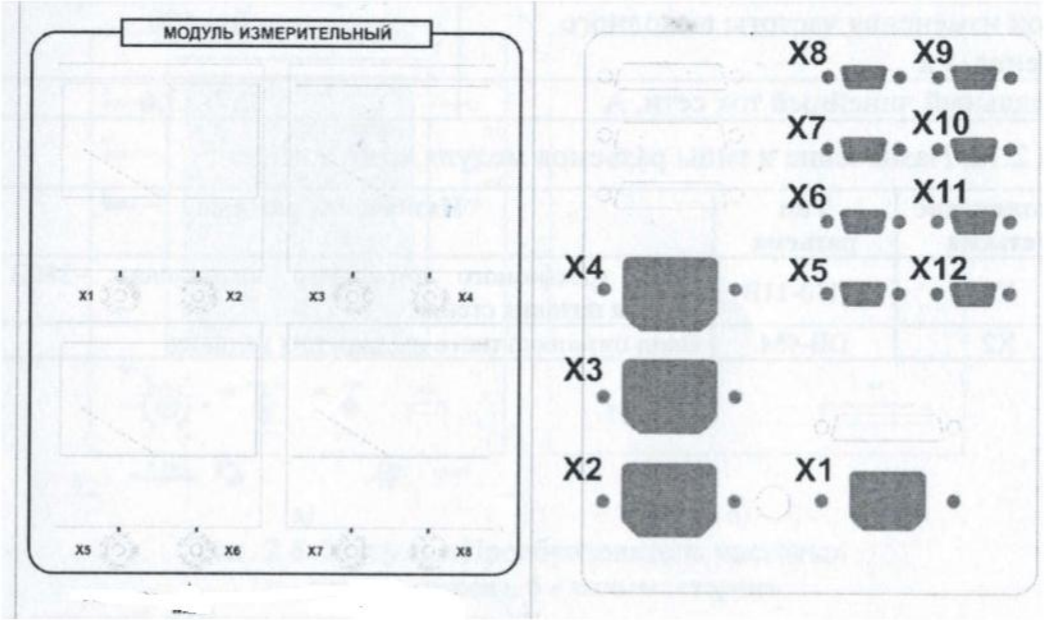
On the back of the module, the connectors are used to connect the supply voltage. The purpose and types of connectors are given in Table 2.14.

Table 2.14 - Purpose and types of connectors of the field module

№	Connector designation	Connector type	Connector assignment
1	XI	РП10-11В	Input of three-phase supply voltage ~ 380V from the power module of the stand
2	X2	DB-9M	Input of low-voltage supply voltage.

The measuring module is designed for measuring AC voltages and frequencies during laboratory work. It contains two voltmeters of type Ц42300 with a measuring limit of 0 ... 500 V for measurement of alternating voltages and two frequency meters of type E8004 with a measuring range of 45 - 55 Hz. Rated voltage of frequency meters 220 V, accuracy class 1.0.

The type of the front panel of the measuring module is shown in Figure 2.14



a - the front side; b - back side
Figure 2.14- Measuring module

The measuring module is also used for supplying single-phase voltage ~ 220V and low-power low-voltage DC power supply to individual stand modules. The module receives these voltages from the stand power module and acts as an intermediate voltage distributor.

On the back side of the module there are connectors for connecting the supply voltage and stand modules. The purpose and types of connectors are given in Table 2.15.

Table 2.15- Purpose and types of connectors of the measuring module

№	Connector designation	Connector type	Connector Assignment
1	XI	СНП	Input of three-phase supply voltage ~ 380V from the power supply module of the stand (connectors X2 ... X4 of the power module of the stand)
2	X2...X4	СНП	The output (splitter) of single-phase supply voltage -220V on the stand modules (all connectors are identical to each other).
3	X5	DB-9	Input of low-voltage supply voltage ± 12 V, + 5V from the power supply module of the stand.
4	X6 ...X12	DB-9	Output (splitter) of low-voltage supply voltage ± 12 V, + SB to the modules of the complex (all connectors are identical to each other).

The I / O module in accordance with Figure 2.15 is intended for input and output of analog and discrete signals to a personal computer (laptop) via current and voltage sensors and an analog I / O card DP mod 5.4.4. for the purpose of oscillographing, recording, processing and displaying analog signals in real time.

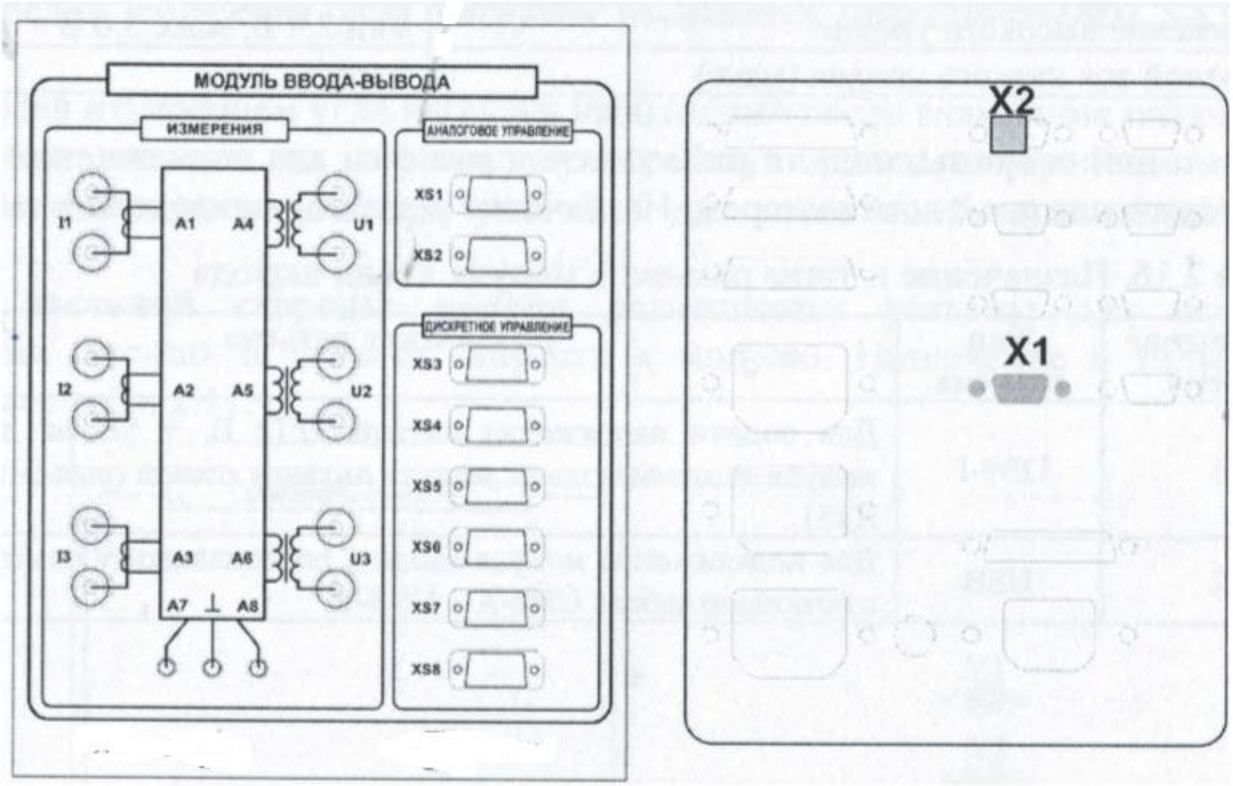
The I / O module contains 3 LV25-P voltage sensors and 3 HY5-P current sensors. The sensors of the input-output module allow to obtain low-power voltages proportional to the values of the input power currents and voltages. Sensors provide potential separation of power circuits and control circuits.

The sensors of the I / O module operate on direct and alternating current. The electrical strength of the insulation of the sensors is 2.5 kV.

The ranges of the sensors are given in Table 2.16.

Table 2.16 - Sensor operating ranges

Sensor	Range of input signals	Range of output signals	V Frequency range of operation, Hz
ДН	±0...500 **В**	±0...5	0...50
Дт	±0...2 **А**	±0...5	0...50



a - the front side, b - the rear side
Figure 2.15 -. I / O Module

The I / O module contains the I / O card DP mod 5.4.4.

Analog I / O card DP mod 5.4.4 is used for input / output and processing of analog and digital information in a personal computer (or laptop). Connects to a computer using a USB-A-USB-B cable (included). The board in the stand is used together with the software included in the stand. Technical characteristics of the board are given in Table 2.17.

Table 2.17 - Technical characteristics of the board

Parameter name	Value
ACP	
Number of channels	8
Bit depth	12 bit
Conversion time	10 мкс
Maximum conversion frequency (per channel)	
- in the input mode of 8 signals	25 кГц
- in the input mode 4 signals	50 кГц
- in the input mode 2 signals	100 кГц

Continuation of table 2.17

Range of input signals	±10 В
Parameter name	Значение
DAC	
Number of channels	2
Bit depth	12 бит
Maximum conversion frequency (per channel)	25 кГц
Range of input signals	8 мкс
Output Range	±10 В
Digital inputs and outputs	
Input port Output current of low level	8 bit CMOS, NST series
Output port 16	16 bit CMOS, NST series
Voltage low level	min 0 V, max 0.4 V
High voltage level	min 2.4 V, max 5.0 V
Output current of low level	(max) 6 Ma

On the back side of the module are located connectors for powering the module and connecting it to the computer. The purpose of the connectors is given in Table 2.18.

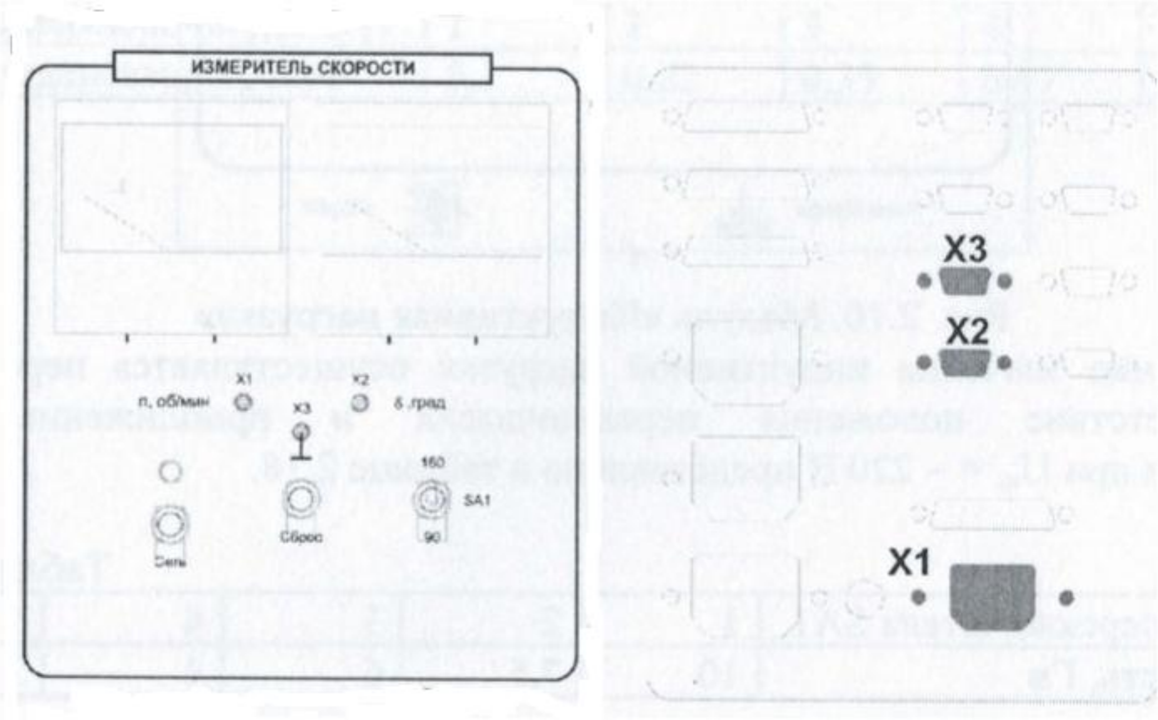
Table 2.18 - Purpose and types of connectors of the I / O module

X*	Notation	connector type	Connector Assignment
1	XI	DB9-F	To supply the supply voltage ± 12 V, + 5 V to the sensors of the I / O module from the stand power module (connectors X8 ... X15)
2	X2	USB	To connect the input module to a personal computer using a USB-A-USB-B cable.

In the "Speed Meter" module, in accordance with Figure 2.16, a frequency-voltage converter (FNC) board is used to convert a pulse signal from a speed sensor into an analog signal. ПЧН converts the speed of rotation of electric machines in the range 0 ..! 2000 rpm in a proportional voltage signal of 0 ... 100 μA. In addition, the calculation of the load angle between the mains voltage and the position of the rotor (z - output of the speed sensor) is performed on the converter board. The range of measured angles is ± 180 ° (± 90 °), the range of proportional output voltage is ± 10 V. The front panel houses:

- panel devices for measuring speed and angle of loading;
- terminals for transmitting an analog signal proportional to the speed and load angle values on the I / O module;
- toggle switch module on the network;
- load angle reset button;
- toggle switching switch for measuring the load angle.

On the panel devices installed in the module, you can observe the current value of the speed of rotation of the electric machine unit n (rpm) and load angle 6 (deg). The limit of measuring the load angle is changed by the switch SA1 (90 ° or 180 °).



a - the front side, b - the back side.

Figure 2.16 - "Speedometer" module

Before measuring the load angle, it is necessary after the module power is turned on and the system is set to parallel operation of the network and the synchronous generator, zero the indicator of the angle indicator 5 - for this, press the "Reset" .

On the back side of the module, connectors are placed for connecting the supply voltage and the speed sensor to the module. The purpose and types of connectors are given in Table 2.19.

Table 2.19 - Purpose and types of connectors of the speed meter module

№	Notation	connector type	Connector Assignment
1	XI	SNP-226-B	Input single-phase supply voltage -220V from the power module stand.
2	X2	DB-9-M	Input of low-voltage supply voltage ± 12 V, + 5V from the power module of the stand;
3	X3	DB-9-F	Input signals from the pulse speed sensor of the electric machine unit.

The module "Inductive load" is used for modeling of reactive consumers when examining electric circuits of alternating current in accordance with Figure 2.17.

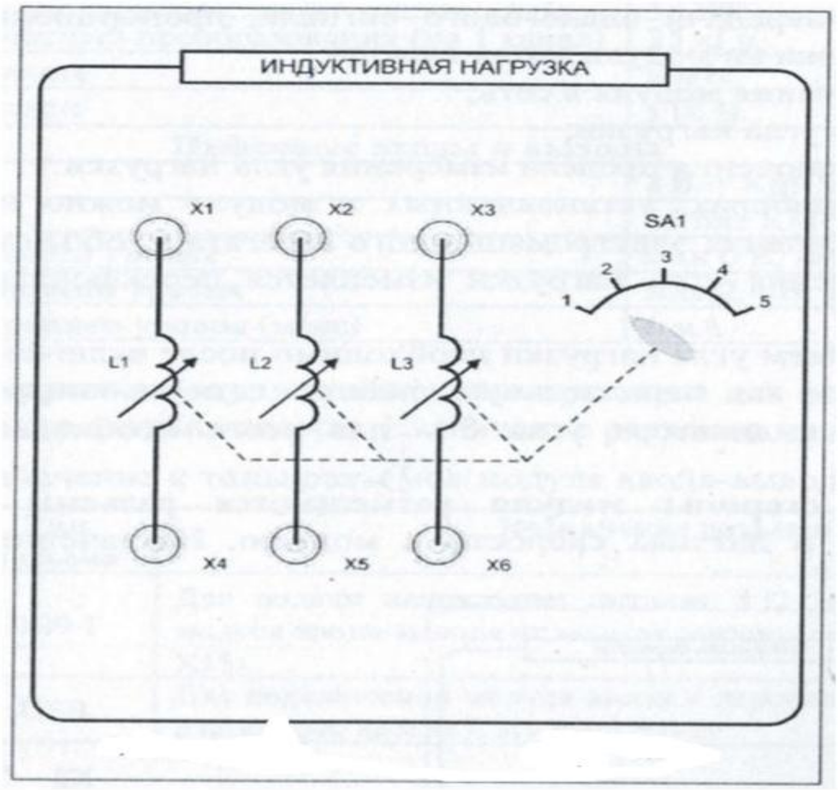


Figure 2.17 - "Inductive load" module

The inductive load value is changed by the switch SA1. The correspondence between the position of the switch and the approximate values of the inductance at UM = ~ 220 V is presented in Table 2.20.

Table 2.20 - Approximate inductance values

Switch position SA1	1	2	3	4	5
Inductance, H	10	7,5	6	4	3

The module "Capacitive load" is used to create an adjustable load. The module view is shown in Figure 2.18.

The value of the capacitive load is changed by the switch SA1. The correspondence between the position of the switch and the load value is shown in Table 2.21.

Table 2.21- Switch positions and load values

Switch position SA1	1	2	3	4	5
Capacitor capacitances, Mf	0,1	0,22	0,33	0,47	0,94

The module "Active load" is used to create a regulated three-phase active load. The module view is shown in Figure 2.19.

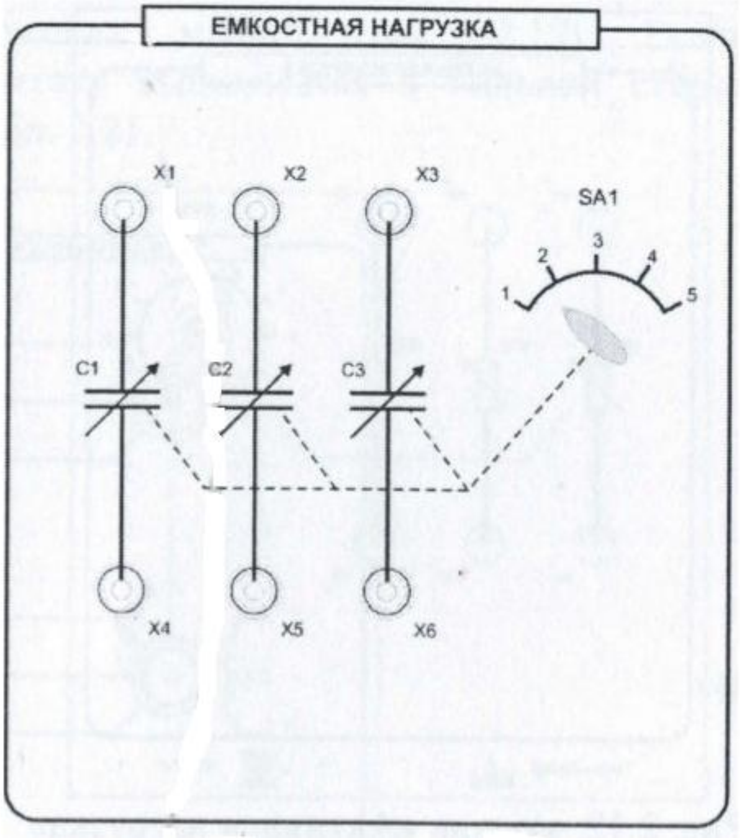


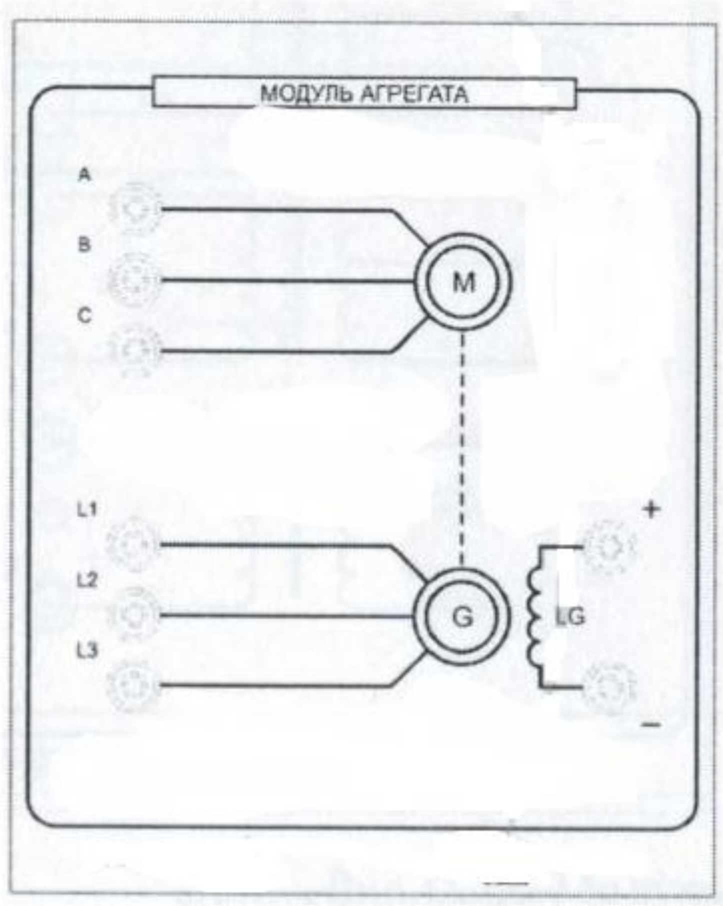
Figure 2.19 - "Active load" module

The active load is changed by the switch SA1. The correspondence between the position of the switch and the load value is shown in Table 2.22.

Table 2.22 - Switch positions and load values

Switch position SA1	1	2	3	4	5	6	7	8	9	10	11
Resistance, kOhmSA1	Z	Z	Z	2,8	3	J	3,4	3,6	J	4	4,2

The module of the unit is designed to simplify the collection of power circuits of laboratory works, namely, to connect power converters to terminals located on the front panel of the module with the corresponding mimic of the images of electric machines in accordance with Figure 2.20. The real connection to the machine is done from the rear. The purpose and type of the connector are shown in Table 2.23.



a - front side, b - rear side

Figure 2.20 - Unit module

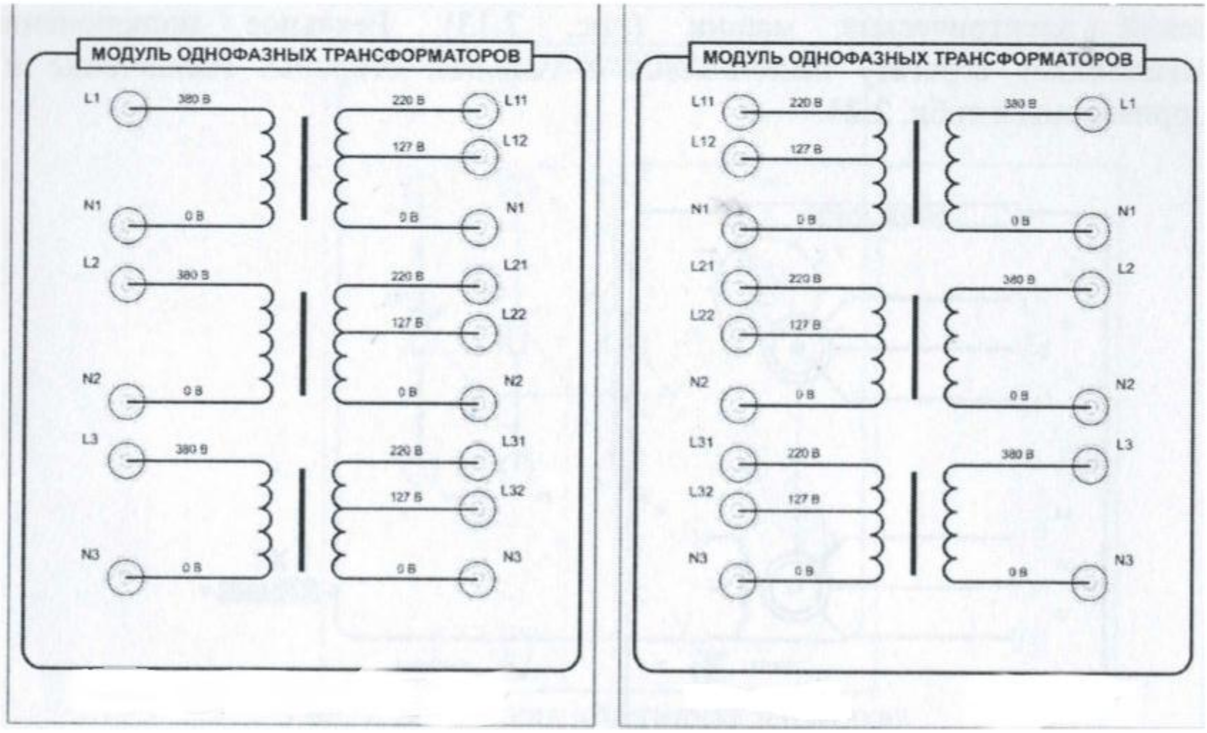
Table 2.23- Purpose and type of connector of the module of the unit

№	Connector designation	Connector type	Connector assignment
1	XI	RP10-11-P	Connecting the machine with a cable KS

The module of single-phase transformers in accordance with the figure figure 2.23. The characteristics of the transformers are given in Table 2.24.

Table 2.24 - Transformer characteristics

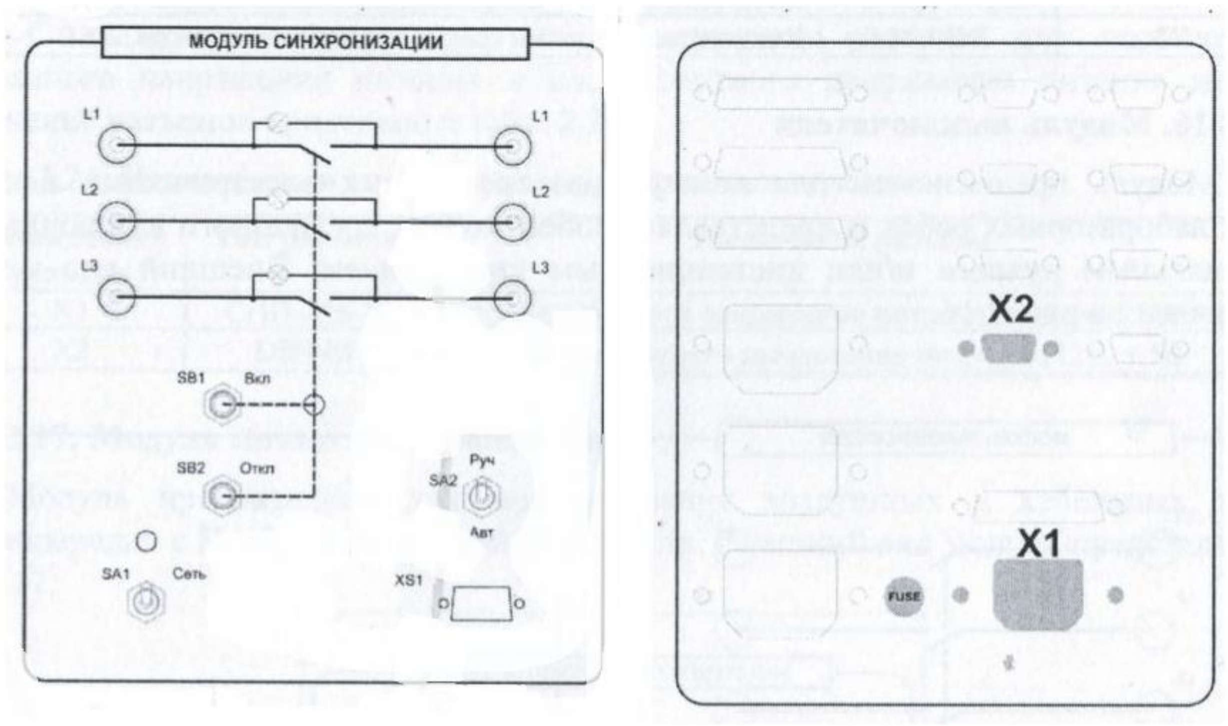
A type	OCM1
Power, Kva	0,1
Input voltage, V	380
Output voltage, V	220/127



a - right, b - left

Figure 2.23 - Module of single-phase transformers

The synchronization module in accordance with Figure 2.24 is designed to connect the synchronous machine to the network by methods of precise synchronization or self-synchronization



a - the front side, b - the back side
Figure 2.24 - The synchronization module

The front panel of the module contains:

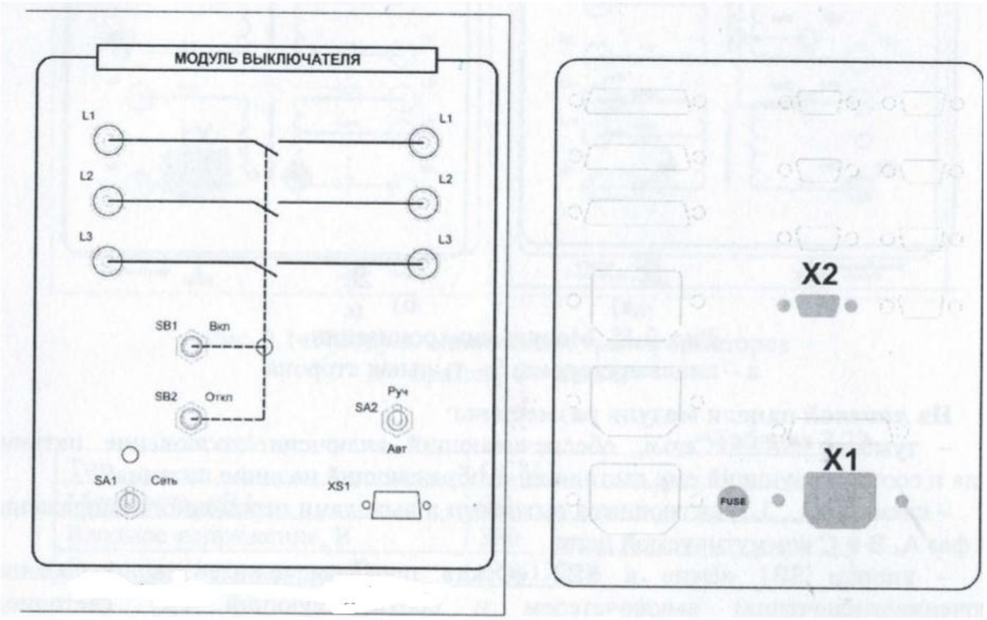
- the SA1 "Network" toggle switch, which provides power on / off of the module and the corresponding LED indicating the presence of power;
- terminals L1 ... L3, which are the outputs and outputs of AC voltage 220V of phases A, B and C of the switched circuit;
- I buttons SB1 "On" and SB2 "Off" intended for control (on / off) by the switch and its corresponding LED showing the current state of the switch (on / off);
- Toggle switch SA2, which selects the operating mode of the module, in the "Manual" position, the circuit-breaker control is carried out manually, with the buttons SB1 and SB2, in the "Auto" position, the switch is controlled via the XSI connector located on the front panel of the module;
- connector XS1 type DB9, providing the possibility of remote control of the switch in case when the toggle switch SA2 is in the "AUT" position.
- LEDs "synchroscope" to visually determine the timing of the synchronization of the generator with the network when it is manually synchronized.

On the back side of the module are located connectors for connecting single-phase supply voltage and low-voltage supply voltage module. The purpose of the connectors is given in Table 2.25.

Table 2.25 - Purpose and types of connectors of the synchronization module

№	Connector designation	Connector type	Connector assignment
1	XI	SNP-226-B	Input single-phase supply voltage module -220B
2	X2	DB9-M	Low voltage power input ±12B, + SB

The breaker module is designed for switching three-phase electrical circuits in laboratory circuits and is a model of a three-phase switch with two-channel manual and remote control. The appearance of the module is shown in Figure 2.25.



a - the front side, b - the back side

Figure 2.25 - The switch module

The front panel of the module contains:

- the SAI "Network" toggle switch, which enables the power on / off of the module and the corresponding LED indicating the presence of power;
- terminals L1 ... L3, which are the outputs and outputs of AC voltage 220V of phases A, B and C of the switched circuit;
- buttons SB1 "On" and SB2 "Off" intended for control (on / off) by the switch and its corresponding LED showing the current state of the switch (on / off);
- Toggle switch SA2, which selects the operating mode of the module, in the "Manual" position, the circuit-breaker control is carried out manually, with the

buttons SB1 and SB2, in the "Auto" position, the switch is controlled via the XSI connector located on the front panel of the module;

- connector XS1 type DB9, providing the possibility of remote control of the switch in case when the toggle switch SA2 is in the "AUT" position.

On the back side of the module are located connectors for connecting single-phase supply voltage and low-voltage supply voltage module. The purpose of the connectors is given in Table 2.26.

Table 2.26 - Purpose and types of connectors of the switch module

№	Connector designation	Connector type	Connector assignment
1	XI	SNP-226-B	Input single-phase supply voltage module- 220B
2	X2	DB9-M	Low voltage power input ±12B, + 5B

The power line module is designed to simulate air and cable power lines with a U-shaped replacement circuit. The appearance of the module is shown in Figure 2.26.

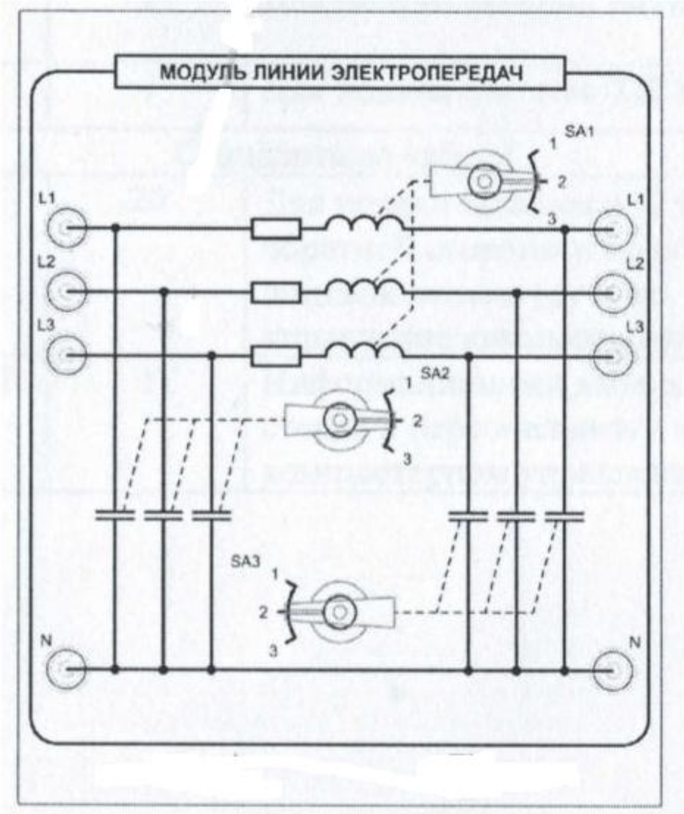


Figure 2.26 - Power Line Module

The front panel of the module contains:

- input and output terminals LI, L2, L3, N to plug the module into the circuit under test; - switch SA1 for changing the value of the active-inductive resistance of the transmission (transmission line length);
- switches SA2, SA3 for changing the value of the capacitive component of the transmission line.

The main technical characteristics and range of changes in the parameters of the transmission line are presented in Table 2.27.

Table 2.27 - Technical Specifications of the Power Line Module

Rated voltage, V	220		
Rated (long-term) current, A	0,8		
Phase inductance, HH	At position SA1		
	1	2	3
	0,14	0,28	0,42
Phase capacity at the beginning / end of the power line, μF	When position SA2/SA3:		
	1	2	3
	0	0,47	0,94

2.5 Conclusions on the chapter

Model of the electrical system" is intended for conducting laboratory and practical work on the courses: "Transient processes in the electric power industry", "Relay protection and automation", "Automatic design in the electric power industry", "Electrical networks and systems".

The stand allows to qualitatively simulate the established operating modes of electric power systems, electromagnetic and electromechanical transient processes with various kinds of short circuits, to investigate the factors influencing the static and dynamic stability of the parallel operation of synchronous generators, to investigate relay protection and automation devices.

A personal computer is one of the components of a laboratory stand. With the help of specialized software included in the stand, it is used for oscillography, data visualization, as a multichannel oscilloscope and recorder, as well as for controlling and protecting electric power objects in real time.

Students of electrotechnical specialties have the opportunity to study the innovative equipment "Model of the electrical system" in the following areas:

- For what measurements is this stand used;
- Features of the "Electric system model";

- Learn the basic characteristics, power consumption, operating temperature range, rated line voltage;
- Determine the purpose of the "Electromagnetic Unit";
- Possibilities for performing various types of laboratory work;
- To study the role, purpose and on what disciplines it is necessary to use this stand;
- Make an opinion on each performed laboratory work.

Chapter 3 Practical application of the stand "Electrical system model" on the discipline "electrical networks and systems"

3.1 Measurement of the parameters of the steady-state mode of the electrical network with one-sided power

Purpose: to master the measurements of the parameters of the steady-state operation of networks with one-sided power;

3.1.1 Assignment to work

- to study the factors influencing the values of the regime parameters of the transmission line (active and reactive powers, currents and voltages);
- to study the methods for calculating the steady-state operation of networks with one-sided power;
- to compare the data of calculated and experimental values.

3.1.2 Theoretical information

The transmission line is the most mass element of the electrical system, connecting the individual nodes of the circuit to each other. Unlike other elements (synchronous electric machines, transformer equipment, electric receivers, etc.), it is characterized by one essential feature, namely, it is an element with long-distributed parameters.

Transmission of electricity along the lines of the electrical network is caused by the spread of the electromagnetic field in the wires (cable veins) and the surrounding space. In an overhead line, under the influence of alternating voltage there is an alternating magnetic field around the wires, as well as a transient electric field between the phase conductors and between each of the wires and the ground.

The appearance of an alternating electric field leads to the appearance of displacement currents (charge currents), the values of which depend on the properties of the dielectric surrounding the conductor and on the potential difference between the wire and the earth, and for the three-phase line also between phase conductors. Charging currents, superimposed on the load current, determine the gradual variation of the total current along the line. The strength of the magnetic field due to this current also varies along the line. This, in turn, leads to the fact that induced EMF self - and mutual inductance are not the same for different elements of the line length. The inequality of these EMFs determines the complex law of voltage variation and displacement currents along the line.

The relationship between the voltages and U currents I at the boundaries of the elementary section of a line of length dl is determined by two equations known in the course of theoretical bases of electrical engineering:

$$-\frac{\partial u}{\partial l} = ir_0 + L_0\frac{\partial i}{\partial t}, \tag{3.1}$$

$$-\frac{\partial i}{\partial l} = ug_0 + C_0\frac{\partial u}{\partial t}, \tag{3.2}$$

where r_0, go, $_{L0}$, C_0, are respectively the active resistance and conductivity, inductance and capacitance per unit length of the line (the "linear" parameters of the line).

Equations (3.1) and (3.2) characterize both the transient and established modes of the line. If the line is connected to a sinusoidal voltage source with an angular frequency ω (U = U · ejω · t), then for steady-state regimes from (3.1) and (3.2) it follows that

$$-\frac{d\dot{U}}{dl} = Z_0\dot{I}, \tag{3.3}$$

$$-\frac{d\dot{I}}{dl} = Y_0\dot{U}, \tag{3.4}$$

where Z0 = r0 + jωL0, Y0 = g0 + jωC0 are the complex resistance and conductivity of a unit of the line length, respectively.

The power transmission line diagram is shown in Figure 3.1, where Π is the generalized energy consumer, Γ is the generalized generator with respect to the given electric power transmission, Rл and Xл are respectively the active and inductive resistance of the line

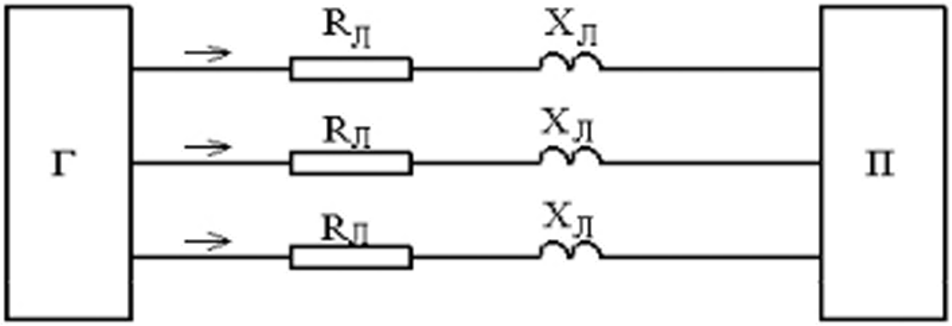


Figure 3.1- Structural diagram of power transmission taking into account line parameters

When calculating electrical networks and transmission lines in symmetrical modes, schemes are generally assumed to be single-line. One line should be understood as all three phases, the currents and voltages in which are equal, and the phase shift is 120 °. Such power transmission in a single-line execution is shown in Figure 3.2

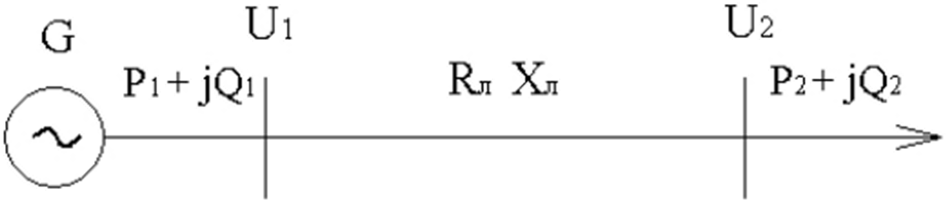


Figure 3.2 - Single-line transmission image

It should be taken into account in the calculations and parameters of the transmission line itself.

Any conductor has active and inductive resistance, as well as capacitive conductivity with respect to other conductors and to the ground.

Since there are no intermediate leaks, the currents in each phase are common both for the generator and for the consumer. A voltage and power for the generator and the consumer will be different (at the beginning and at the end of the line).

When calculating power transmission lines and electric grids, the method of connecting the phases of the consumer load and their resistance is usually not specified.

The symbolic resistances RH and XH (or R2 and X2 in Figure 3.2 reflect the following real physical processes: power consumption for heating of motor and transformer motor coils, compensation of motor drive EMF, compensation of EMF self and mutual inductance in windings, energy consumption for heating in electrotechnical devices, the conversion of electricity into the energy of the light flux in lighting installations.

The generalized characteristics of these processes, as practice and experience of operation shows, it is convenient to consider the components of power remember that for the absolute majority of electrical installations and household electrical appliances, the main characteristic is the so-called "nominal power" (industrial motors and transformers, lighting devices, household appliances: televisor, refrigerator, electric oven, electric shaver, computer , audio and video equipment, etc.) Although for electronic and computer equipment, the main thing is not the nominal power, but other parameters that determine the transformation of information (frequency range, memory size, etc.), the no less, from the point of view of power consumption by these devices they are characterized by power, and not by electrical resistance. In calculations of modes of electrical networks, parameters of their substitution circuits are involved: active and reactive resistances and conductances.

Therefore, it is necessary to be able to correctly determine them depending on the materials used, the geometric dimensions of the equipment sizes. The scheme for replacing the air or cable power line is shown in Figure 3.3.

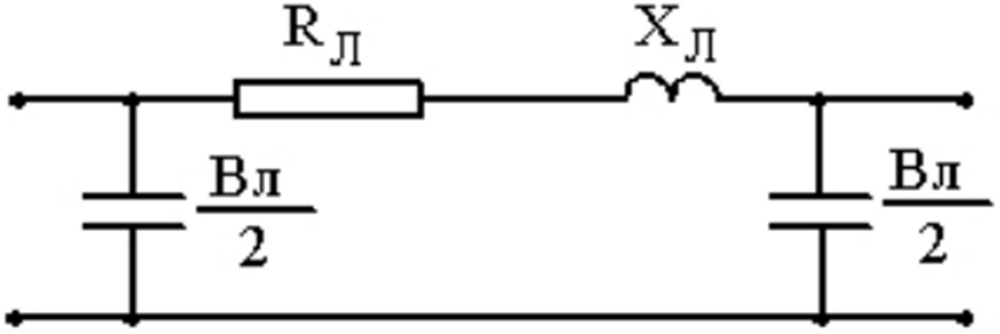


Figure 3.3 - Power line substitution scheme

The active resistance of AC conductors is somewhat different from the ohmic resistance to direct current. However, at a frequency of 50 Hz, this difference is insignificant, and in practical calculations it is neglected. The value of r0 can be chosen according to the reference tables depending on the brand and section of the wire, or calculated by the resistivity of the conductors.

3.1.3 Procedure for completing the work

1) To assemble the test scheme Figure 3.4. (ALL booth modules must be OFF!). The circuit is a network with a radial feed. Power supply 1, which is a network of infinite power, through a step-down transformer 2 and a power meter module 3, supplies power lines 4 and 5, each of which feeds its consumers 6 and 7, respectively.

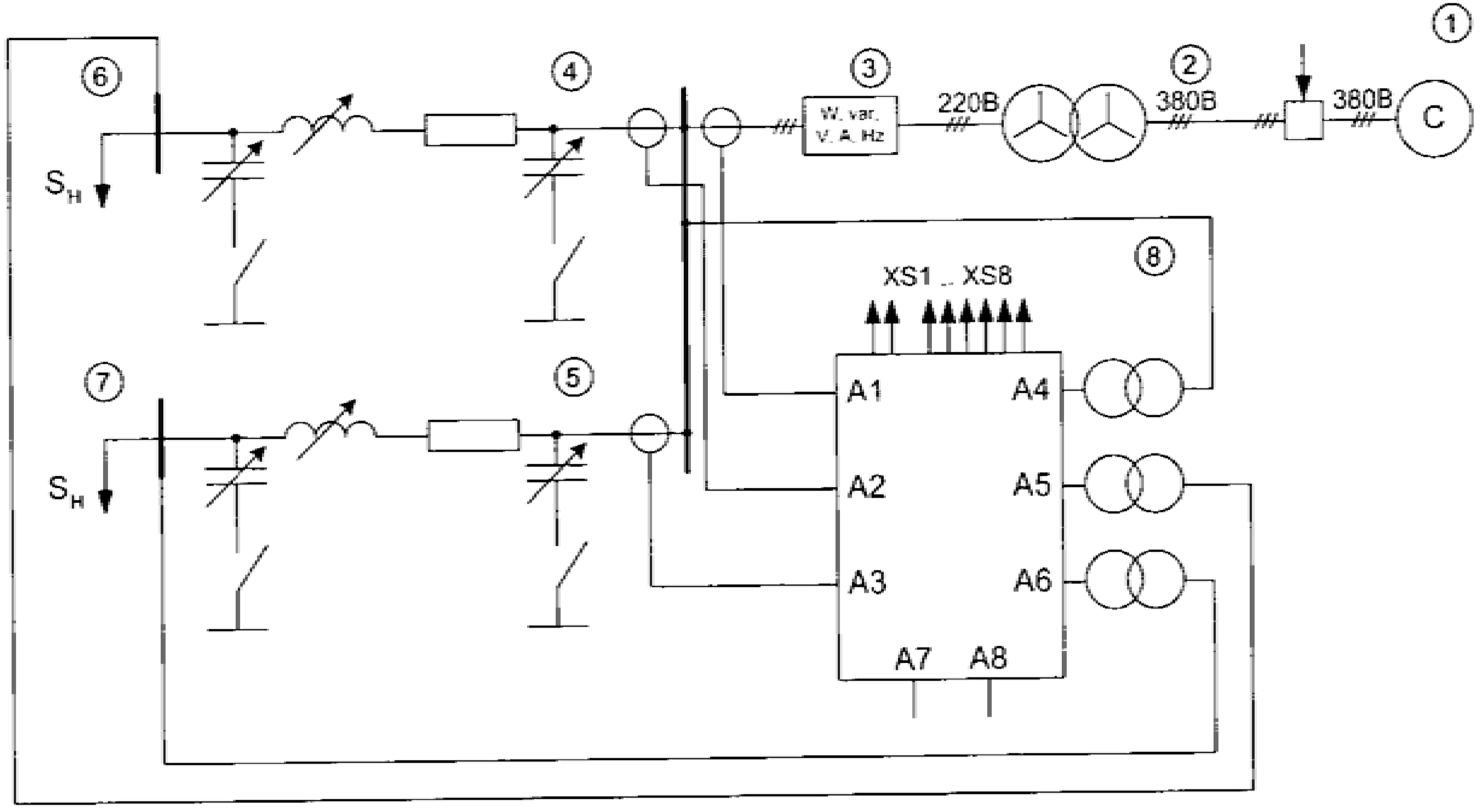


Figure 3.4 - Scheme of laboratory studies

As load 6 it is recommended to use the inductive load module, and as load 7, the active load module. The connection scheme of both load modules is a star without a zero wire. To measure the mode parameters, the current and voltage sensors of the I / O module 8 are used. In this case, the current sensors are connected in series to the measured circuit in phase A, and the voltage sensors to the phase A voltage (the measurements are made with respect to the neutral of the power transformer).

2) Set the parameters of the power line: a) the maximum value of the longitudinal component (switch SA1 to position 3); b) switching off the transverse component (switches SA2, SA3 to position 1). Set the parameters of active and inductive load: switches SA1 to position 1.

3) Start the DeltaProfi software package on the PC (Start - Programs - Laboratory complex - DeltaProfi).

Open the laboratory work with the team "Works - Transmission and quality of EE - Work №1 Measurement of the parameters of the steady-state mode of the electrical network with one-sided power supply".

4) Switch on the power of the stand.

5) Switch on the breaker of the three-phase network module (SB1 button on the front panel of the three-phase network module). Turn on power to the power meter module. Transfer the power meter module to the phase current measurement mode.

6) Start the program with the "Start" button or with the command of the main menu "Control - Start" or with the hot key FS.

7) In Table 3.1, record the readings of the measuring instruments on the mnemonic diagram of the PC.

8) Press the "Off" button of the three-phase network module.

9) Change the length of the power line 4 by switching the switch SA1 to position 1.

10) Press the "On" button of the three-phase network module. In Table 3.1, record the readings of the measuring instruments on the mnemonic diagram of the PC.

11) Press the "Off" button of the three-phase network module. Switch off the power to the stand.

12) Return switch SA1 of line 4 to the initial (third - 3) position.

13) Change the supply voltage of the network from 220V to 127V (by switching to other outswings of the power transformer).

14) Switch on the power of the stand. Press the "On" button of the three-phase network module. In Table 3.1, record the readings of the measuring instruments on the mnemonic diagram of the PC.

Table 3.1 - Measuring instrument readings

Network operation mode			U nom = 220B Act. load. SA1 = ind. load. SA1 = LEP W1 SA1 =	U nom = ' 220B Act. load. SA1 =ind. load. SA11 LEP W1 SA1 =	U nom = 127B Act. natr. SA1 = ind. load. SA11 LEP W1 SA1 =_	U nom = 220B Act. natr. SA1 =ind. load. SA11 LEP W1 SA1 =
Feeding Connection		P1, W				
		Q1,War				
LEP W1	Start	P2, W				
		Q2,War				
	End	P4, W				
		Q4,War				
	Loss	ДР, W				
		AQ,War				
LEP W2	Start	P3, W				
		Q3,War				
	End	P5, W				
		QS,War				
	Loss	DP, W				
		AQ,War				
		U1,B				
		U2, B				
		U3, B				

15) Press the "Off" button of the three-phase network module. Change the supply voltage of the network from 127V to 220V (by switching to other branches of the power transformer). Change the value of active and / or inductive load according to the individual task.

16) Press the "On" button of the three-phase network module. In Table 3.1, record the readings of the measuring instruments on the mnemonic diagram of the PC.

17) Stop the program with the "Stop" button, the main menu command "Control - Stop" or the hot key F6. Press the "Off" button of the three-phase network module. Switch off the power to the stand.

18) Analyze the obtained data: determine how the load magnitude, the nominal voltage of the power transmission and the length of the power transmission lines affect the voltage at the network nodes, the amount of the overflows of the active and reactive powers, the magnitude of the losses in the

power lines. Explain why the total power consumed from the network is greater than the total load capacity, as well as the difference between the capacities at the beginning and end of the power lines 4 and 5.

19) Issue a report on laboratory work.

3.1.4 Test Questions

1. What modes of operation do you know about the electrical network?
2. The concept of steady-state operation of a power plant with one-sided power?
3. What does one-way power mode mean?
4. Explain the operation of a single-line electrical circuit?
5. List and purpose of the equipment, what functions are performed, measurement parameters?
6. List the order of the experiment?
7. Explain the purpose of the software package.
8. Assigning the elements to the electrical installation diagram.
9. What are the parameters of the active and inductive load?
10. Analyze the obtained data in the experimental part of the work.

3.2 Measurement of the parameters of the steady-state mode of the electric network with two-sided power supply.

The purpose of the work is to investigate the effect on the parameters of the power transmission lines (length, nominal voltage) and load parameters in individual nodes on the values of the regime parameters in the ring network (voltage in nodes, active and reactive power flows,).

3.2.1 Task to work

- to study the procedure of research, parameters, steady-state mode of electric network with two-way power supply.

3.2.2 Theoretical information

The electrical network consists of different elements each having its own purpose and constructive implementation. Each of the sections of the electrical network is characterized by the same set of parameters (r, x, g, b, Kt).

r - resistance, Ohm;

x - reactance, Ohm;

g - active conductivity, cm;

b - reactive conductivity, cm;

Kt is the transformation ratio.

The parameters reflect the characteristic properties of network elements and differ only quantitatively.

For the quantitative determination of the properties of the elements of the electrical network, a replacement scheme is made up. It indicates all the parameters that determine the state of the electrical network. Network substitution schemes are made up of substitution schemes for individual elements, they differ from the schematic diagrams of connecting these elements.

Principal circuits of connections (switching schemes) are needed only to determine the direction of transmission of electrical energy and the degree of redundancy of power to consumers. In them, each element of the network has an image that reflects its action in solving the problem of electricity supply.

The network replacement scheme is compiled to perform calculations of operating conditions. Each element of the network in it can be reflected by several sub-elements.

When characterizing the symmetrical operating modes, the substitution circuitry is composed of one phase of the three-phase network, the neutral of the circuit is common. The loss of active power is reflected by the active resistances (r) or conductances (g). The loss of reactive power is reflected by reactive (inductive) resistances or conductivities. The generation of reactive power is reflected by negative reactive capacitive resistances or conductances.

There are longitudinal and transverse branches of substitution schemes. Longitudinal branches are called the current of the load. The power losses in these branches are determined by the load current. Transverse branches are called, which are included in the total voltage (directly connected to the neutral of the circuit). The power losses in these branches are determined by the supplied voltage.

The phenomenon of transformation is especially reflected in the substitution schemes. This applies to networks consisting of sections of different nominal voltages and considered together.

The element of transformation reflects the fact of changing the parameters of the regime - voltages and currents. The values of the total power do not change at the same time (the losses in the transformers are reflected by other elements of the circuit).

Particular are the elements that reflect the work of consumers and food points. They reflect the fact of consumption and power generation, they are represented by active elements of the scheme - loads. In this case, power generation is considered as a negative load.

The set of loads determines the network mode.

Transmission of electrical energy along the lines is due to the spread of the electromagnetic field in the wires and the surrounding space. Under the action of alternating voltage, an alternating magnetic field arises around the wires and an alternating electrostatic field between the phase conductors and between each of the wires and the ground. A conditional image of the elements of these fields is shown in Figure 3.5 for one overhead line.

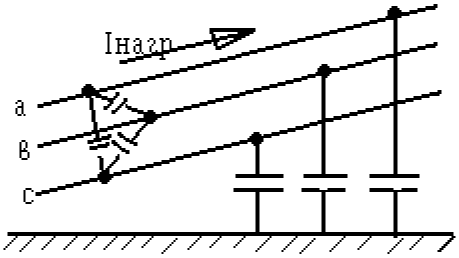


Figure 3.5 - Conditional display of field elements

The appearance of an alternating electric field leads to the appearance of displacement currents (charging currents), the values of which depend both on the properties of the dielectric surrounding the conductor and on the potential difference between the wire and ground, and for the three-phase line also between the phase wires. Charging currents, superimposed on the load current, determine the gradual change in current along the length of the line.

The electromagnetic field is characterized by a strength that also varies along the length of the line. This leads to the formation of emfs of self-induction and mutual induction, unequal for different elements of the line length. The inequality of these EMFs determines the complex law of voltage variation along the line and the variation of displacement currents (charging currents) along the line length.

The active resistance of wires and cables is determined by the material of current-carrying veins and their cross-sections.

With the change in the cross-section of wires and cables, their active resistances change significantly.

The active resistance is inversely proportional to the cross-section of the wire or cable. The magnetic field that arises around and inside the wires of the VL and live cables determines their inductive resistance. The inductive resistance depends on the relative arrangement of the wires.

The inductive resistance of the phase conductors of the OL will be the same if they are located along the vertices of an equilateral triangle, and will differ from each other if the phase wires are suspended in the horizontal plane. To avoid undesirable asymmetry, the transposition of the wires is applied, which consists in changing the phase wires on the supports at several points of the line. In this case, each wire alternately occupies all three possible positions with approximately the same extent.

Due to the transposition, the emfs induced in the phase wires are equalized and the inductive resistances become the same.

For illustration, we give an example of inductive resistances of three voltages for average wire cross-sections and distances between wires:

1) line 6.10 kV x0 = 0.362 Om / km;
2) 35 kV line x0 = 0.401 Ohm / km;
3) the line 110 kV x0 = 0.433 Ohm / km.

When performing VL single (unsplit wires) their inductive resistance: $x_0$0,4≈ Om / km.

The inductive resistance of the split wires, due to an increase in the equivalent radius, will be less and when splitting into three wires it will be x00.29≈ Om / km.

A small dependence on the design characteristics of the OL is also inherent in capacitive conductivity.

3.2.3 Procedure for performing the work

1) Collect the scheme of laboratory tests in accordance with Figure 3.6. (ALL booth modules must be OFF!). The circuit is an annular network in which the power supply 1, which is an infinite power system, through the step-down transformer 2 and the power meter module 3, supplies power to the power lines 4 and 5. The power lines supply the node substation having the load 6. As the load 6 it is recommended to use an inductive load module. The connection diagram of the load module is a star without a zero wire. For the measurement of the mode parameters, the current and voltage sensors of the I / O module 7 are used. In this case, the current sensors are connected in series to the measured phase A circuit, and the voltage sensors to the phase A voltage (the measurements are made with respect to the neutral of the power transformer).

2) Set the parameters of the power line: a) the maximum value of the longitudinal component (switch SA1 to position 3); b) switching off the transverse component (switches SA2, SA3 to position 1). Set the value of the inductive load: switch SA1 to the maximum possible position.

3) Start the DeltaProfi software package on the personal computer (Start - Programs - Laboratory complex - DeltaProfi). Open the laboratory work by the team "Works - Transmission and quality of EE - Work # 2 Measurement of the parameters of the steady-state power network with two-sided power supply".

4) Switch on the power supply of the stand Switch on the power of the power meter module. Transfer the power meter module to the phase current display mode.

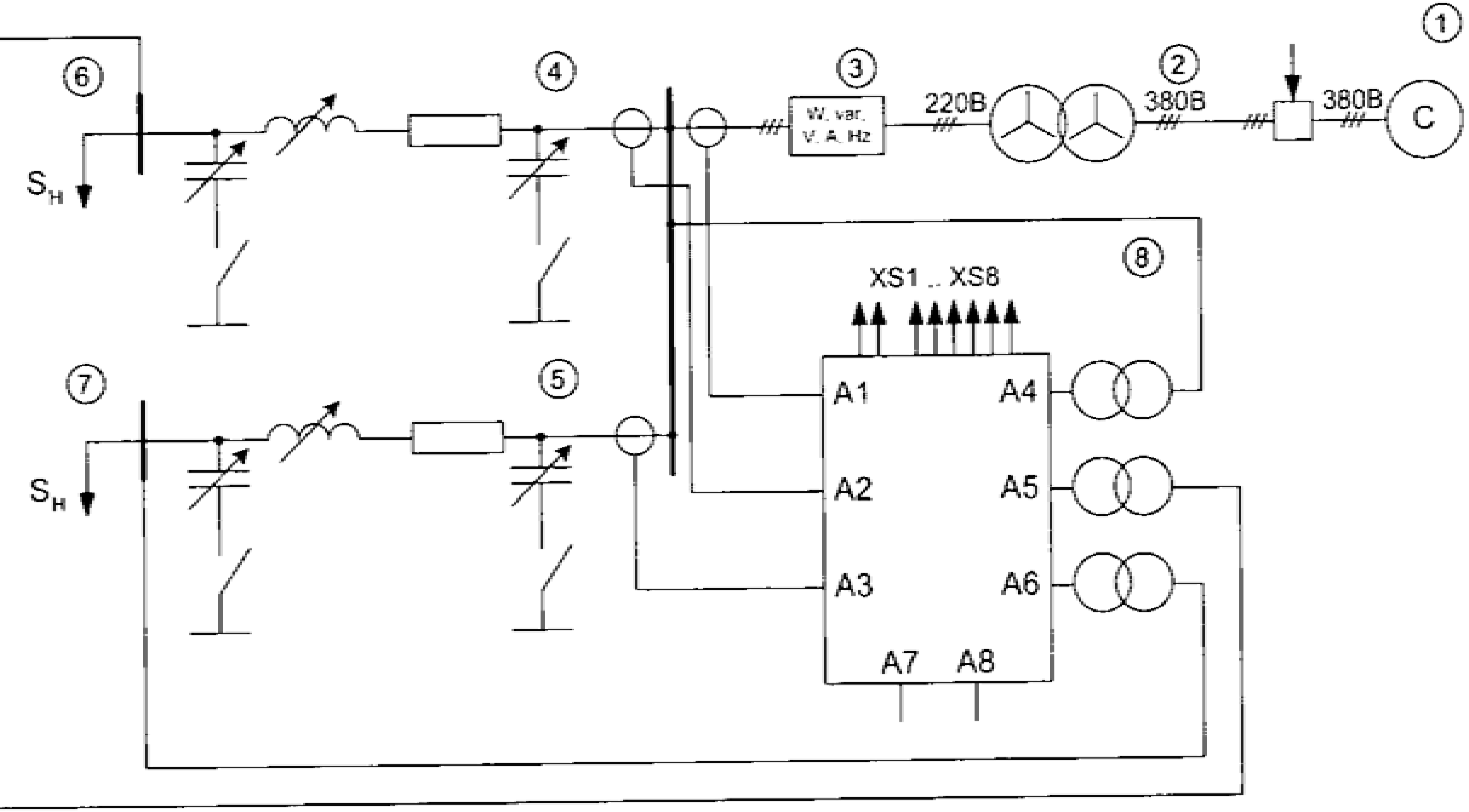


Figure 3.6 - Scheme of laboratory researches

5) Switch on the breaker of the three-phase network module (SB 1 button on the front panel of the three-phase network module).

6) Start the program with the "Start" button or with the command of the main menu "Control - Start" or with the hot key FS.

7) In Table 3.2, record the readings of the measuring instruments on the mnemonic diagram of the PC.

8) Press the "Off" button of the three-phase network module.

9) Change the length of the power line 5 by switching the switch SA1 to position 1.

10) Switch on the three-phase network module switch (SB1 button on the front panel of the three-phase network module). In Table 3.1, record the readings of the measuring instruments on the mnemonic diagram of the PC.

11) Press the "Off" button of the three-phase network module. Switch off the power to the stand.

12) Return switch SA1 of line 5 to the initial (third - 3) position.

13) Change the supply voltage of the network from 220V to 127V (by switching to other outswings of the power transformer).

14) Switch on the power of the stand. Switch on the breaker of the three-phase network module (button SB 1 on the front panel of the three-phase network module). 15) In Table 3.2, record the readings of the measuring instruments on the mnemonic diagram of the PC.

16) Press the "Off" button of the three-phase network module. Change the supply voltage of the network from 127V to 220V (by switching to other tap-offs of the power transformer). Change the value of the inductive load by moving the switch SA1 to position 1. Switch on the breaker of the three-phase network module (SB button 1 on the front panel of the three-phase network module).

17) In Table 3.2, record the readings of the measuring instruments on the mnemonic diagram of the PC.

18) Stop the program with the "Stop" button, the main menu command "Control - Stop" or the hot key F6. Press the "Off" button of the three-phase network module. Switch off the power to the stand.

19) Analyze the obtained data: determine how the resistance values of the transmission lines (their lengths) affect the voltages at the network nodes, the flow of active and reactive power through power lines.

20) Calculate the losses of active power, explain the causes of their occurrence and propose measures aimed at reducing their magnitude.

21) Issue a report on laboratory work.

Table 3.2 - Measuring instrument readings

Network operation mode End of P4, W Q4, Var Loss of DR, W AQ, Var LEP W2 Start RZ, W Q3, Var End of P5, W			U nom. = 220B Act. load. SA1 =ind. load. SA1 = LEP W1 SA1 =	U nom = ' 220B Act. load. SA1 ind. load. SA11 LEP W1 SA1 =	U nom = 127B Act. natr. SA1 = ind. load. SA11 LEP W1 SA1 =_	U nom = 220B Act. natr. SA1 ind. load. SA11 LEP W1 SA1 =
Feeding Connection		P1, W				
		Q1,War				
LEP W1	Start	P2, W				
		Q2,WAR				
	End	P4, W				
		Q4,War				
	Loss	DR, W				
		AQ,War				
LEP W2	Start	P3, W				
		Q3,War				
	End	P5, W				
		QS,War				
	Loss	ДР, W				
		AQ,War				
		U1,B				
		U2, B				
		U3, B				

3.2.4 Control questions

1. How is the measurement of the parameters of the steady-state electrical network with a two-way power supply?
2. Describe all modules used in laboratory work.
3. What is an electrical network?
4. What are the characteristics of the electrical network?
5. What is the circuit for replacing the network?
6. What is the loss of active power?

7. Explain the procedure for filling the table in the laboratory.
8. What is the sequence of performing the laboratory work?
9. How is the software package run in the laboratory?
10. How much and what experimental data are removed in the laboratory?

3.3 Losses of electrical energy in distribution networks

Objective: to study the factors that affect the loss of electrical energy in distribution networks

3.3.1 Task to work

-to determine the factors affecting the amount of active and reactive power losses in the distribution network;

- to study the dependence of power losses on the magnitude of the load and its nature;
- study the effect of the rated voltage of the distribution network on the amount of active and reactive power losses.

3.3.2 Theoretical information

In the transmission of electrical energy, losses occur in each element of the electrical network. To analyze the components of losses in various elements of the network and to assess the need for any measure aimed at reducing losses, an analysis of the structure of electric power losses is performed.

The actual (reported) energy losses ΔWWh are determined as the difference between the electric power supplied to the grid and the electricity supplied to the consumers. These losses include components of a different nature: losses in network elements that are purely physical in nature, the consumption of electricity for the operation of equipment installed in substations and providing electricity transmission, the error of fixing electricity by devices to account for it, and finally, the theft of electricity, non-payment or incomplete payment readings of counters, etc.

The separation of losses into components can be carried out according to different criteria: the nature of losses (constants, variables), voltage classes, groups of elements, production units, etc.

Given the physical nature and specificity of methods for determining the quantitative values of actual losses, they can be divided into four components:

1) technical losses of electric power ΔWT, caused by physical processes in wires and electrical equipment, which occur when electricity is transmitted through

electric networks.

2) electric power consumption for the needs of the substations ΔWCH, which is necessary to ensure the operation of the technological equipment of substations and vital functions of the maintenance personnel, determined by the meter readings installed on transformers for the auxiliary needs of the substations;

3) power losses caused by instrumental errors in their measurement (instrumental losses) ΔWIS;

4) commercial losses ΔWK, caused by theft of electricity, inconsistency of meter readings, payment for electricity by household consumers and other reasons in the sphere of organization of control over energy consumption. Their value is defined as the difference between actual (reported) losses and the sum of the first three components:

$$\Delta W_{\text{К}} = \Delta W_{\text{Отч}} - \Delta W_{\text{Т}} - \Delta W_{\text{СН}} - \Delta W_{\text{Изм}}. \tag{3.5}$$

The first three components of the loss structure are due to the technological needs of the transmission of electricity through networks and the instrumental accounting of its receipt and leave. The sum of these components is well described by the term technological losses. The fourth component - commercial losses - is the impact of the "human factor" and includes all its manifestations: conscious theft of electricity by some subscribers by changing meter readings, non-payment or incomplete payment of meter readings, etc.

The criteria for attributing a portion of electricity to losses can be of a physical and economic nature.

The amount of technical losses, electricity consumption for own substation needs and commercial losses can be called physical losses of electricity. These components are really connected with the physics of energy distribution over the network. In this case, the first two components of physical losses relate to the technology of electricity transmission through networks, and the third - to technology to control the amount of electricity transferred.

The economy defines losses as a part of electricity, for which its registered useful leave for consumers was less electricity produced at its power plants and purchased from its other producers. At the same time, the registered useful supply of electricity here is not only that part of it, the cash funds for which actually arrived at the settlement account of the energy supply organization, but also the one on which bills are issued, i.e. energy consumption is fixed. In contrast, the actual readings of meters that record energy consumption by household subscribers are unknown. The useful supply of electricity to residential customers is determined directly from the monthly payment received, therefore all losses are attributed to the unpaid energy.

From the economic point of view, the electricity consumption for the substation's own needs is no different from the expenditure in the elements of the networks for the transfer of the rest of the electricity to consumers.

Underestimation of the volumes of usefully released electricity is the same economic loss as the two components described above. The same can be said about the theft of electricity. Thus, all four losses described above are economically the same.

Technical losses of electricity can be represented by the following structural components:

- load losses in substation equipment. These include losses in lines and power transformers, as well as losses in current measurement transformers, high-frequency barriers (HV) of high-frequency communications and current-limiting reactors. All these elements are included in the "line" of the line, i.e. consequently, the losses in them depend on the power flowing through them.
- Idle losses, including losses in electric power in power transformers, compensating devices (CU), voltage transformers, meters and RF coupling devices, as well as losses in insulation of cable lines.
- climatic losses, which include two types of losses: losses on the corona and losses due to leakage currents along insulators of overhead lines and substations. Both species depend on weather conditions. Technical losses in the electric networks of power supply organizations (power systems) should be calculated in three voltage ranges:
- in high-voltage supply networks 35 kV and above;
- in medium voltage distribution networks 6 - 10 kV;
- in low voltage distribution networks 0.38 kV.

Distribution networks 0.38 - 6 - 10 kV, operated by RES and PES, are characterized by a significant share of electricity losses in total losses throughout the power transmission chain from sources to electrical receivers. This is due to the features of construction, operation, organization of operation of this type of network: a large number of elements, branching schemes, insufficient provision of accounting devices, relatively low loading of elements, etc.

Currently, for each RES and PES of power systems, technical losses in 0.38 - 6 - 10 kV networks are calculated monthly and are summed up over the year. The received values of losses are used for calculation of the planned norm of losses of the electric power for the next year.

3.3.3 Procedure for performing the work

1) Collect the scheme of laboratory tests in accordance with Fig. 3.7. (ALL booth modules must be OFF!). The circuit is a network with a radial feed. The power supply 1, which is an infinite power network, through the step-down transformer 2 and the power meter module 3, feeds the power line 4 operating on the active-inductive load 5. Two modules are used as the load: active module and inductive load module. Each of the modules is 3 independent resistors. The active and inductive elements of the modules are connected in series, and the resulting active-inductive elements are connected to a star without a zero wire. The current and voltage sensors are used to measure the power line parameters. In this case, the current sensors are connected in series to the measured phase A circuit, and the voltage sensors to phase A voltage (measurements are made with respect to the neutral of the power transformer). The power from the primary side of the transformer is measured using a universal power meter 3.

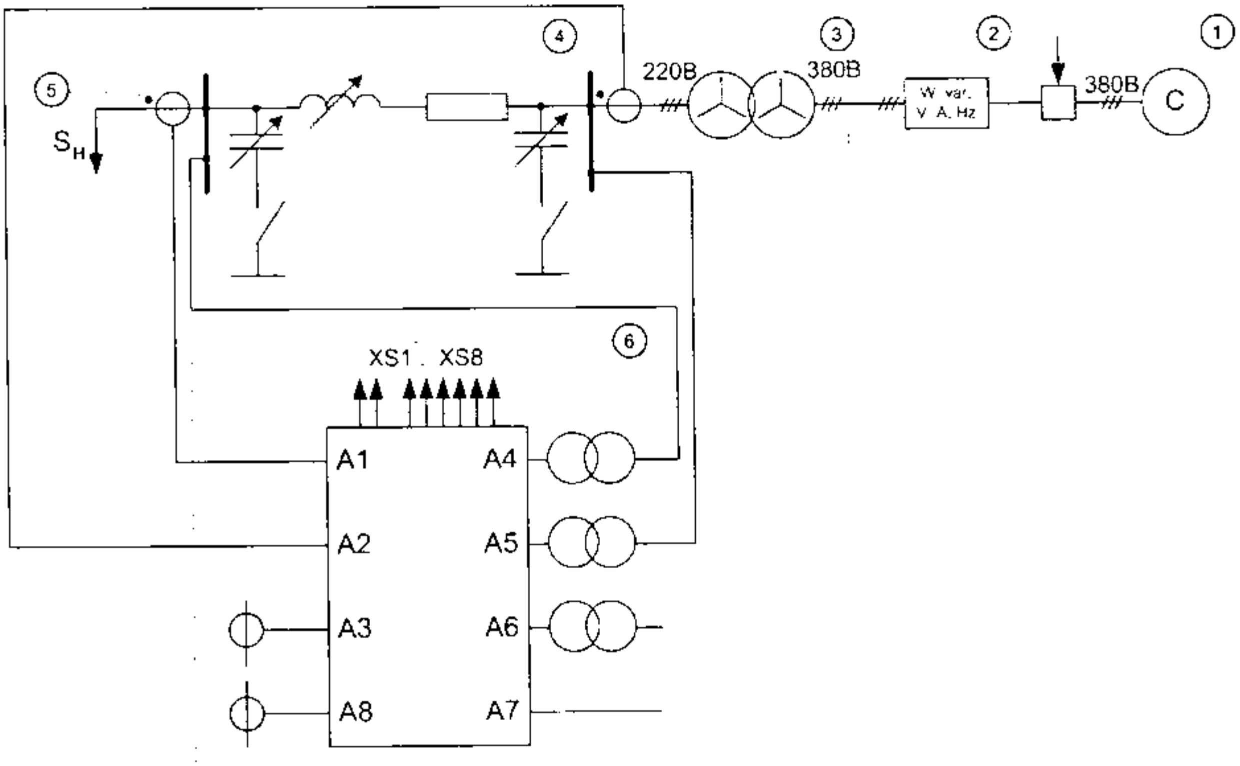


Figure 3.7 - Diagram of laboratory tests

2) Set the parameters of transmission lines: a) the maximum value of the longitudinal component (the switch SA1 in position 3); b) to disable cross-component (switch SA2, SA3 in position 1). To set the parameters of the active

and inductive loads: switch SA1 in the highest possible position. The neutral of the transformer to leave is not grounded (with isolated neutral).

3) On a personal computer to run the software complex "DeltaProfi" (start – Programs – Laboratory complex – DeltaProfi). Open lab team, "the Work – Transfer and quality of EE Work No. 3 electric power Losses in distribution networks".

4) Turn on the power stand.

5) Enable the switch module three phase network (SB 1 button on the front panel of the unit three-phase network).

6) Run the program into operation by start button or main menu item "Control – start" or F5 hot key.

7) In table 3.3 to record the meter readings on the mimic PC.

8) Press button "Off" module three phase network. Power off of the stand.

9) According to the obtained results to calculate the magnitude of the losses of active and reactive power in transmission line. The calculation results recorded in table 3.3.

10) Repeat the test at two different values of load (minimum and average). In table 3.3 to record the meter readings on the mimic PC.

11) Based on the results obtained, calculate the values of active and reactive power losses in the transmission line. Calculate the results of the calculation in Table 3.3. Construct a graph of the dependence of losses on the magnitude of the load and explain the dependence obtained.

Table 3.3 - Results of the calculation

Network operation mode		Mode №1	Mode №2	Mode №3	Mode №4
		U nom = 220B Ind. load. SA1 = SA1 = ЛЭП SA1 = 3	U nom = 220B Ind. load. SA1 = Ind. load. SA1= ЛЭП W2 SA1 = 3	U nom = 220B Ind. load. SA1 - Инд. нагр. SA1 = ЛЭП W2 SA1 = 3	U nom = 127B Ind. load.. SA11 Инд. нагр. SA1 = ЛЭП W2 SA1 =3
Measured Options	P1, Вт				
	Q1, Вар				
	U1, в				
	P2, Вт				
	Q2, Вар				
	U2, В				
Estimated options	ДР, Вт				
	AQ, Вар				
	ди, В				
	COS $\varphi_{\text{нагр}}$.				

Continuation of table 3.3

Network operation mode		Mode №5	Mode №6	Mode №7	Mode №8
		U nom = 220B Акт. натр. SA1 = Ind. load. SA1 = ЛЭП SA1 = 3	U nom = 220B Акт. натр. SA1 = Ind. Load SA1 = ЛЭП W2 SA1 = 3	U nom = 220B Акт. нагр. SA1 = Ind. Load SA1 = ЛЭП W2 SA1 = 1	Unom = 127B Акт. нагр. SA11 Ind. Load SA11 ЛЭП W2 SA1 =2
Measured options	P1, Vt				
	Q1, Bap				
	U1, B				
	P2, Вт				
	Q2, Bap				
	U2, B				
Estimated options	ДР, Вт				
	AQ, Bap				
	ди, B				
	COS $\varphi_{\text{нагр.}}$				

12) Translate power to low voltage (127V instead of 220V). For this, switch to a tap of a power transformer with less voltage on the secondary winding.

13) Set the parameters of the active and inductive load: switch SA1 to the maximum possible position.

14) Switch on the power supply of the stand and press the "On" button of the three-phase network module.

15) In Table 3.3, record the readings of the measuring instruments on the mnemonic diagram of the PC.

16) Press the "Off" button of the three-phase network module.

17) Switch off the power to the stand.

18) Based on the results obtained, calculate the amount of active and reactive power losses in the transmission line. Calculate the results of the calculation in Table 3.3. 19) Compare the received loss values with losses when the power line operates at a higher voltage and draw the appropriate conclusions. 20) Restore the power voltage of 220V.

21) Set the switch of the value of the active load to the middle position.

22) Without changing the value of the active load, carry out tests at two different values of the inductive load. In Table 3.3, record the readings of the measuring instruments on the mnemonic diagram of the PC.

23) Calculate the power losses in the transmission line, as well as the corresponding cos φ values. Make conclusions about the effect of the nature of the load on power losses in the network.

24) Set the parameters of the active and inductive load: switch SA1 to the maximum possible position.

25) Without changing the values of the active and inductive loads, conduct tests at two different values of the transmission line length (switch SA1 of the power line module). In Table 3, record the readings of the measuring instruments on the mnemonic diagram of the PC.

26) Stop the program by pressing the "Stop" button, using the main menu "Control - Stop" or the hot key F6. Press the "Off" button of the three-phase network module. Switch off the power to the stand.

27) Calculate the power losses in the transmission line, and also the corresponding cos φ values. Make conclusions about the effect of the length of the power line on the power losses in the network.

28) Issue a report on laboratory work.

3.3.4 Control questions

1. What factors influence the loss of electrical energy?
2. What determine actual losses?
3. What do you understand by the term electricity consumption for the substation's own needs?
4. Describe all the modules involved in this lab.
5. How are commercial losses determined?
6. What is the range of technical losses?
7. How much and what experimental data are investigated in laboratory work?
8. Describe the scheme of laboratory tests involved in this work.
9. Explain the results of the study and calculations on Table 3.3.

3.4 Voltage regulation by transverse compensation of reactive power with a capacitor battery

Purpose: - to study the effect of transverse capacitive compensation on the magnitude of the voltages in the nodes of the distribution network.

3.4.1 Task to work

- to study the influence of voltage regulation by transient compensation of reactive power with a capacitor battery

3.4.2. Theoretical information

The voltage in the network nodes is constantly changing due to the change in load, the mode of operation of power supplies, the network scheme. The voltage regime in the electrical network must be such that the requirements of GOST are satisfied with respect to permissible voltage deviations for electric receivers that are powered from this network.

The values of voltage deviations often exceed permissible for the following reasons:

- large voltage losses in the network;
- wrong choice of cross-sections of current-carrying elements and power of power transformers;
- wrong construction of the network scheme.

Very often, these reasons arise during the development of the network, when it is reconstructed. Therefore, to ensure the necessary voltage deviations on the buses of electric receivers, voltage regulation should be applied.

Voltage regulation refers to the process of voltage variation at characteristic points of the network with the help of special technical means. Local regulation can be centralized and local.

Centralized management is performed in the power centers. Local regulation is carried out directly by consumers. Voltage regulation in the power centers leads to a change in the voltage mode in the entire network, which is powered by it. Local regulation leads to a change in the voltage mode in a limited part of the network. In power stations, voltage regulation is performed on generators and step-up transformers.

Changing the voltage of the generators is possible due to the regulation of the excitation current. Without changing the active power of the generator, the voltage can be varied within 5%. An increase in voltage by 5% over the nominal voltage is accompanied by an increase in losses in steel and an increase in its heating. When the voltage drops to 0.95 Unom, the rated current of the stator increases by 5% and, accordingly, the heating of the winding increases.

At each step of the transformation approximately 5-10% of the voltage is lost. Therefore, the adjustment range of the generators is clearly not enough to maintain the necessary level of voltage in the network. In addition, it is difficult to reconcile the voltage regulation requirements for nearby and remote electrical receivers. Therefore, power plant generators are an auxiliary means of voltage regulation. As the only means of regulation, generators are used only for the simplest system: power plant - unallocated load. In this case, on the buses of power plants, there is a counter voltage regulation. By changing the excitation current, the voltage is raised during peak hours and reduced during the minimum load period. Step-up transformers in power plants are also an auxiliary means of voltage regulation. Transformers with a capacity of up to 250 MVA with a voltage of 110 and 220 kV have a voltage regulator of the PBW type (switching without excitation, that is, with a disconnection from the network). The device has a voltage regulation limit of 2 x 2.5%. Increasing transformers of higher power are produced without PBW devices.

For voltage regulation by substation transformers, it is possible to change the transformation ratio in the range of 10 - 20%. According to the design, two types of switching devices are distinguished:

- with regulation without excitation (PBW), that is, to change the transformer ratio, the transformer is disconnected from the network;
- with voltage regulation under load (RPN).

The regulation step is the voltage between adjacent branches. It is expressed as a percentage of the nominal voltage of the winding, which has adjusting branches. The deadband is defined as a certain range of voltage variation, at which control equipment does not operate. The dead band of the regulator should be slightly larger than the regulating stage: otherwise the regulator will be unstable. The time delay of the regulator serves to prevent its operation during short-term voltage changes. The dead band and the time delay of the controller determine the accuracy of the control.

3.4.3 Procedure

1) Assemble the scheme of laboratory tests as in figure 3.8 (ALL of the stand modules must be OFF!). The circuit is a power line with a radial feed. The power supply (three-phase network module) 1, which is a network of infinite power, feeds a power line 3 operating in the idle (no load) mode through the step-down transformer 2. The power meter 4 is designed to measure the line voltage on the consumer's tires.

2) Set the transmission line parameters: a) the minimum value of the longitudinal component (switch SA1 to position 1); b) disable the transverse component (switches SA2, SA3 to position 1). The neutral of the transformer should not be left grounded (operating mode with isolated neutral).

3) Switch on the power supply of the stand and press the "On" button of the three-phase network module.

4) Transfer the power meter module to the linear voltage measurement mode. Record the voltage of the power line when idling.

5) Press the "Off" button of the three-phase network module.

6) Switch off the power to the stand

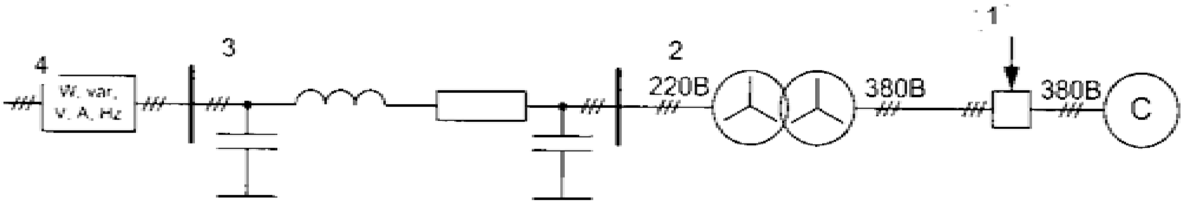


Figure 3.8 - Diagram of laboratory tests

7) To assemble the scheme of laboratory tests figure 3.9 (ALL modules of the stand must be OFF!), Which is a power line that operates on an inductive load.

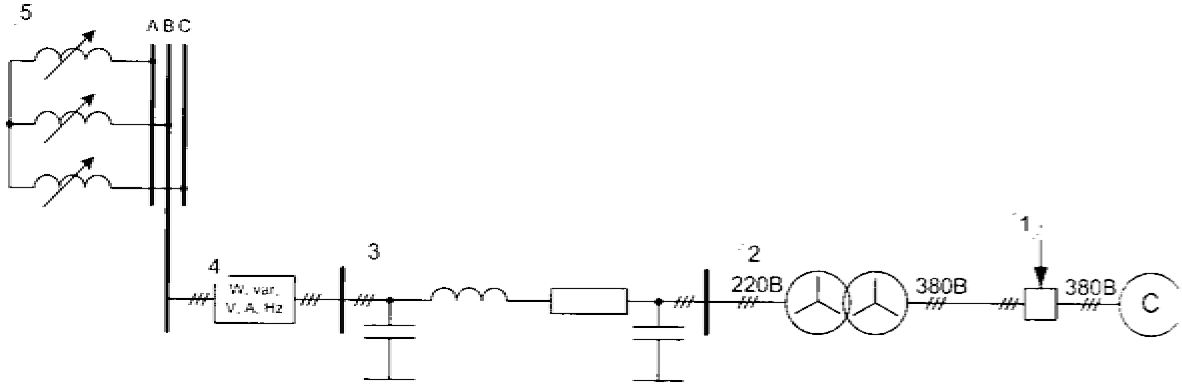


Figure 3.9 - Diagram of laboratory tests

8) to Set the switch SA1 of the magnitude of the inductive load in position 3.

9) Turn on the power stand and press the button On the module three-phase network.

10) to Translate a module of the power meter mode to measure the line voltages. Record the amount of voltage in a transmission mode of operation for inductive load.

11) Press button "Off" module three phase network.

12) turn Off the power stand.

13) Assemble the circuit of laboratory tests of figure 3.10 (ALL modules of the stand must be DISCONNECTED!), which is a transmission line with a device cross capacitive compensation 6 running on inductive load 5. As a device for transverse capacitive compensation (capacitor Bank) to use the module capacitive load. Switch capacity value of the capacitor Bank SA1 set in position 5.

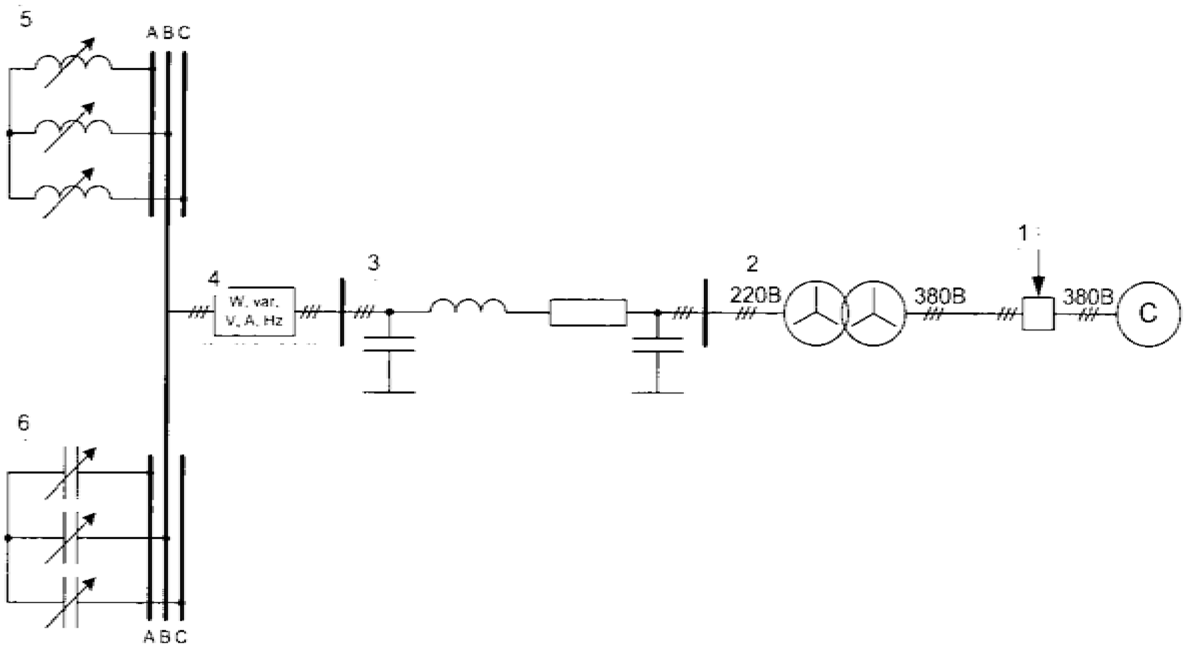


Figure 3.10 - Diagram of laboratory tests

14) Switch on the power supply of the stand and press the "On" button of the three-phase network module.

15) Transfer the power meter module to the linear voltage measurement mode. Record the value of the power transmission voltage with a device for transverse capacitive compensation in the operating mode for an inductive load.

16) Press the "Off" button of the three-phase network module.

17) Switch off the power to the stand.

18) On the basis of the results obtained, fill in Table 3.4 (for the nominal voltage of the transmission take the value of the voltage in idling mode), conclude that the effect of the transverse capacitive compensation on the voltage values in the nodes of the distribution network and the parameters of the quality of electrical energy (the value of the long-term voltage deviation).

19) Issue a report on laboratory work.

Table 3.4 - Results of calculations

Operating mode of the power line	Rated mains voltage, V	Power supply voltage, V	Voltage deviation,% %
Idling U ab Ubc U ca			
Inductive Load U ab Ubc U ca			
Transversal capacitive compensation, inductive load U ab Ubc Uca			

3.4.4 Test questions

1. Assign modules to the laboratory.
2. What should be the voltage mode in the electrical network?
3. What are the reasons for exceeding the allowable values of voltage deviations.
4. Give the definition of voltage regulation.
5. What does local regulation mean?
6. Where is the local voltage regulation performed?
7. To what extent does the voltage in the networks change?
8. Explain the process of performing laboratory work.
9. Explain the scheme of laboratory tests.
10. What do you mean by the term "regulation stage"?

3.5 Determination of the influence of voltage deviation on the power consumed by the active load.

Objective: - to study the effect of the voltage value on the power consumed by the active load.

3.5.1 Assignment to work

- to study the determination of the influence of the voltage deviation on the power consumed by the active load.

3.5.2 Theoretical information

The considerable influence of the mains voltage on the operation of electric receivers pays much attention to maintaining the voltage at the terminals of consumers close to the nominal voltage. The voltage applied to consumers is one of the qualitative indicators of electricity.

Changes in the voltage in the network can be classified as follows:

1. Slowly occurring voltage changes that occur during operating modes of the network. These changes are called voltage deviations. Voltage deviations are defined as the difference between the actual voltage at the terminals of the electrical receivers and the nominal voltage. Voltage deviations may be negative and positive. The first corresponds to the voltage drop in relation to the rated voltage, the second corresponds to the voltage increase.

Deviations in voltage in electrical networks are due to changes in network loads, power plant operation modes, etc.

2. Rapidly occurring voltage changes due to accidents in electrical systems and other causes. Examples include short circuits, machine failures, the inclusion and deactivation of one of the plant elements, etc. Rapidly occurring changes are called voltage fluctuations.

All receivers of electrical energy are designed to operate at a certain rated voltage. The deviation of the voltage from the rated voltage at their terminals leads to a deterioration in the operation of the electric receivers.

Reducing the light flux of the lamps leads to a decrease in the illumination of the workplace, as a result of which productivity decreases and quality indicators deteriorate.

An increase in the voltage of the network leads to an increase in the efficiency of the lamps, but an increase in voltage leads to a sharp decrease in the service life of the lamps. When the voltage is increased by 5%, the service life of incandescent lamps is halved, and with an increase of 10% - more than 3 times.

Fluorescent lamps are less sensitive to network voltage fluctuations. Deviations of voltage by 1% on average cause a change in the lamp's light flux by 1.25%.

Reducing the mains voltage causes a sharp decrease in the power output from the heating device. The latter leads to a significant increase in the operating time of the device and the overexpenditure of electricity for cooking, etc.

The characteristics of all other household electrical appliances also depend on the voltage applied. With changes in the voltage at the terminals of the motors, the torque, power consumption and the service life of the winding insulation change.

The rotational moments of induction motors are proportional to the square of the voltage applied to their terminals. If the motor torque at the rated voltage is taken as 100%, then at a voltage of 90%, for example, the torque is 81%. A strong reduction in voltage may even lead to a stoppage of the motors or the inability to start the electric motor driving the machine with severe starting conditions (lifts, crushers, mills, etc.).

Dependencies of the change in the power consumed by the motors from the voltage in the stationary mode of operation of the system are called static characteristics of the electric load of consumers.

When the voltage is lowered, the active power consumed by the electric motor decreases due to the reduction in torque and the associated increase in slip. Increasing the slip causes an increase in the loss of active power in the engine. When the voltage increases, the slip decreases and the power required for driving the mechanism increases. The loss of active power in the motor is reduced.

The analysis shows that the active load from electric motors under voltage changes corresponding to normal operating modes of the system changes insignificantly and therefore can be assumed constant.

The change in the reactive load of the motors from the voltage depends on the ratio of the reactive power of the magnetization and the reactive power of the motor scattering. The reactive power of magnetization varies approximately in proportion to the fourth power of the voltage. The reactive power dissipation, depending on the current of the motors, varies inversely with approximately the second degree of voltage.

When the voltage drops against the nominal (to some extent), the reactive load of the motors is always reduced. This is explained by the fact that the reactive power of magnetization, accounting for up to 70% of all the reactive power consumed by the electric motor, decreases more rapidly than the reactive power of the scattering increases.

3.5.3 Procedure

1) Collect the wiring diagram shown in figure 3.11, and all the stand modules must be OFF! The three-phase asynchronous motor M of the electric machine unit 2, which is a turbine model, receives power from the frequency converter 1 and generates a torque on the shaft of the synchronous generator G of the electric machine assembly 2. The supply of the synchronous generator drive winding is provided from the excitation module 3, which is an adjustable constant current source. The three-phase output voltage, taken from the stator winding of the synchronous generator G, through the step-up transformer 4 (single-phase transformer module), the power meter module 5 and the switch module 6 are fed to the three-phase active load 7 (active load module).

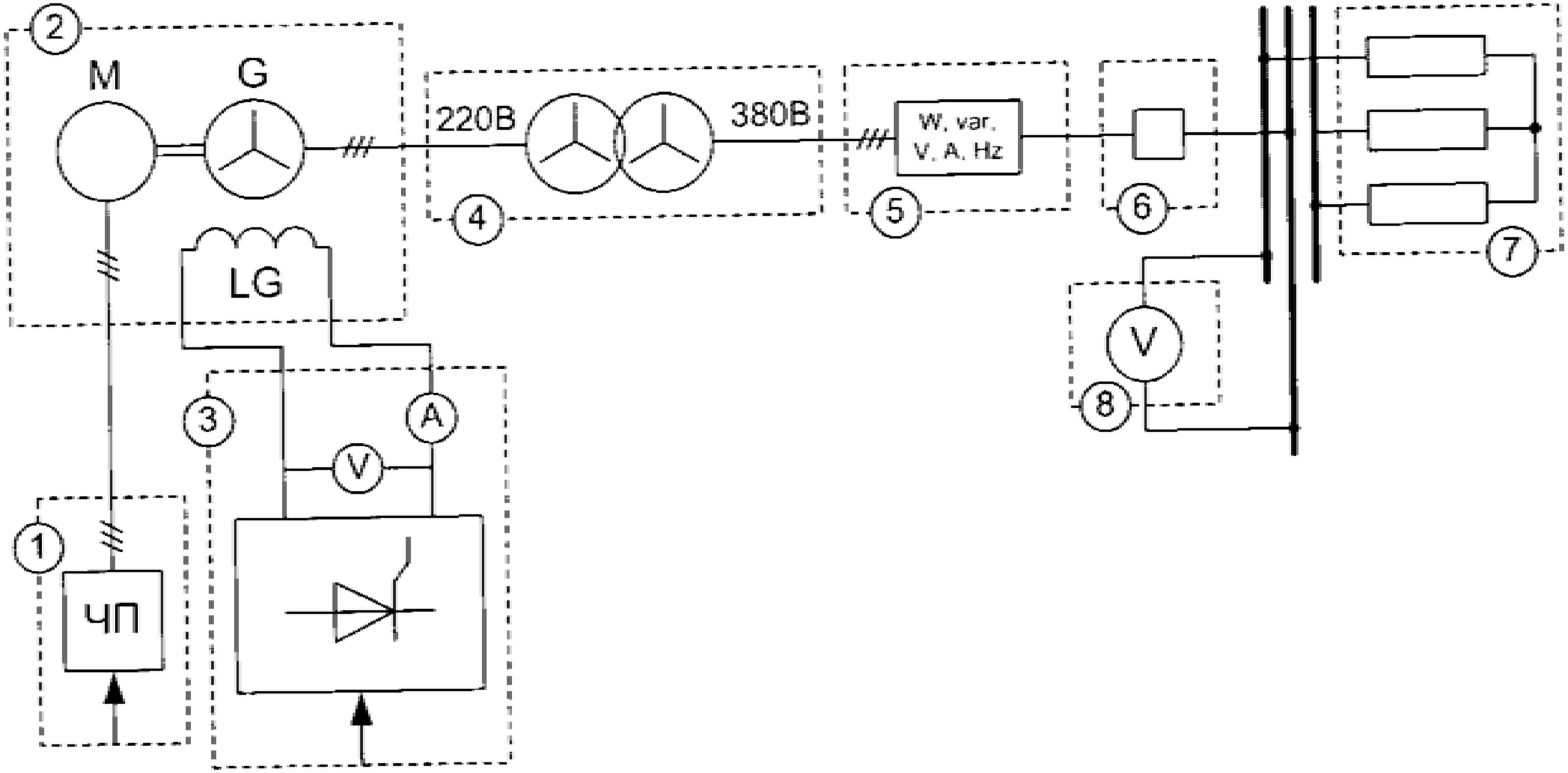


Figure 3.11- Scheme of laboratory researches

The load switching circuit is a star without a zero wire. The connection scheme for the windings of the transformers is "star / star". Thus, the circuit of the circuit under study is a model of an autonomous power supply network with adjustable parameters, which include: voltage value and frequency. The change in the value of the supply voltage is carried out by changing the excitation current of the synchronous generator (potentiometer RP1 on the front panel of the excitation module). The frequency of the supply voltage is varied by changing the speed of the drive motor M (potentiometer RP1 on the front panel of the inverter module). The power meter 5 is used to measure the amount of active and reactive power consumed by the load. The voltmeter 8 is used to measure the value of the line voltage on the load. As a voltmeter, one of the instruments of the measuring module is used. The frequency of the supply voltage is measured from the indicator of the frequency converter module.

2) Set the manual mode of the frequency converter, drive and switch modules and the knob of all the potentiometers of the modules involved to the zero position (end position counter-clockwise). The load value switch SA1 is set to the middle position. 3) Turn on the circuit breaker of the stand power module.

4) Turn on the frequency converter and start the drive motor and set the frequency to 50 Hz.

5) Switch on the power of the power meter and select the measurement of the line voltage at the output of the transformer, at this stage it is zero.

6) Switch on the excitation module and, changing the excitation current, set the line voltage at the transformer output equal to 380V.

7) Switch on the circuit breaker, check the voltmeter's readings for voltage on the load, and for the power meter, the presence of currents in all phases of the load.

8) Under load, the linear value of the voltage at the output of the transformer is set lower than the nominal, adjusting the excitation voltage of the generator to bring it to 380V.

9) Set the power meter reading for active power measurements (total three-phase active power).

10) By reducing the excitation current of the generator, remove the dependence of the active load power on the network voltage P = f (U) for U = 380 ... 110V at £ = 50Hz. 11) Turn off the stand, for this purpose make the excitation current of the generator equal to zero and turn off the excitation module, turn off the frequency converter module, turn off the automatic switch of the stand power module.

12) Process the results obtained, build the dependence of the active load power on the supply network voltage, draw conclusions and draw up a work report.

3.5.4 Test questions

1. What modules are involved in laboratory work?
2. How is the voltage variation of the network classified?
3. What is the light flux?
4. Define the static characteristics of the electric load of consumers.
5. Why does the active power consumed by the motor decrease?
6. Explain the procedure for performing laboratory work.
7. Explain the electrical installation.
8. List the purpose of the elements in the diagram.
9. What is the frequency of the network?
10. What is a load-off circuit?

3.6 Determination of the influence of the voltage deviation on the power consumed by the inductive load.

The purpose of the work: - to study the influence of the magnitude of the voltage on the power consumed by the inductive load.

3.6.1 Assignment to work

- to study the procedure for determining the influence of voltage deviation on the power consumed by the inductive load.

3.6.2 Theoretical information

Depending on the type of equipment used, the load is divided into active, inductive and capacitive. Inductive and capacitive loads are also called reactive loads. As such, the active load is rare. Most often, electric receivers represent an active-inductive load. Accordingly, active and reactive energy is consumed from the electrical network. Active energy is converted into useful energy: mechanical, thermal, etc. Reactive energy does not perform useful work. It is spent on the creation of electromagnetic fields in electric motors, transformers, induction furnaces, welding transformers and chokes. Reactive power is a part of the total power spent on electromagnetic processes in a load having a capacitive and inductive component. Does not perform useful work, causes additional heating of conductors and requires the use of a high-power power source. Inductive reactive load generated by electrical consumers can be counteracted by capacitive load, connecting an accurately calculated capacitor. This reduces the reactive power consumed from the network and is called the power factor correction or reactive power compensation.

The distribution of reactive loads between sources is completely determined by the influence of the network. The change in power losses as a result of the redistribution of reactive loads between the sources turned out to be insignificant, however, the radical redistribution of reactive loads should substantially change the mode of stresses in the network.

Control over the distribution of loads is carried out by wattmeters, and control over the distribution of reactive loads is based on phase meters, the readings of which must be the same for all parallel generators, regardless of their power. If these readings do not match, they should be equalized by adjusting the excitation of the generators (shunt regulator), while increasing the excitation of the generator, which has a greater phase meter reading, or to reduce the excitation of the generator having a lower indication of the phase meter.

Automatic excitation control devices are used to maintain the voltage according to a given characteristic and to distribute the reactive load between power supplies during normal operation of power systems.

Correct compensation of reactive power allows:

- to reduce the total cost of electricity;
- reduce the load of the elements of the distribution network (supply lines, transformers and switchgears), thereby prolonging their service life;
- Reduce thermal current losses and electricity costs;
- Reduce the influence of higher harmonics;
- Suppress network interference, reduce non-phase symmetry;
- to achieve greater reliability and profitability of distribution networks.

3.6.3 Procedure

1) Assemble the wiring diagram shown in figure 3.12, with all the stand modules must be OFF! The three-phase asynchronous motor M of the electromachine unit 2, which is a turbine model, receives power from the frequency converter 1 and generates a torque on the shaft of the synchronous generator G of the electric machine assembly 2. The supply of the synchronous generator drive winding is provided from the excitation module 3, which is an adjustable constant current source. The three-phase output voltage, taken from the stator winding of the synchronous generator G, through the step-up transformer 4 (single-phase transformer module), the power meter module 5 and the switch module 6 are supplied to a three-phase inductive load 7 (inductive load module). The load switching circuit is a star without a zero wire. The connection scheme for the windings of the transformers is "star / star".

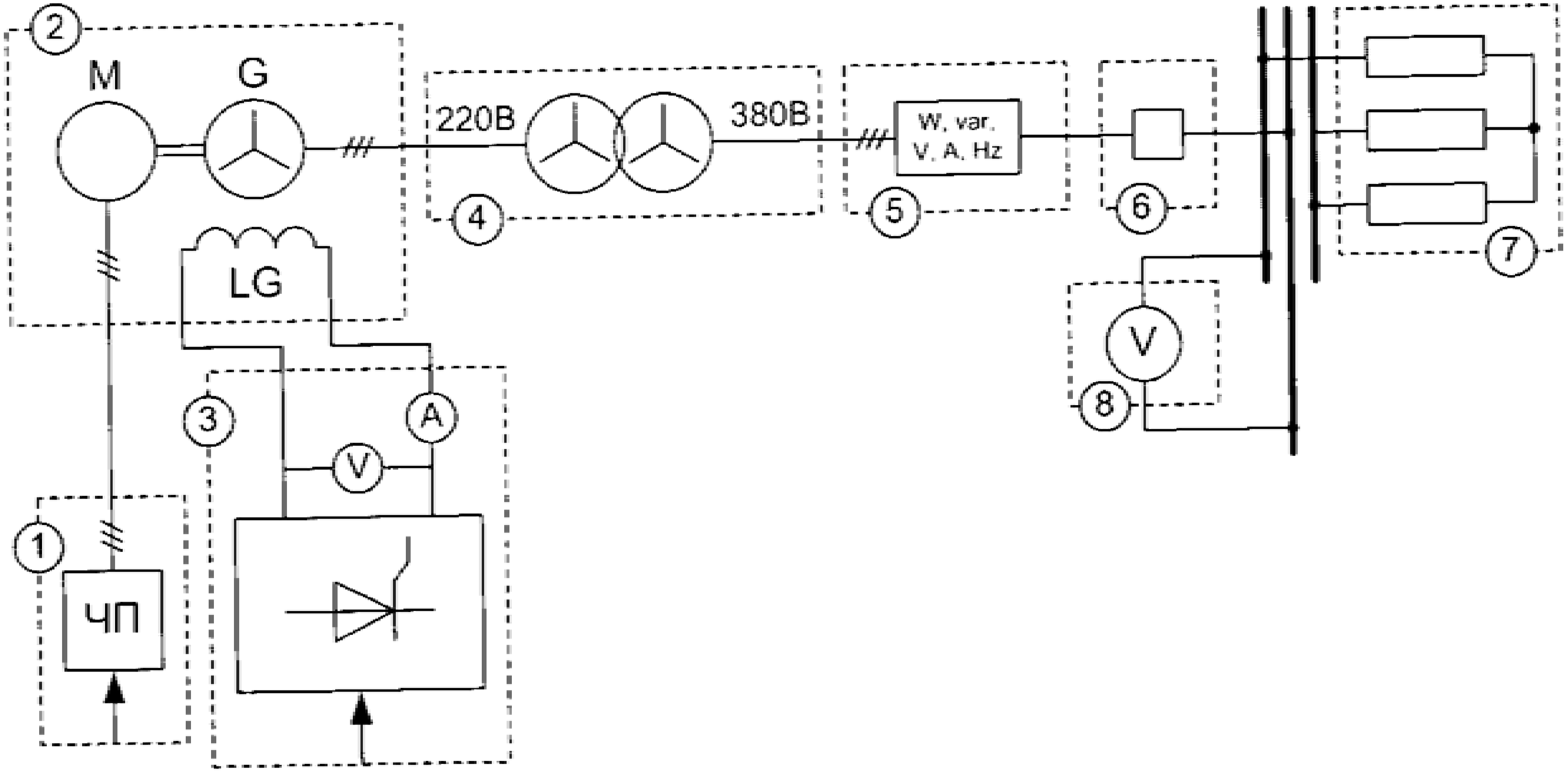


Figure 3.12 - Scheme of laboratory researches

Thus, the circuit of the circuit under study is a model of an autonomous power supply network with adjustable parameters, which include: voltage value and frequency. The change in the value of the supply voltage is carried out by changing the excitation current of the synchronous generator (potentiometer RP1 on the front panel of the excitation module). The frequency of the supply voltage is varied by changing the speed of the drive motor M (potentiometer RP1 on the front panel of the inverter module). The power meter 5 is used to measure the amount of active and reactive power consumed by the load. The voltmeter 8 is used to measure the value of the line voltage on the load. As a voltmeter, one of the instruments of the measuring module is used.

The frequency of the supply voltage is measured from the indicator of the frequency converter module.

2) Set the manual mode of the frequency converter, drive and switch modules and the knob of all the potentiometers of the modules involved to the zero position (end position counter-clockwise). The load value switch SA1 is set to the middle position. 3) Turn on the circuit breaker of the stand power module.

4) Switch on the frequency converter and start the drive motor and set the frequency to 50 Hz.

5) Switch on the power of the power meter and select the measurement of the line voltage at the output of the transformer, at this stage it is zero.

6) Switch on the excitation module and, changing the excitation current, set the line voltage at the transformer output equal to 380V.

7) Switch on the circuit breaker, check the voltmeter's readings for voltage on the load, and for the power meter, the presence of currents in all phases of the load. 8) Under load, the linear value of the voltage at the output of the transformer is set lower than the nominal, adjusting the excitation voltage of the generator to bring it to 380V.

9) Set the power meter reading for active power measurements (total three-phase active power).

10) By decreasing the excitation current of the generator, remove the dependence of the active load power on the network voltage P = f (U) for U = 380 ... 110V at 1 = 50Г ц.

11) Increase the excitation current of the generator to restore the voltage at the load 380V. Transfer the power meter module to the reactive power measurement mode. Decreasing the excitation current of the generator, remove the dependence of reactive load power on the network voltage Q = f (U) for U = 380 ... 110V at £ = 50Hz.

12) Turn off the stand, for this purpose make the excitation current of the generator equal to zero and turn off the excitation module, turn off the frequency converter module, turn off the automatic switch of the power module of the stand.

13) Process the results obtained, build dependencies of active and reactive load power on the supply network voltage, draw conclusions and draw up a work report.

3.6.4 Test questions

1. What is reactive power?
2. What is the purpose of increasing the power factor of the circuit?
3. How is the distribution of the reactive load controlled?
4. Why do we need compensating devices?
5. Full power formula.
6. What are the types of compensation?
7. Advantages of installing compensating devices?
8. List the names of the elements.
9. Describe the procedure for performing laboratory work.
10. Where are the compensating devices applied?

3.7 Determination of the influence of the voltage deviation on the power consumed by the capacitive load.

The purpose of the work: - to study the influence of the voltage value on the power consumed by the capacitive load.

3.7.1 Assignment to work

-to learn the procedure for determining the influence of voltage deviation on the power consumed by the capacitive load

3.7.2 Theoretical information

Depending on the connection of the condenser installation, the following compensation types are possible:

1 Individual or permanent compensation, in which the inductive reactive power is compensated directly at the site which leads to the unloading of the lead-in wires (for individual, long-running consumers with a constant or relatively large power - asynchronous motors, transformers, welding machines, discharge lamps, etc.).

2Group compensation, in which, similar to individual compensation for several simultaneously operating inductive consumers, a common constant capacitor is connected (for nearby electric motors, groups of discharge lamps).

Here, too, the supply line is unloaded, but only before distribution to individual consumers.

3 Centralized compensation, in which a certain number of capacitors are connected to the main or group switch cabinet. Such compensation is used, usually, in large electrical systems with variable load. Control of such a capacitor installation is performed by an electronic regulator, a controller that constantly analyzes the reactive power consumption from the network. Such regulators include or disable capacitors, by which the instantaneous reactive power of the total load is compensated and, thus, the total power consumed from the network is reduced.

The advantages of using capacitor plants as a means of compensating for reactive power are

small specific losses of active power (the intrinsic losses of modern low-voltage cosine capacitors do not exceed 0.5 W per 1000 VA);

- absence of rotating parts;
- simple installation and operation (no need for a foundation);
- relatively low capital investment;
- the possibility of selecting any necessary compensation power;
- possibility of installation and connection at any point of the power grid;
- No noise during operation;
- low operating costs.

Correct compensation of reactive power allows:

- to reduce the total cost of electricity;
- reduce the load of the elements of the distribution network (supply lines, transformers and switchgears), thereby prolonging their service life;
- reduce thermal current losses and electricity costs;
- reduce the influence of higher harmonics;
- suppress network interference, reduce non-phase symmetry;
- to achieve greater reliability and profitability of distribution networks.

In addition, in existing networks

- exclude the generation of reactive energy in the network during hours of minimum load;
- reduce the cost of repair and renewal of the electrical equipment park;
- increase the capacity of the consumer's electricity supply system, which will allow additional loads to be connected without increasing the cost of networks;
- to provide information on the parameters and status of the network, and in the newly created networks
- to reduce the power of substations and the cross-section of cable lines, which will reduce their cost.

Reactive energy does not perform useful work. It is spent on the creation of electromagnetic fields in electric motors, transformers, induction furnaces, welding transformers and chokes.

3.7.3 Procedure

1) Assemble the wiring diagram shown in figure 3.13, all modules of the stand must be OFF! The three-phase asynchronous motor M of the electromachine unit 2, which is a turbine model, receives power from the frequency converter 1 and generates a torque on the shaft of the synchronous generator G of the electric machine assembly 2. The supply of the synchronous generator drive winding is provided from the excitation module 3, which is an adjustable constant current source. The three-phase output voltage, taken from the stator winding of the synchronous generator G, through the step-up transformer 4 (single-phase transformer module), the power meter module 5 and the switch module 6 are fed to a three-phase capacitive load 7 (capacitive load module). The load switching circuit is a star without a zero wire. The connection scheme for the windings of the transformers is "star / star". Thus, the circuit of the circuit under study is a model of an autonomous power supply network with adjustable parameters, which include: voltage value and frequency. The change in the value of the supply voltage is carried out by changing the excitation current of the synchronous generator (potentiometer RP1 on the front panel of the excitation module). The frequency of the supply voltage is varied by changing the speed of the drive motor M (potentiometer RP1 on the front panel of the inverter module). The power meter S is used to measure the amount of active and reactive power consumed by the load. The voltmeter 8 is used to measure the value of the line voltage on the load. As a voltmeter, one of the instruments of the measuring module is used. The frequency of the supply voltage is measured from the indicator of the frequency converter module.

2) Set the manual mode of the frequency converter, drive and switch modules and the knob of all the potentiometers of the modules involved to the zero position (end position counter-clockwise). The load value switch SA1 is set to the middle position.

3) Turn on the circuit breaker of the stand power module.

4) Turn on the frequency converter and start the drive motor and set the frequency to 50 Hz.

5) Switch on the power of the power meter and select the measurement of the line voltage at the output of the transformer, at this stage it is zero.

6) Switch on the excitation module and, changing the excitation current, set the line voltage at the transformer output equal to 380V.

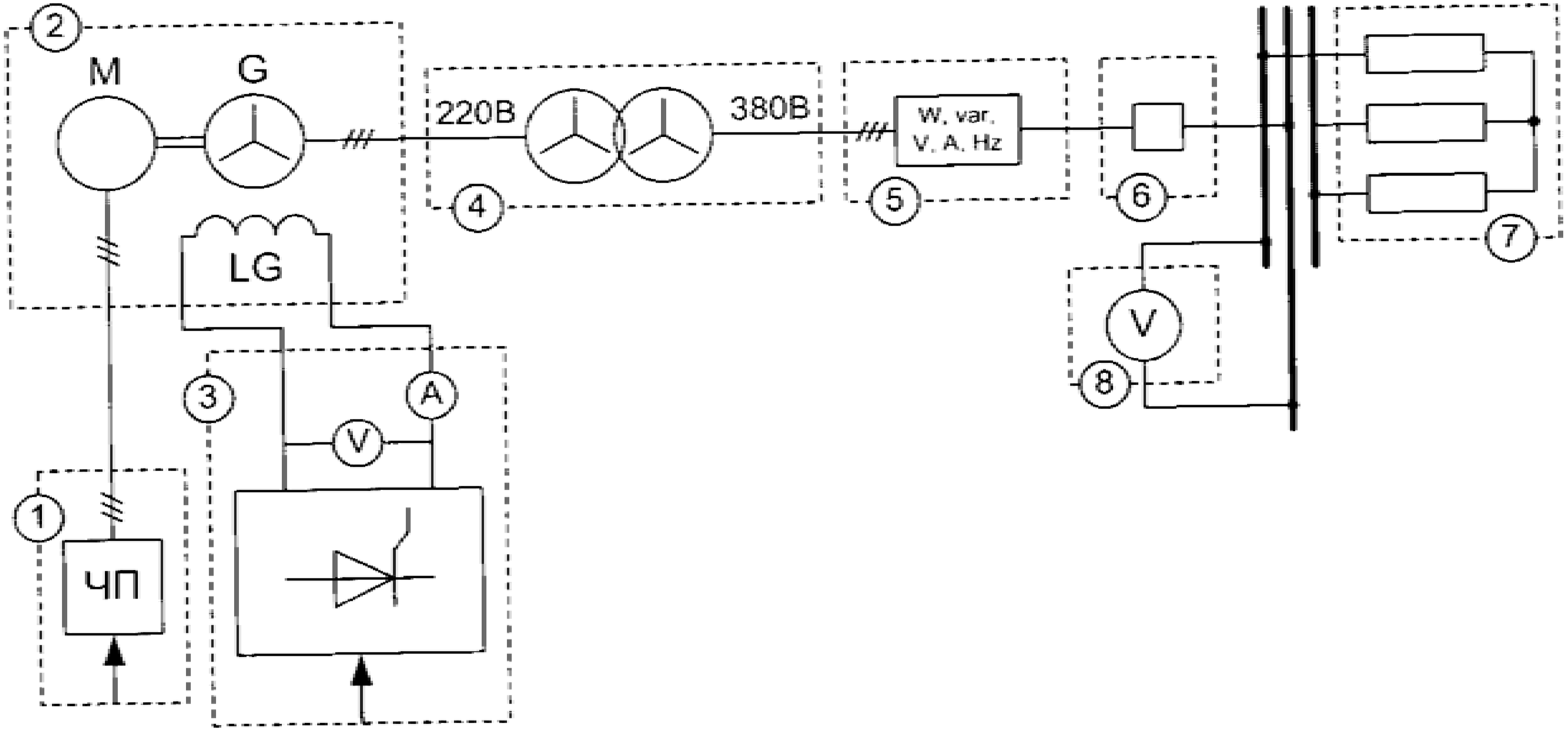


Figure 3.13 - The scheme of laboratory tests

7) Switch on the circuit breaker, check the voltmeter's readings for voltage on the load, and for the power meter, the presence of currents in all phases of the load.

8) Under load, the linear value of the voltage at the output of the transformer will change, adjusting the excitation voltage of the generator to bring it to 380V.

9) Set the power meter reading for reactive power measurements (total three-phase reactive power).

10) By decreasing the excitation current of the generator, remove the dependence of the reactive load power on the network voltage Q = f (U) for U = 380 ... 110V at £ = 50Hz.

11) Turn off the stand, for this purpose make the excitation current of the generator equal to zero and turn off the excitation module, turn off the frequency converter module, turn off the automatic switch of the stand power module.

12) Process the results obtained, build the dependence of reactive load power on the supply network voltage, draw conclusions and draw up a work report.

3.7.4 Control questions

1. Purpose of the elements in laboratory work.
2. What experimental studies are conducted in the laboratory?
3. What does individual and group compensation mean?
4. What are the advantages of using condenser units?
5. What makes correct compensation of reactive power possible?
6. Explain the purpose of the elements in the laboratory work.
7. What load switching schemes are investigated in the work?
8. What is an asynchronous motor?
9. What connection schemes for transformer windings are investigated in laboratory work?
10. How did you process the experimental studies and what was the dependency built?

3.8 Investigation of static characteristics of active, inductive and capacitive loads

The purpose of the work: - to investigate the dependence of active and reactive powers on the voltage and frequency of the supply network for active linear and nonlinear loads, as well as inductive loads.

3.8.1 Assignment to work

- To study the study of static characteristics of active, inductive and capacitive loads

3.8.2 Theoretical information

There is no strict unaltered regime in the electric power system, therefore the steady regime can be called only conditionally, because due to its features the power system is subject to a continuous flow perturbations that should not cause a violation of the stability of the system, i.e., should not lead to a progressive increasing change in the parameters of its original dir ma. The electric power system must be stable under small perturbations. In the case of small perturbations, the concept of static stability is introduced. Static stability is the ability of the electric power system to independently restore the initial steady-state regime after small perturbations or a regime very close to the initial one if the perturbation is not lifted.

Proceeding from the definition of the static stability of the system, it can be concluded that there exists such a regime in which a very small increase in the load causes a violation of its stability.

Such a regime is called the limiting one, and the system's loads are the maximum or maximum loads under the conditions of static stability. Restriction of loads can be caused by other factors, for example, voltage levels in the nodes, heating of generators, transformers and power lines.

The capacity of the element of the electric power system is called the maximum power that can be transmitted through this element, taking into account all the limiting factors (stability, heating, voltage at the nodes, etc.), sometimes bandwidth is determined only by one factor and say, for example, on static stability.

The value of parallel connected active and reactive resistances is calculated from the power and voltage of the initial mode:

$$R_н = U^2 P_н^{-1};\ X_н = U^2 Q_н^{-1}. \tag{3.6}$$

For the case of series connection of resistances

$$Z_н = R_н + jX_н = U^2 S_н^{-1}(cos\varphi_н + jsin\varphi_н). \tag{3.7}$$

where cosφH is the load power factor.

If the voltage in the initial mode is unknown, then the nominal or average voltage is substituted in expressions (3.6), (3.7).

Replacement of loads by constant resistance RH, XH allows to simplify considerably the calculations, but it is connected with the greatest errors.

The state of the system, characterized by a combination of conditions and quantities at any time or time interval, is called the system mode, as shown in Figure 3.14. The regime is characterized by quantitative indicators, which are called mode parameters. These include the values of power, voltage, frequency, current, EMF, etc.

The mode parameters are related to each other by dependencies, which include the system parameters

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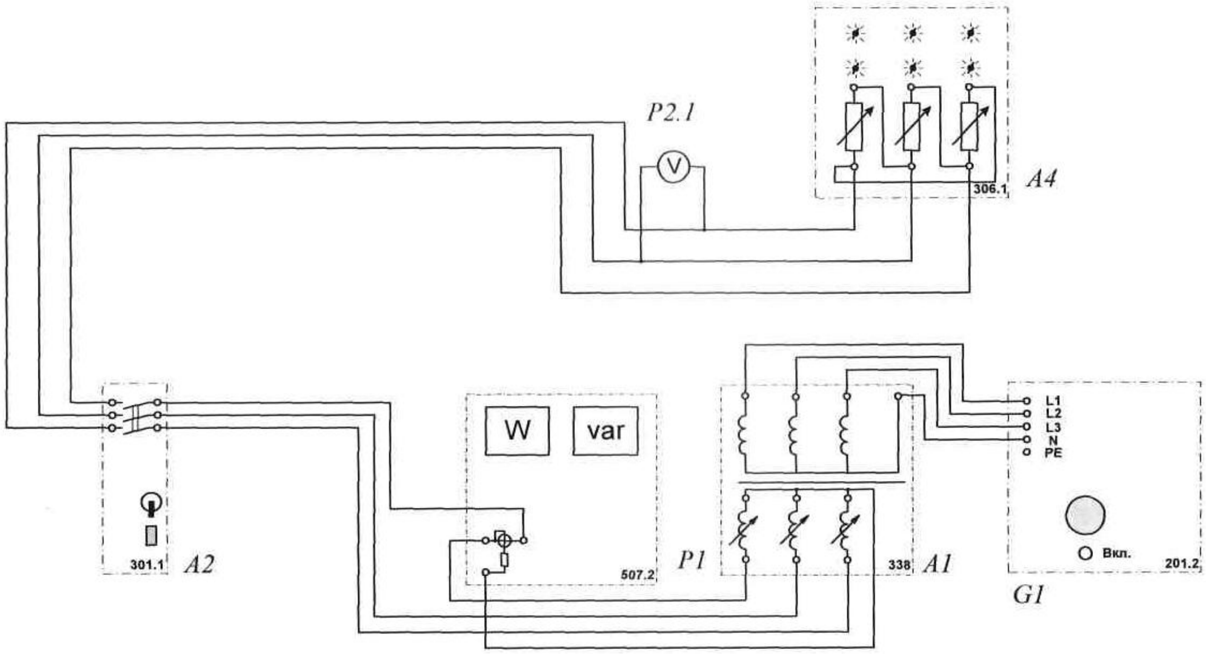


Figure 3.14 - Electrical connection diagram for removing the static characteristic P = f (U) of the active load.

System parameters are indicators that are quantitatively determined by the physical properties of the elements of the system, the scheme of their connection, and also the calculated data. Parameters of the system include resistance and conductivity of elements, transformation coefficients, time constants, etc.

As an example, we give the well-known expressions:

$$P = \frac{U^2}{R};\ \Delta Q = \frac{P^2 + Q^2}{U^2} X$$

R, X are the parameters of the system.

The power system mode can be steady or transient, normal or emergency (Figure 3.15).

The reasons for changing the parameters of the regime are called disturbing influences.

Dynamic stability is the ability of the electric power system to restore, after a large disturbance, the initial state or practically close to it.

If, after a disturbance, the synchronous operation of generators or engines of the system is violated, and then, after a certain period of recovery permitted for the operating conditions, such a system is generally considered to have the resultant stability.

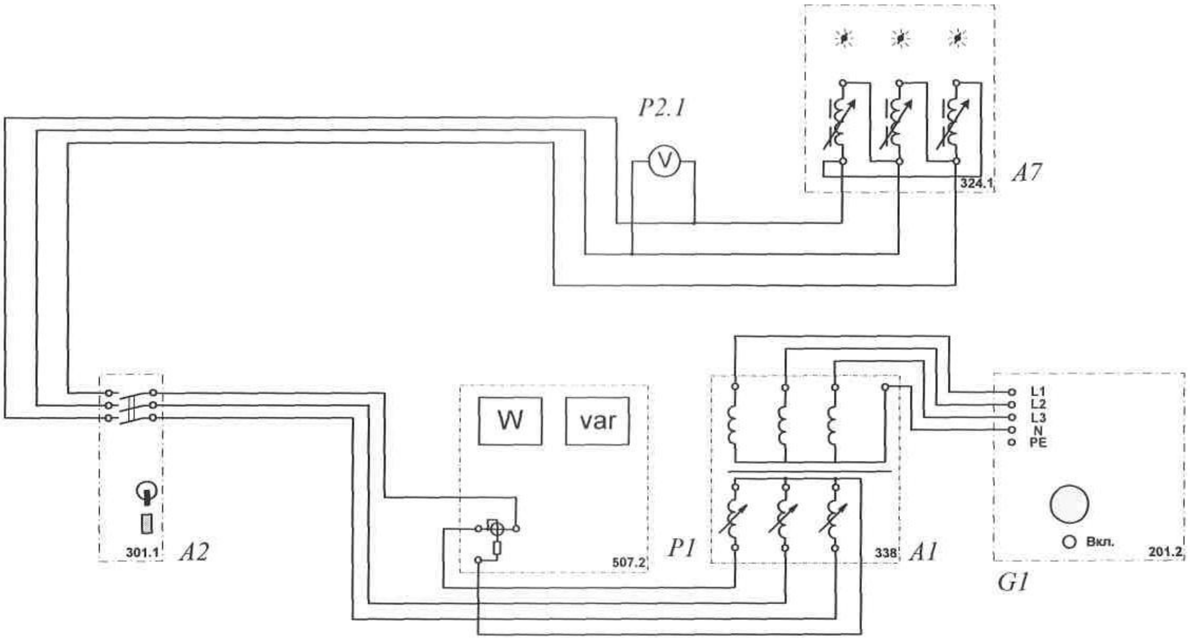


Figure 3.15 - Electrical diagram of the connections for removing the static characteristic Q = f (U) of the inductive load

It should be noted that the concept of "power system is stable" is not definite until the conditions under which the stability of the power system is ensured are not established. These include, first of all, the parameters of the network and the initial mode, as well as the type and nature of the disturbance that occurs in the power system. In fact, it is almost always possible to find such an outrage (sometimes very severe and extremely rare), which will cause a violation of the stability of the power system. Therefore, often the term "energy system is stable" is put in the concept of "maintaining the stable operation of generators and motors under regulatory requirements in the part of disturbances."

In the study of stability, the static and dynamic characteristics of the system elements are widely used (Figure 3.16). By static characteristics are understood the analytical and graphical dependencies of the parameters of the regime, determined by their slow changes, when each mode can be considered steady. An example is the dependence of the active P or reactive Q load power on the voltage U and frequency f: $P = F_1(U, f); Q = F_2(U, f)$.

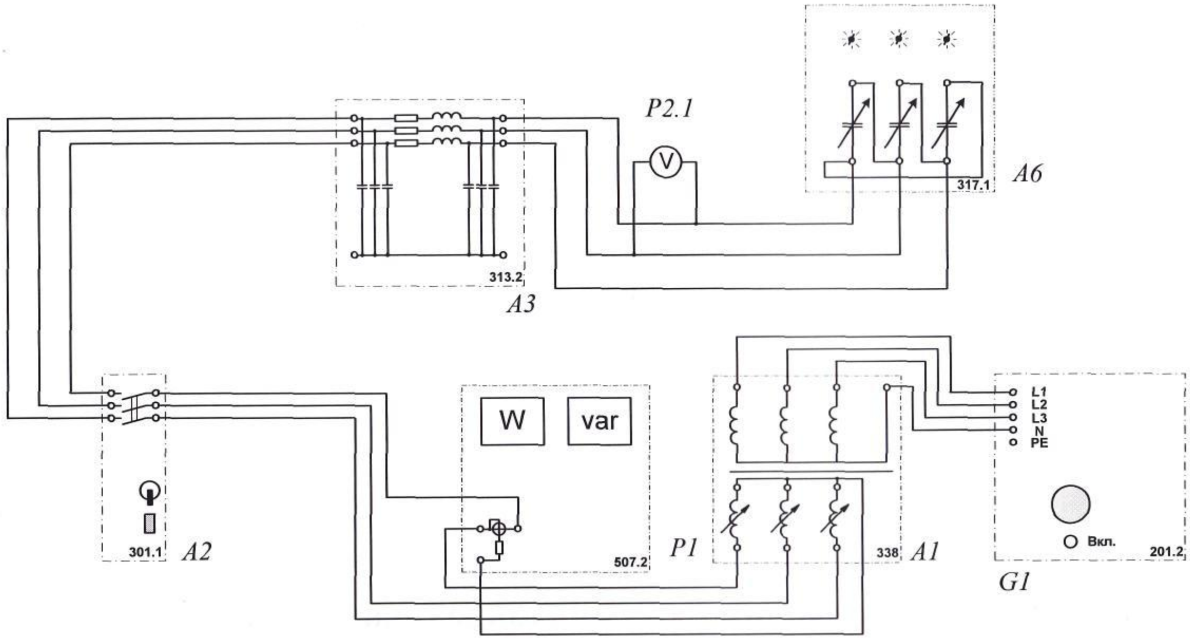


Figure 3.16 - Wiring diagram for removing the static characteristic Q = f (U) of the capacitive load

Dynamic characteristics are the dependencies of the system mode parameters determined with fast changes in the mode taking into account the time and the rate of its change. For example, $P = \varphi_1\left(U, f, t\frac{dU}{dt}, \dots\right); Q = \varphi_2\left(U, f, t, \frac{dU}{dt}, \dots\right);$

the representation of the load in the calculation of electromechanical transients in power systems are performed in different ways. The correctness of the mathematical description of the load can have a significant effect on the results of stability calculations.

There are several ways to represent the load. The most accurate loading in the calculation of stability can be represented by asynchronous and synchronous motors, as well as static consumers.

The simplest most commonly used static load model is based on the replacement of the latter with power or linear conductivity, i.e., with constant active and reactive resistances.

3.8.3 Procedure for completing the work

1) To assemble the electrical circuit shown in figure 3.17, all the stand modules

The three-phase asynchronous motor M of the electromachine unit 2, which is a turbine model, receives power from the frequency converter 1 and generates a torque on the shaft of the synchronous generator G of the electric machine unit 2. The supply of the synchronous generator drive winding is provided from the excitation module 3, which is an adjustable constant current source. The three-phase output voltage, taken from the stator winding of the synchronous generator G, through the step-up transformer 4 (single-phase transformer module), the power meter module 5 and the switch module 6 are fed to the three-phase active load 7 (active load module). The load switching circuit is a star without a zero wire. The connection scheme for the windings of the transformers is "star / star". Thus, the circuit of the circuit under study is a model of an autonomous power supply network with adjustable parameters, which include: voltage value and frequency. The change in the value of the supply voltage is carried out by changing the excitation current of the synchronous generator (potentiometer RP1 on the front panel of the excitation module). The frequency of the supply voltage is varied by changing the speed of the drive motor M (potentiometer RP1 on the front panel of the inverter module). The power meter S is used to measure the amount of active and reactive power consumed by the load. The voltmeter 8 is used to measure the value of the line voltage on the load. As a voltmeter, one of the instruments of the measuring module is used. The frequency of the supply voltage is measured from the indicator of the frequency converter module. In addition to the active load, this circuit allows you to investigate the characteristics of inductive and capacitive loads connected instead of the active load module 7 (connection scheme of inductive and lighting loads - a star without a zero wire)

2) Set the manual mode of the frequency converter, excitation and switch modules and the handle of all potentiometers of the activated modules to the zero position (extreme position counter-clockwise). The load value switch SA1 is set to the middle position.

3) Turn on the circuit breaker of the stand power module.

4) Switch on the frequency converter and start the drive motor and set the frequency to 50 Hz.

5) Switch on the power of the power meter and select the measurement of the line voltage at the output of the transformer, at this stage it is zero.

6) Switch on the excitation module and, changing the excitation current, set the line voltage at the transformer output equal to 380V.

must be OFF !.

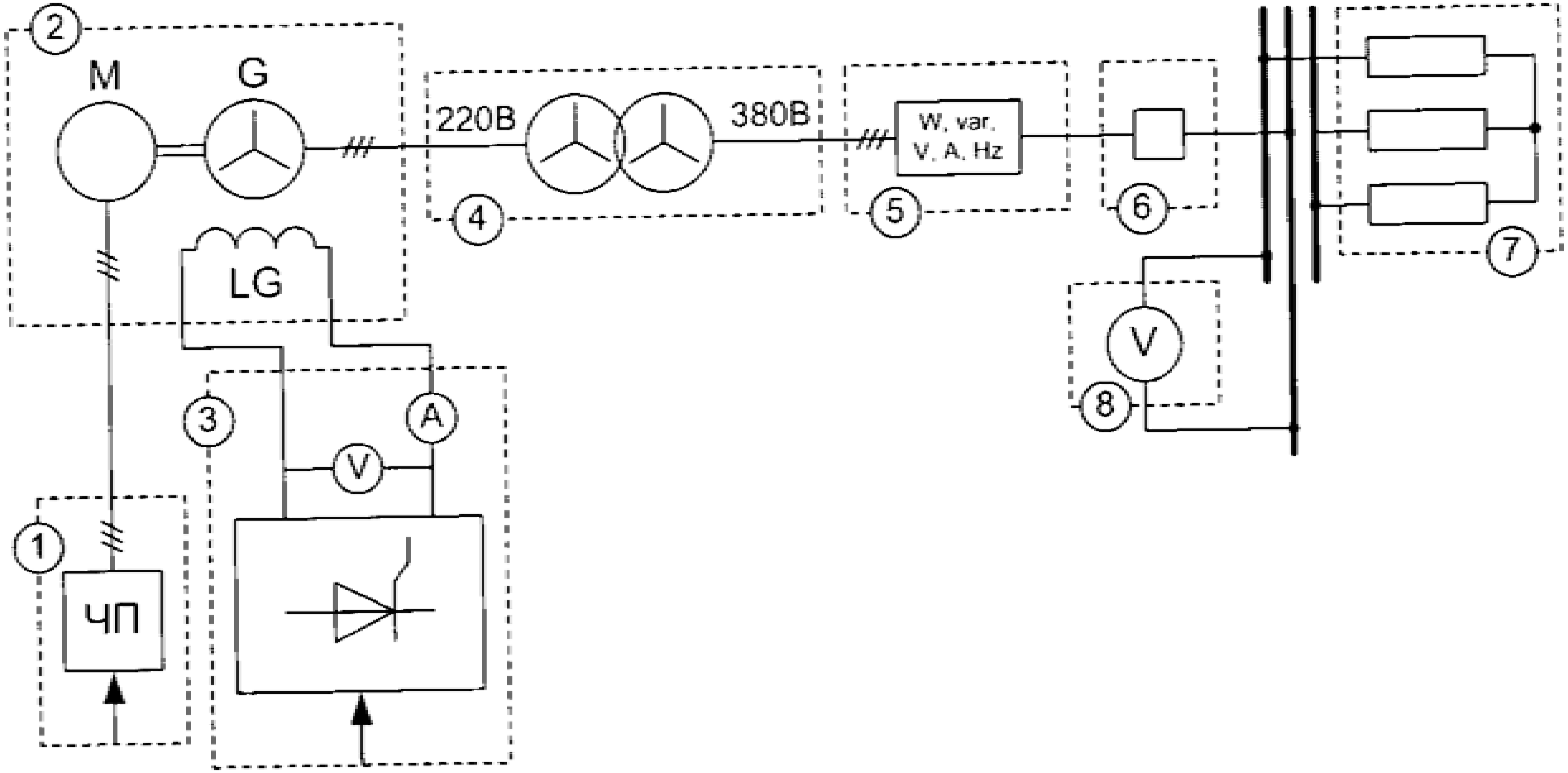


Figure 3.17 - Diagram of laboratory tests

7) Switch on the circuit breaker, check the voltmeter for the presence of voltage on the load, and the power meter for the presence of currents in all phases of the load.

8) Under load, the linear value of the voltage at the output of the transformer is set lower than the nominal, adjusting the excitation voltage of the generator to bring it to 380V.

9) Set the power meter reading for active power measurements (total three-phase active power).

10) By changing the excitation current of the generator, remove the dependence of the active power on the network voltage P = f (U) for U = 380 ... 220 V at f = 50ru.

11) Set the power meter reading for reactive power measurement and similarly remove the reactive power dependence on the network voltage Q = f (U).

12) By changing the frequency of the generator voltage using the frequency converter module and by monitoring the voltage at the multimeter, remove the dependence of the active power on the frequency of the network P = f (f) for f = 45 ... 55Hz at U = 380V (do not exceed the voltage at a load greater than 400V).

13) Similarly, remove the dependence of reactive power on the frequency of the network Q = f (f) for f = 45 ... 55Hz at U = 380V.

14) Switch off the stand, for this purpose make excitation current of the generator equal to zero and turn off the excitation module, turn off the frequency converter module, turn off the automatic switch of the stand power module.

15) Collect the circuit with the inductive load and perform the activation and validation of the stand modules in the same after the sequence as for the active load.

16) Remove the analogous characteristics P = f (U), Q = f (U) at f = 50Hz and P = f (f), Q = f (f) for U = 380V for the inductive load.

17) Perform steps 14 ... 16 and perform a capacitive load test, while carefully meeting the voltage requirement on the load U <380V.

18) Switch off the stand in the same sequence as in item 14.

19) Process the results obtained, build the active and reactive power dependencies on the voltage and frequency of the supply network for the active and reactive loads, draw conclusions and draw up a report on the work.

3.8.4 Control questions

1. What are the main stages in the emergence and solution of the problem of the stability of electric power systems?
2. What are the main causes of instability in power systems?
3. What is the electric power system and what elements does it consist of?

4. What is the difference between the terms "mode parameters" and "system parameters"?
5. What kinds of regimes exist in electric power systems?
6. What is considered a violation of the regime of the electric power system?
7. What is the "capacity" of the system element?
8. What is meant by the static, dynamic and resultant stability of the system?
9. What experimental studies have been carried out? 10. List all the modules in this lab and their purpose.

3.9 Measurement of electrical energy quality indicators

Objective: to learn to remove the indicators of the quality of electrical energy

3.9.1 Task to work

- to study methods for measuring the indicators of the quality of electrical energy;
- to carry out measurements of the main indicators of the quality of electrical energy, to compare the results obtained with the requirements of the state standard for the quality of electrical energy.

3.9.2 Theoretical information

Transmission of electricity from power supplies to electrical receivers is accompanied by a loss of voltage in the lines and transformers. Therefore, the consumers' voltage does not remain constant.

There are deviations and voltage fluctuations. Voltage deviations are caused by slow-moving processes of changing loads in individual network elements, changing voltage regimes on power supplies. As a result of such changes, the voltage at individual points of the network varies in magnitude, deviating from the nominal value.

Voltage fluctuations are fast-acting (with a speed of at least 1% per minute) short-term voltage changes. Occur when there are abnormal violations of the normal mode of operation when power switches are turned on or off, or short circuits.

Voltage deviations are expressed as a percentage of the rated voltage of the network

$$[\Delta U_i] = \frac{U_i - U_{\text{ном}}}{U_{\text{ном}}} \cdot 100\%,$$

Voltage fluctuations are calculated as follows:

$$V_t = \frac{U_{\max} - U_{\min}}{U_{\text{ном}}} \cdot 100\%.$$

where $U_{\max}, U_{\min}$ – the greatest and smallest values of the voltage at the same point of the network.

To ensure the normal operation of electric receivers, their buses should maintain a voltage close to the nominal.

The GOST sets the following permissible deviations in the normal operating mode:

- at the motor terminals -$\pm(5-10)\%$ от $U_{\text{ном}}$;

- at the terminals of the lighting fixtures (interior and exterior lighting) - $\pm(2{,}5-5)\%$ от $U_{\text{ном}}$;

- at the terminals of the other receivers $\pm 5\%$ от $U_{\text{ном}}$.

In post-emergency modes, an additional voltage drop of 5% is allowed for these values.

To ensure the proper level of voltage on the buses of electric receivers, the following measures are applied:

- Transformers with transformation ratios are used, which take into account the voltage loss, both in the transformer windings and in the supply network;

- transformer windings are supplied with branches that allow changing the transformation ratio within certain limits;

- network layout, rated voltages, wire sections are chosen so that the voltage loss does not exceed the permissible value.

Permissible voltage loss is established with a certain degree of accuracy, based on the normalized voltage deviations on the buses of electric receivers:

- for 220 - 380 V networks, from 5 to 6.5% of the power source to the last power receiver;

- for a supply network with a voltage of 6 - 35 kV - from 6 to 8% in normal mode; from 10 to 12% in the post-accident mode;

- for rural networks with voltage 6 - 35 kV - up to 10% in normal mode.

These values of permissible voltage loss are selected in such a way that when the voltage regulation in the network is properly regulated, the requirements of the PES for voltage deviations on the buses of electric receivers are satisfied.

3.9.3 Procedure for performing the work

1) Collect the scheme of laboratory tests Figure 3.18 (All stand modules must be OFF!). The circuit is a power supply (three-phase network module) 1 which, through the step-down transformer 2, supplies phase voltages to the inputs A4, A5, and A6 of the input-output module 3.

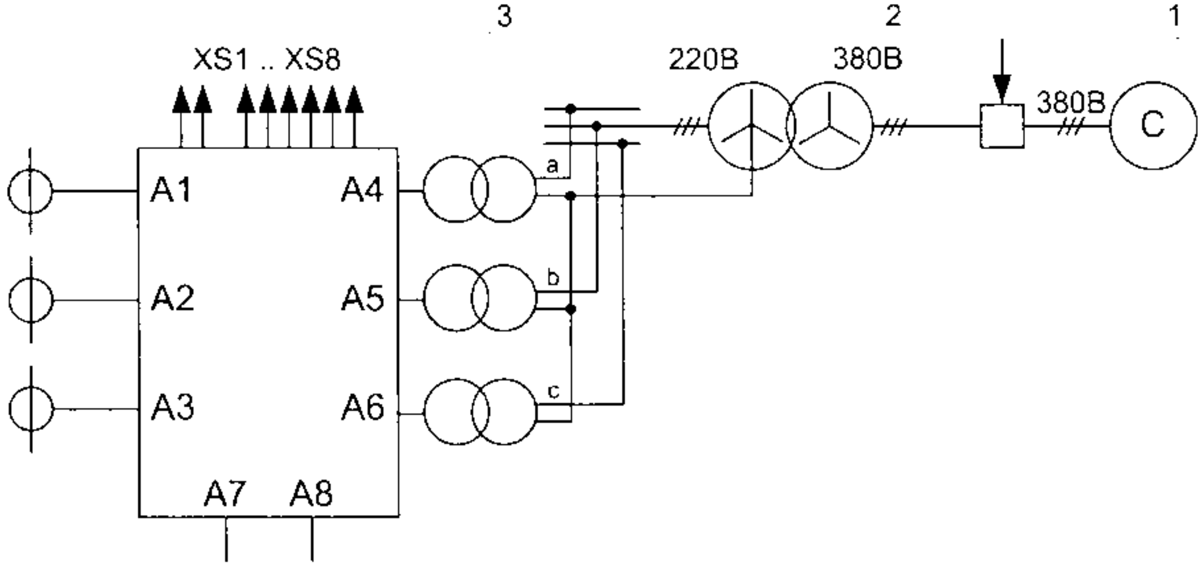


Figure 3.18 - The scheme of laboratory tests

2) Switch on the power of the stand and press the "On" button of the three-phase network module.

3) Start the DeltaProfi software package on the personal computer (Start - Programs - Laboratory complex - DeltaProfi). Open the laboratory work with the team "Works - Transmission and quality of EE - Measurement of indicators of the quality of electrical energy."

4) Start the program with the "Start" button or with the command of the main menu "Control - Start" or with the hot key FS.

5) Carry out measurements in 5 .. 10 min. In Table 3.5, record the results obtained, namely, the maximum values of the steady-state voltage deviation, the magnitude of the voltage variation, the sinusoidal voltage distortion factor, the reverse-sequence unbalance factor, the zero-sequence unbalance coefficient, and the frequency deviation.

In Table 3.6, enter the current values of the relative values of the higher harmonics of the voltage under the numbers from 2 to 11. Press the "Stop" button to stop the measurement mode. Determine the GOST requirements for these quality parameters, and compare the results obtained.

6) Press the "Off" button of the three-phase network module.
7) Switch off the power to the stand.
8) Issue a report on laboratory work.

Table 3.5 – Results

Parameter of the quality of electrical energy	Measured value	Permissible value
Steady-state voltage deviation,%		
Range of voltage variation,%		
Sinusoidal voltage distortion factor,%		
Unbalance factor of stresses in the reverse sequence,%		
Unbalance coefficient of stresses in zero sequence,%		
Frequency deviation, Hz		

Table 3.6 - Current values of relative values

Parameter of the quality of electrical energy	Measured value	Permissible value
Coefficient 2 of the harmonic component,%		
Coefficient 3 of the harmonic component,%		
Coefficient 4 of the harmonic component,%		
The coefficient 5 of the harmonic component,		
Coefficient 6 harmonic component,%		
Coefficient 7 of the harmonic component,%		
The coefficient 8 of the harmonic component,%		
The coefficient 9 of the harmonic component,%		
Coefficient of 10 harmonic component,%		
, Coefficient 11 harmonic component,		

3.9.4 Control questions

1. Purpose of modules in laboratory work.
2. What are the coefficients of the quality of electrical energy?
3. What kinds of deviations and voltage fluctuations exist in the electrical network?
4. Explain the formula for determining voltage deviations.
5. List the voltage tolerance.
6. What measures are used to ensure the proper level of voltage on the buses of electric receivers?

7. How is the permissible voltage loss established?
8. Describe the procedure for performing laboratory work.
9. Explain the operation of the electrical circuit presented in the laboratory.
10. Describe the results obtained in the laboratory.

3.10 Conclusions on the chapter

The chapter shows the practical application of the electric system model in the discipline "Electrical networks and systems".

The studies are conducted in the following directions:

- Measurement of the parameters of the steady-state mode of the electrical network with one-sided power;
- Losses of electrical energy in distribution networks;
- Voltage regulation by transverse compensation of reactive power by means of a capacitor bank;
- Determination of the influence of voltage deviation on the power consumed by the active load;
- Determination of the influence of the voltage deviation on the power consumed by the inductive load;
- Determination of the influence of the voltage deviation on the power consumed by the capacitive load;
- Study of static characteristics of active, inductive and capacitive loads;
- Measurement of the quality of electrical energy.

The purpose of all the works is to learn the following questions from students:

- to study the factors influencing the values of the regime parameters of the transmission line (active and reactive powers, currents and voltages);
- to study the methods for calculating the steady-state operation of networks with one-sided power;
- Investigate the effect on the parameters of power transmission lines (length, nominal voltage) and load parameters in individual nodes on the values of the regime parameters in the ring network (voltage at the nodes, overflows of active and reactive power, losses);
- determine the factors that affect the amount of active and reactive power losses in the distribution network;
- to study the dependence of power losses on the magnitude of the load and its nature; - study the effect of the rated voltage of the distribution network on the amount of active and reactive power losses;
- to study the effect of transverse capacitive compensation on the magnitude of the voltages in the nodes of the distribution network;

-to study the influence of the magnitude of the voltage on the power consumed by the active load;

- study the procedure for determining the effect of voltage deviation on the power consumed by the inductive load;
- to study the effect of the voltage value on the power consumed by the capacitive load;
- investigate the dependence of active and reactive power on the voltage and frequency of the supply network for active linear and nonlinear loads, as well as inductive loads;
- study methods for measuring the quality of electrical energy;
- carry out measurements of the main indicators of the quality of electrical energy, compare the results with the requirements of the state standard for the quality of electrical energy

Chapter 4. Practical application of "Electrical system models" in the discipline "transitional processes used in electric power"

4.1 Analysis of transients in three-phase short-circuit in an electrical network feeding from an infinite power source.

Objective: to study the analysis of transients in three-phase short-circuit in an electrical network, powered from a source of infinite power

4.1.1 Assignment to work

- to investigate the factors affecting the values of short-circuit currents in electrical networks;
- determine the factors affecting the shock value of the short-circuit current and the decay rate of the aperiodic component.

4.1.2. Theoretical information

The nature of the electromagnetic transient in the case of a three-phase short-circuit depends on the degree of remoteness of the fault point from power supplies. First, consider a short circuit at a point remote from the station and the system. Since the short-circuit point is electrically isolated from the power supplies, all faults occurring on it do not have a significant effect on the operation of the system generators. This circumstance makes it possible to consider the parameters of the system unchanged. In this case, the power supply bus is called an unchanging voltage bus or an infinite bus.

A three-phase symmetrical circuit with lumped active and inductive resistances in the absence of transformer bonds in it is called the simplest three-phase circuit. The electromagnetic process in such a circuit is considered under the assumption that its power is supplied from a source of infinite power. Such a source is characterized by the invariance of the voltage across the buses in amplitude and frequency. Any real source has a finite power, but if it is many times higher than the power of the elements behind which the short circuit is considered, then the voltage on the bus bars of the supply system changes insignificantly, which makes it impossible to take into account this change in practical calculations. In addition, the presence of automatic excitation control (ARV) further facilitates the adoption of this assumption. When this assumption is accepted, the overcurrent is exaggerated, which, as a rule, does not affect the choice of the equipment to be installed. As a basic assumption, we assume that the linear relationship between the currents and voltages of the circuits under consideration is conserved and, consequently, they can be connected by linear differential equations with constant coefficients. Figure 2.1 shows a three-phase symmetric circuit fed by a source with a constant sinusoidal voltage:

$$\begin{aligned} u_A &= \sqrt{2}\, U_п \sin(\omega t + \alpha),\ кВ, \\ u_B &= \sqrt{2}\, U_п \sin(\omega t + \alpha - 120°),\ кВ, \\ u_C &= \sqrt{2}\, U_п \sin(\omega t + \alpha + 120°),\ кВ. \end{aligned} \tag{4.1}$$

where Un is the effective value of the power supply voltage;

α - phase of inclusion - the angle between the voltage vector of phase A and the real axis (figure 4.1).

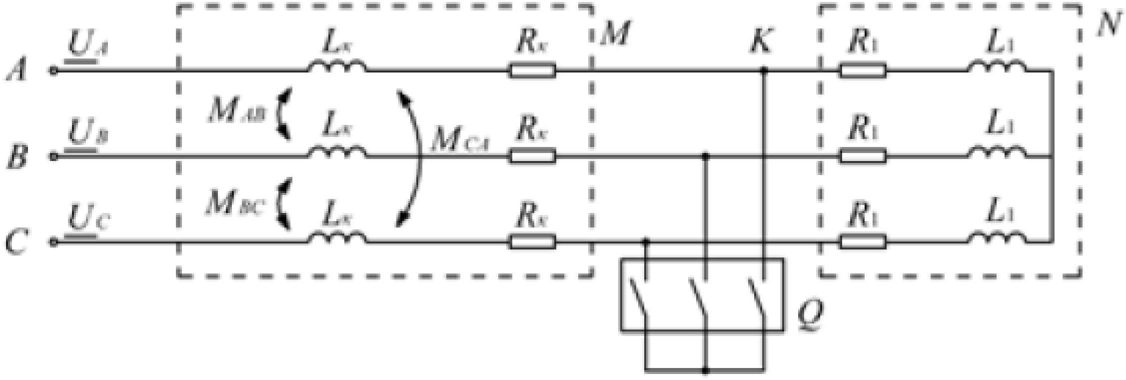


Figure 4.1 - The simplest three-phase circuit

In the scheme under consideration, the capacitance of phases relative to the earth and each other is not taken into account because of its negligible effect on the transient electromagnetic process. This excludes the possibility of the appearance of oscillatory circuits at the industrial frequency, which greatly simplifies the analysis of the course of the transient process in the circuit. In the normal operating mode of the circuit, a current flows through the phases, determined by the voltage of the power source and the resulting resistance:

$$\begin{aligned} i_A &= \sqrt{2}\, I_п \sin(\omega t + \alpha - \varphi_п), \\ i_B &= \sqrt{2}\, I_п \sin(\omega t + \alpha - \varphi_п - 120°), \\ i_C &= \sqrt{2}\, I_п \sin(\omega t + \alpha - \varphi_п + 120°). \end{aligned} \tag{4.2}$$

where $I_п = U_п / Z_\Sigma$ is the effective value of the periodic component of the current;

$Z_\Sigma = \sqrt{R_\Sigma^2 + X_\Sigma^2}$ - impedance of the circuit;

$R_\Sigma = R_K + R_1$ - active resistance of the circuit;

$X_\Sigma = \omega\,(L_K + L_1)$ - inductive resistance of the circuit;

$\varphi_п = \mathrm{arctg}\frac{X_\Sigma}{R_\Sigma}$ - the angle of shear between the voltage and current of the same circuit

At K3 at point K (Fig. 4.1) the simplest electric circuit breaks up into two independent chains (we denote them M and N), one of which - M - remains attached to the source, and the other - N - turns into a short-circuited circuit, the current in which will be maintain until the energy stored in the magnetic field in it goes into the heat released in the active resistance R1. For the part of scheme N, the differential equation of stress balance will be

$$0 = i_j R_1 + L_1 \frac{di_j}{dt}, \tag{4.3}$$

Where $j = (A, B, C).$

The solution of equation (4.3) will be

$$i = i_0 e^{-\frac{t}{T_{a1}}}, \tag{4.4}$$

Where i_0 - initial value of free current;

T_{a1} - time constant of free current decay. Equation (4.4) shows that in the section N there is only a free current, which decays exponentially with a time constant T1, the value of which is determined from expression

$$T_{a1} = \frac{L_1}{R_1} = \frac{X_1}{\omega R_1}, \text{ c}. \tag{4.5}$$

Since the chain is symmetric, expression (4.4) is valid in structure for all three phases. The initial values of the currents i0 for the phases will be different.

4.1.3 Procedure of the work

Collect the scheme of laboratory tests Figure 4.2 (ALL of the stand modules must be DISABLED!). The diagram shows the option of connecting a short-circuit (three-phase switch Q) to simulate a three-phase short circuit at point K1. The short-circuit current of each phase passes through the current sensor of the I / O module (channels Al, A2, A3). This allows you to use a personal computer as a recording oscilloscope. Similarly, a circuit is constructed to simulate a three-phase short circuit at the point K2.

2) Set the maximum value of the longitudinal component of the line resistance (switch SA1 to position

3) and disable the transverse component (switches SA2, SA3 to position 1). 3) Set the inductance value switch SA1 of the inductive load module to position 3.

4) Switch the control mode switches of all the activated blocks to the "Manual" position.

5) Feed the power to the stand (turn on the power unit of the power module of the stand).

6) Include all the modules involved, which have a separate power switch "Network".

7) Switch on the three-phase mains switch.

8) Start the DeltaProfi software package on the personal computer (Start - Programs - Laboratory complex - DeltaProfi). Open the laboratory work with the team "Works - Transient processes in EPS - Transient processes with symmetrical short-circuits". 9) Start the oscilloscope process of the currents with the "Start" button or with the command of the main menu "Control - Start" or the hot key F5.

10) Press the ON / OFF switch Q and, after a second, press the Q switch off button. Repeat the test several times.

11) Stop the oscilloscope process with the "Stop" button, the main menu command "Control - Stop" or the hot key F6. Press the "Off" button of the three-phase network module. Switch off the power to the stand.

12) Set the required value of the scanning and scale of the signal display by amplitude, using the control elements of the DeltaProfi software.

13) Using the navigation controls at the bottom of the graph, view the recorded waveform.

14) Determine the effect of the moment of inclusion on the nature of the transient process.

15) Carry out a similar three-phase short circuit test at point K2. Determine the value of the periodic component of the short-circuit current.

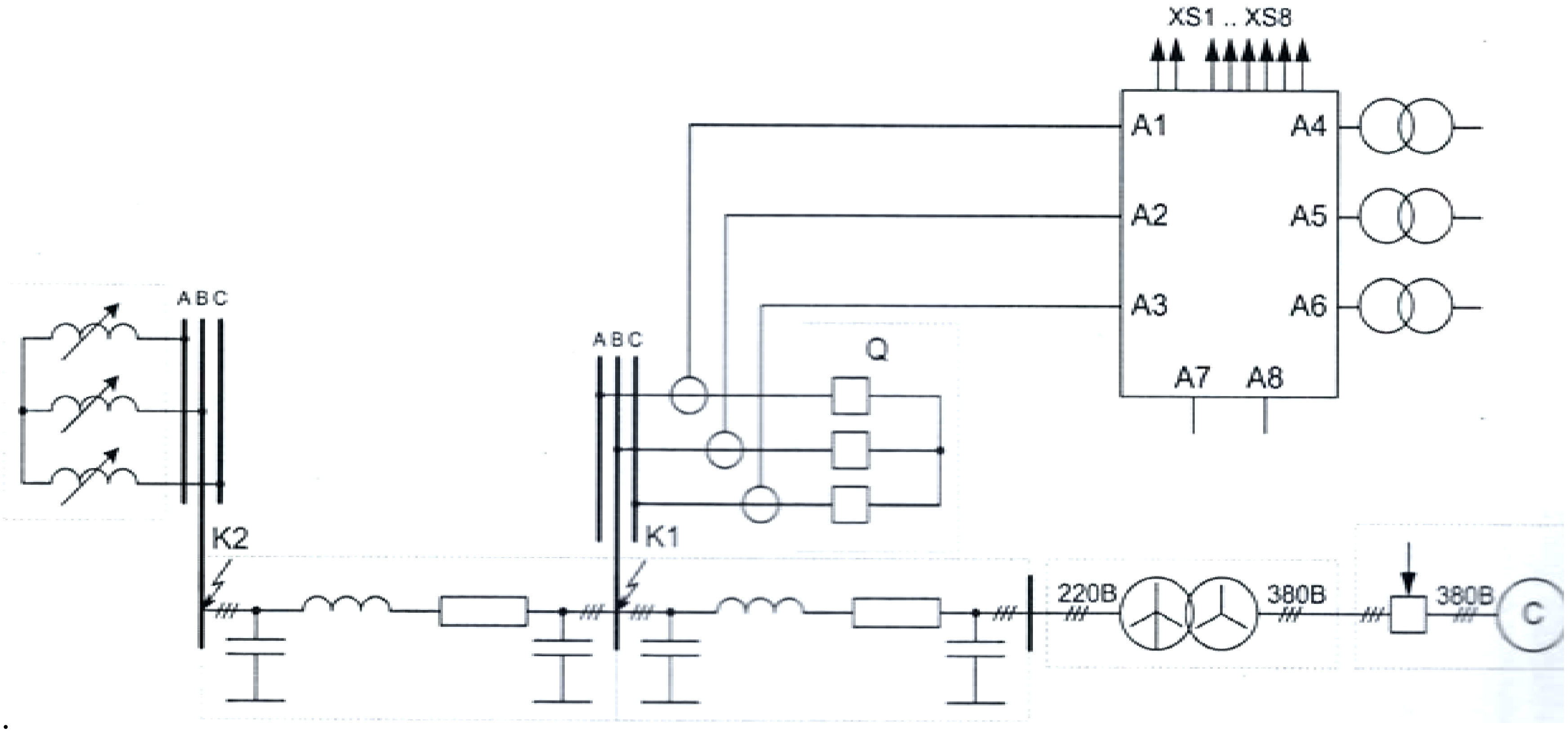


Figure 4.2 - The scheme of laboratory tests

16) From the data obtained, determine the effect of the short-circuit remoteness from the power source on the effective value of the three-phase short-circuit current.

17) To issue a report on laboratory work.

4.1.4 Control questions

1. Describe all modules used in laboratory work.
2. What do you mean by the term "short circuit"?
3. What connection options are used in laboratory work?
4. How is the maximum value of the longitudinal component of the line resistance established?
5. How is the food delivered to the stand?
6. What software package is used in laboratory work?
7. How is the oscilloscope process performed in the laboratory?
8. What is the value of the scanning and the scale of the signal mapping by amplitude to be established in the laboratory work?
9. Explain the electrical circuit diagrammed in the lab.
10. What kinds of load are used in the performance of laboratory work?

4.2 Analysis of transients in asymmetric short-circuits in an electrical network powered by an infinite power source.

Objective: to investigate the dependence of the value of short-circuit current on the type of fault in networks with isolated and earthed neutral.

4.2.1 Assignment to work

To carry out an analysis of transient processes with asymmetric short-circuits in an electrical network powered from a source of infinite power

Perform experimental studies.

4.2.2 Theoretical information

For asymmetric faults at the fault point, there are reverse and zero sequence voltages that are not present during normal operation of the electrical network. Under the influence of these voltages, the circuit currents with reverse and zero sequence voltages flow.

At the fault point where 3-phase faults occur, the voltage at the fault location equals 0 (metallic short-circuit). If there was a residual fault, it remained symmetrical. If a non-symmetric fault occurs, then there is a voltage of direct, reverse and zero sequence, therefore currents of direct, reverse and zero sequence will flow along the lines.

Elements of the circuit generally represent forward, reverse, and zero sequence currents. Unequal resistance, and accordingly the resistance of the forward, reverse and zero sequence: X1, X2, X0.

In the electrical system, there are only direct emfs. The currents of the zero and reverse sequences are determined only by the voltages of the symmetrical components at the fault points, respectively the voltages of the zero and reverse sequences UK0 and UK2.

Thus, the calculation of transients for asymmetric short circuits reduces to determining the resultant resistance of the replacement circuit of each sequence, finding the currents and voltages of the symmetrical components from the solution of the reduced system of equations, and from them - the total phase currents and voltages at the fault site

4.2.3 Procedure for performing the work

1) To assemble the scheme of laboratory tests in accordance with Figure 4.3 (ALL booth modules must be OFF!). The diagram shows the option of connecting a short-circuit (three-phase switch Q) to simulate a two-phase short-circuit at point K1. The short-circuit current of each phase passes through the current sensor of the I / O module (channels Al, A2, A3), and phase voltages are fed through the channels A4, A5, A6. This scheme allows you to monitor both the currents of the damaged phases, and the currents and voltages of the undamaged phases.

2) Set the maximum value of the longitudinal component of the line resistance (switch SA1 to position 3); disable the transverse component (switches SA2, SA3 to position 1).

3) Switch the control mode switches of all the activated units to the "Manual" position. 4) Supply power to the stand (turn on the power module of the power module of the stand).

5) Include all the modules involved, which have a separate power switch "Network".

6) Switch on the three-phase mains switch.

7) Start the DeltaProfi software package on the personal computer (Start - Programs - Laboratory complex - DeltaProfi). Open the laboratory work with the team "Works - Transient processes in EPS - Transient processes with asymmetric short-circuits".

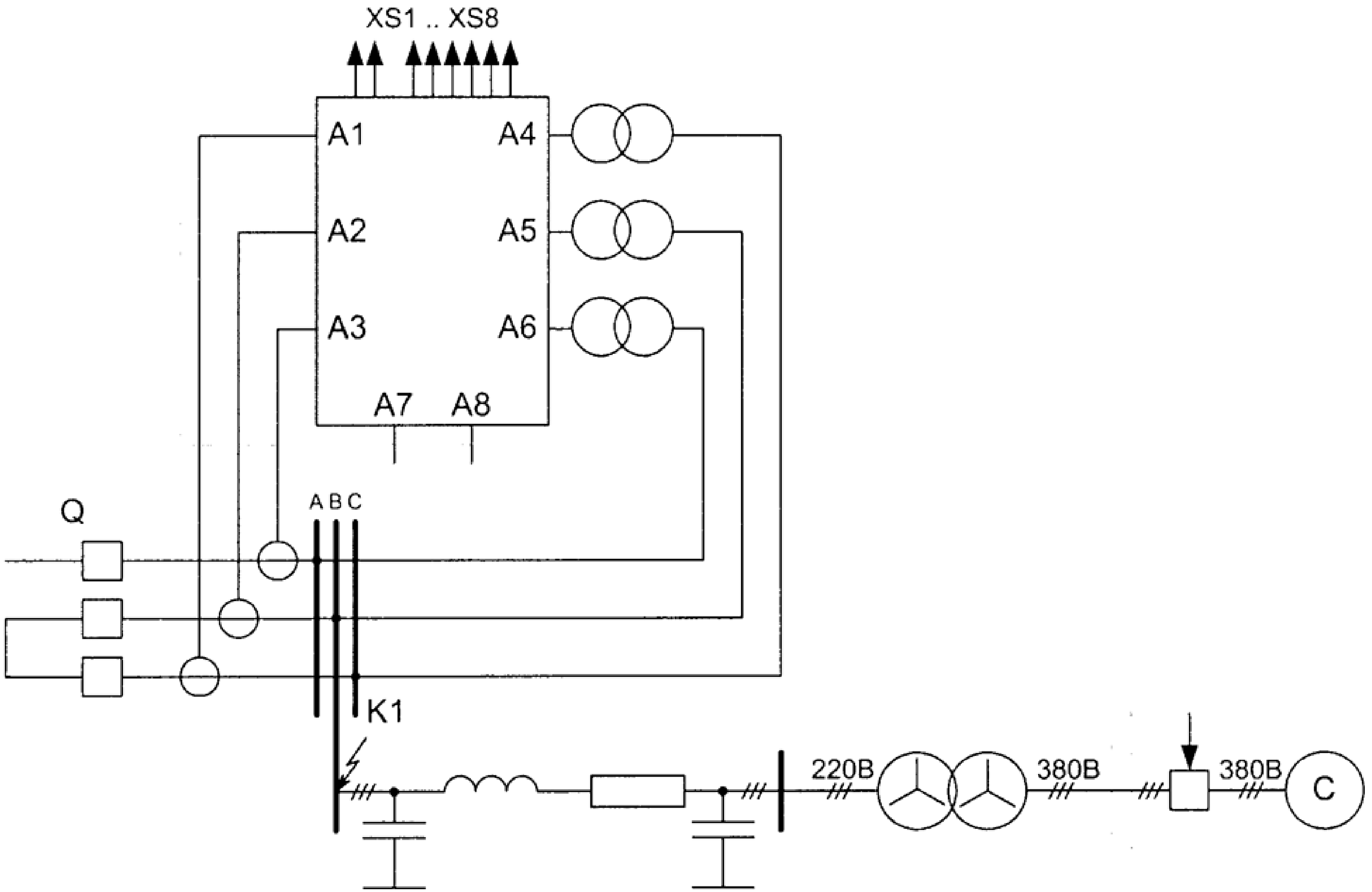


Figure 4.3 - The scheme of laboratory tests

8) Start the oscilloscope process with the "Start" button or the main menu command "Control - Start" or the hot key F5. - Press the switch button Q and after a second press the switch button Q. Stop the oscilloscope process with the stop button, the main menu command "Control - Stop" or the hot key F6. Save the received waveform with the command of the main menu of the program "File-Save to file ...".

9) Repeat the experiment with other types of two-phase short circuit. ATTENTION! To change the type of damage, it is necessary to DISCONNECT the stand, change the scheme and switch on the stand again.

10) Repeat items 5..11. Disconnect the three-phase mains switch, turn off the power to the stand. Process the data received, draw conclusions and draw up a report on laboratory work.

4.2.4 Test questions

1. What is meant by a short circuit?

2 What types of short circuits exist?

2. What is the probability of short circuits in various electrical systems?

3. What types of short-circuits occur in electrical systems?

4. What is the relative probability of short circuits in various electrical systems?

5. Describe the modules used in this lab.

6. What parameters do I need to set when performing lab work?

7. How do I set the switches and how does the power supply work during the lab work?

8. How do I start the oscilloscope process?

9. How is the magnitude of the amplitude sweep and scale of the signals displayed?

10. How can I view the recorded waveform?

4.3 Analysis of transients in single-phase short circuits in networks with isolated and earthed neutral

Objective:

- to investigate the dependence of the short-circuit current on the type of fault in networks with isolated and earthed neutral.

4.3.1 Assignment to work

- learn how to analyze transients in single-phase short circuits in networks with isolated and deaf-earthed neutral;
- carry out experimental studies;
-form a report on laboratory work;
-Answer to control questions.

4.3.2 Theoretical information

The electrical networks of industrial enterprises can operate both with the neutral of the transformer isolated from the ground and with the neutral of the transformer connected to the ground tightly or through low resistance.

A network with isolated neutral effectively works only if it has a reliable device for continuous monitoring of insulation with a mains failure with a decrease in insulation resistance below a predetermined limit, and also under the condition of continuous monitoring of the integrity of the breakdown fuse.

Currently, industrial enterprises have the most widespread four-wire networks with a deadly grounded neutral, allowing the use of two operating voltages - linear and phase. The use of a simpler and more reliable system for the combined supply of power and lighting electrical receivers from common transformers reduces the cost of the installation as a whole by installing a smaller number of transformers, reducing the conductor material, etc.

In view of the safety of a network with a deadly neutral, are more dangerous in comparison with networks with isolated neutral. The presence of a considerable capacity relative to the ground of branched cable networks with isolated neutral substantially nullifies the known advantages of these networks. As the basic protective measures providing electrical safety, they are used: in systems with isolated neutral - protective earthing, and in networks with a deadly neutral neutral - zeroing. At zeroing, all metal non-conductive parts that can be energized are electrically connected to the zero protective conductor. Due to such a connection, any short circuit to the housing or metal structure passes into a single-phase short circuit, the nearest fuse burns out or the machine is triggered and the damaged section is shut off.

The protective effect of grounding depends on the resistance of the grounding device, the reliability of the circuit between the earthing switches and grounded elements. For fast and reliable disconnection of the damaged area of the electrical installation in networks with a deadly neutral neutral, the resistance of the circuit to the phase conductor, the zero protective conductor, is of considerable importance. All these factors depend on the accuracy of the calculation of the grounding device, the correctness of its installation and operation.

Therefore, before starting up the newly installed electrical installations, and periodically during their operation, a thorough test of the grounding devices is carried out.

4.3.3 The order of the work:

1) Collect the scheme of laboratory tests Figure 4.4 (ALL of the stand modules must be OFF!). The diagram shows an option for connecting a short-circuit (three-phase switch Q) to simulate a single-phase short circuit at point K1. The short-circuit current of each phase passes through the current sensor of the I / O module (channels Al, A2, A3), and phase voltages are fed through the channels A4, A5, A6. This scheme allows you to monitor both the currents of the damaged phases, and the currents and voltages of the undamaged phases.

2) Set the maximum value of the longitudinal component of the line resistance (switch SA1 to position 3); switch on the transverse component (switches SA2, SA3 to position 2).

3) Set the isolated mode of operation of the neutral of the transformer group from the power line side (do not connect the common point to neutral).

4) Switch the control mode switches of all the connected units to the "Manual" position.

5) Feed the power to the stand (turn on the power unit of the power module of the stand).

6) Include all the modules involved, which have a separate power switch "Network".

7) Switch on the three-phase mains switch.

8) Start the DeltaProfi software package on the personal computer (Start - Programs - Laboratory complex - DeltaProfi). Open the laboratory work with the team "Works - Transient processes in EPS - Transient processes with asymmetric short-circuits".

9) Start the oscilloscope process of the currents with the "Start" button or with the command of the main menu "Control - Start" or the hot key F5.

10) Press the switch Q and turn off the Q switch a second later. Stop the oscilloscope process with the stop button, the main menu command "Control - Stop" or the hot key F6. Save the received waveform with the command of the main menu of the program "File - Save to file ...".

11) Repeat the experiment for other types of single-phase short circuit. ATTENTION! To change the type of damage it is necessary to DISCONNECT the stand, change the scheme and switch on the stand again.

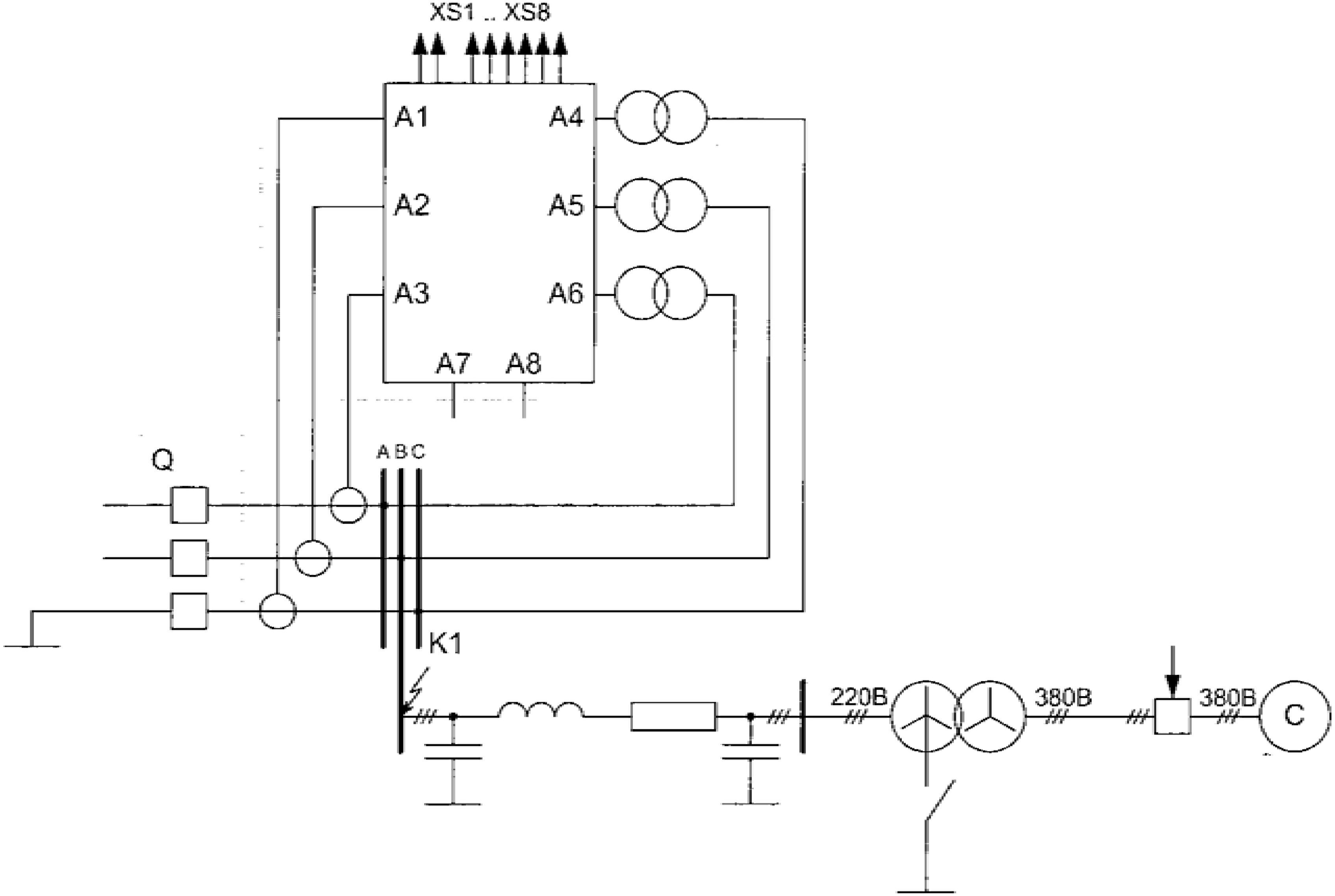


Figure 4.4 - The scheme of laboratory tests

12) Change the operating mode of the neutral: connect the neutral point of the transmission line and the secondary windings of the transformers (winding from the power line side). ATTENTION! Changing the circuit must be done with the POWER OFF of the stand (QF1 circuit-breaker).

13) Repeat items 5..11. Process the data received, draw conclusions and draw up a report on laboratory work.

4.3.4 Control questions

1. What is the purpose of this laboratory work?
2. Describe the procedure for performing laboratory work.
3. What types of short circuit are investigated when performing laboratory work?
4. What is the value of the resistance of the transmission lines installed during the experiments?
5. How is the power supply of the stand?
6. What programs are used in laboratory work?
7. How do I start the oscilloscope process?
8. What kinds of short-circuits are investigated experiments in laboratory work.
9. Describe the installation scheme used in laboratory work.
10. Give information about the modules used in this lab.

4.4 Investigation of the process of synchronization of a natural synchronous generator with a network and regulation of its active and reactive powers.

The purpose of this work is to investigate the synchronization process of a natural synchronous generator with the network and to regulate its active and reactive powers.

4.4.1. Task

1) master the technique of precise manual synchronization of the generator with the network ;

2) to study the principles of regulation of the main regime parameters of the SG: voltage, current, active and reactive power.

4.4.2. Theoretical information

Preparation of the SG for the inclusion of the parallel operation and the switching process itself are called synchronization.

There are three ways to synchronize

1. accurate;
2. rough;
3. Self-synchronization.

These methods are discussed below.

For a shockless activation of the SG for parallel operation, it is necessary to fulfill the following synchronization conditions:

1. Equalization of the voltage Uc of the network and the EMF Ez of the connected generator, i.e. | Uc | = | Ez | .
2. The equality of frequencies of the network fc and the connected generator fz, that is, fc = fz.
3. the phase coincidence of the same phase vectors of the phase voltages of the two generators, or, in other words, the phase angle of these vectors is zero, that is, $\varphi = 0°$.
4. the same order of alternation of phases of 3-phase generators, i.e. AaB c-Cc and Az-Bz-Cz. In practice this means that the terminals A, B and C of each generator must be connected to the busbars A, B and C, respectively, when turning on the bus. We will explain how the fulfillment of these conditions is checked and what must be done if they are disturbed. To verify the first condition, a voltmeter with a switch is used to alternately measure the voltage on the buses (network) and on the terminals of the generator connected to the bus. If the voltage of the connected generator is greater than (less) the voltage on the busbars, then proceed as follows:

1. when manually adjusting manually (increase) the excitation current of the connected generator by means of an excitation rheostat, the handle of which is output to the front of the generator panel of each generator;
2. Automatic control reduces (increases) the excitation current by acting on the regulator of the voltage setpoint of the automatic voltage regulator (AVR) of the generator, the handle of which is output to the front part of the generator panel of each generator.

To check the second condition, a frequency meter with a switch is used to alternately measure the frequency of the voltage on the buses (network) and on the terminals of the generator connected to the bus.

If the frequency of the current of the connected generator is more (less) than the frequency of the current on the busbars, then the connected generator has to reduce (increase) the fuel supply to the diesel engine by turning the servo motor control handle towards "Less" ("More").

This handle is outputted to the front of the generator panel of each generator.

To test the third condition, use a lamp or arrow synchroscope. To switch on the generating set it is necessary at the moment when all 3 lamps go out (if the synchroscope is switched on in the "darkness" scheme) or the upper one (if the synchroscope is switched on in the "fire rotation" scheme) or if the synchroscope arrow takes the "12 hours" position.

The fourth condition is not checked during the operation of the vessel. This is due to the fact that the required order of connecting generators to the tires is provided by electrical installation specialists of the shipyard.

Therefore, ship electricians do not need to check the fulfillment of this condition.

However, after performance of repair and maintenance work, during which the generator is disconnected from the tires of the GORSH, verification of the fulfillment of this condition is mandatory.

If all the synchronization conditions are fulfilled, then the inclusion of the generator on the bus MGTS will be unstressed, and the generator itself after the switch-on will remain idle.

4.4.3 Procedure for performing the work

1) Assemble the scheme of laboratory tests in accordance with Figure 4.5 (ALL of the stand modules must be OFF!).

2) Set the maximum value of the longitudinal component of the line resistance (switch SA1 to position 3) and disable the transverse component (switches SA2, SA3 to position 1).

3) Switch the control mode switches of all the activated units to the "Manual" position.

4) Set the potentiometers RP1 of the frequency inverter module and the field module to the extreme left position.

5) Feed the power to the stand (turn on the power unit of the power module of the stand).

6) Switch the rotation direction switch SA1 of the drive motor of the inverter module to the "Forward" position.

7) Turn on all modules that have a separate power switch "Network".

8) Gradually increase the voltage setting of the frequency inverter module (potentiometer RP1), set the nominal speed (1500 rpm) of the electric machine (follow the speed meter readings).

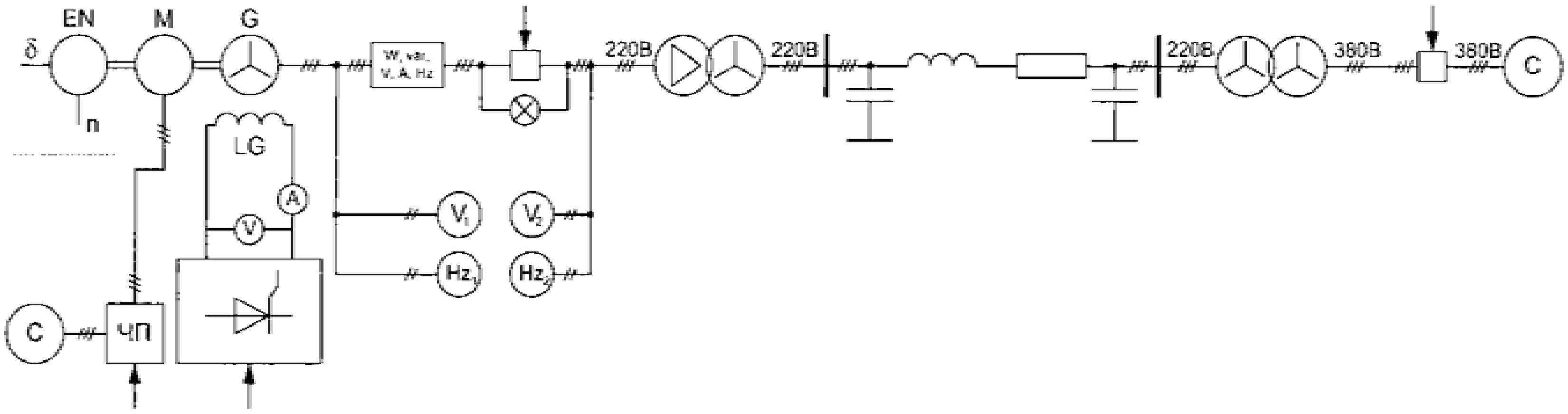


Figure 4.5 - Diagram of laboratory tests

9) Gradually increasing the voltage of the excitation module (potentiometer RP1), set the value of the line voltage on the stator winding of the SG around 220V (follow the voltmeter VI).

10) Switch on the three-phase mains switch (SB1 button).

11) Align by the frequency meter Hzl and Hz2 frequencies of the frequency of the electric machine unit and the electrical network. To do this, it is necessary to adjust the voltage setting of the frequency converter (potentiometer RP1).

12) Align the voltmeters VI and V2 on the generator side and on the network side. For this, it is necessary to adjust the voltage of the excitation module (potentiometer RP1).

13) Items 11 and 12, if necessary, repeat several times until the voltage is close (AU <= 10B), and the period of the envelope voltage envelope change will be not less than several seconds.

14) At the moment of coincidence of the voltage vectors of the same phases on the switch of the synchronization module (the lamps must go out), give the command to turn it on (button SB1).

15) Translate the universal instrument of the power meter into active and reactive power measurement mode (see technical description of the "power meter" module) and record the value of active and reactive power. Evaluate them and conclude that all the conditions for accurate synchronization are met.

16) By varying the drive motor drive voltage, determine the influence of the magnitude of the torque on the shaft of the electric machine aggregate on the amount of active power, reactive power, and voltage at the generator terminals.

17) By changing the voltage of the excitation module specification, determine the influence of the excitation current of the synchronous generator on the value of the active power, the reactive power of the generator and the voltage at its terminals.

18) The procedure for shutting down the stand: - unload the generator by active power to zero. To do this, smoothly decrease the voltage setting of the frequency converter until the active power (according to the power meter) becomes zero. - unload the generator by reactive power to zero. To do this, smoothly decrease the voltage of the excitation module until the reactive power (according to the voltmeter) becomes zero. - disable the synchronization module switch (SB2 button). - reduce the excitation current of the generator (potentiometer RP1 of the excitation module) but zero. - reduce the speed of the drive motor (potentiometer RP1 of the frequency converter module) to the minimum value (which is set in the frequency converter settings). - turn off the power of all modules. - switch off the power to the stand.

19) Process the results, draw conclusions and draw up a report on laboratory work.

4.4.4 Test questions

1. What does short circuit in networks with isolated and deeper-grounded neutral mean?

2. What is the purpose of the laboratory work?

3. How is it necessary to assemble a laboratory test plan?

4. What is the magnitude of the longitudinal component of the line resistance?

5. What mode should be installed during the operation of the neutral of the transformer group from the power line side? 6. What stand modules are involved in this lab work? 7. What experimental data have been studied in laboratory work and how many experiments have been carried out?

8. Describe the work of the electrical circuit given in the laboratory work?

9. Define the short-circuit current and what kinds of short-circuits occur in electrical networks?

10. What is the research data and what is the conclusion when performing laboratory work?

4.5 Determination of the angular characteristic of a synchronous generator

Objective: to learn how to determine the angular characteristics of a synchronous generator.

4.5.1 Assignment to work

- to remove the angular characteristic of the SG in the nominal mode;
- determine the limit of static stability of the SG in the nominal mode.

4.5.2 Theoretical information

The angular characteristic of a synchronous machine is the dependence P1 = f (Θ) at a constant excitation current, voltage and network frequency (If = const, Uc = const, fc = const). Knowledge of this characteristic makes it possible to establish a number of important properties of a synchronic machine that determine the stability of its operation in parallel with the network.

Let us find this dependence for a synchronous machine with a pole pole rotor, assuming that the armature resistance is zero (ra = 0) and the machine is not saturated.

The active power of a synchronous machine is given by

$$P_1 = m_1\, U_1 I_1 xos\varphi_1 \qquad (4.1)$$

To convert this expression to the required dependence P1 = f (Θ), we use the vector diagram of a synchronous machine included in a powerful network with a voltage Uc = const and fc = const and operating in the generator mode with reactive power output to the network in accordance with Fig. 4.6.

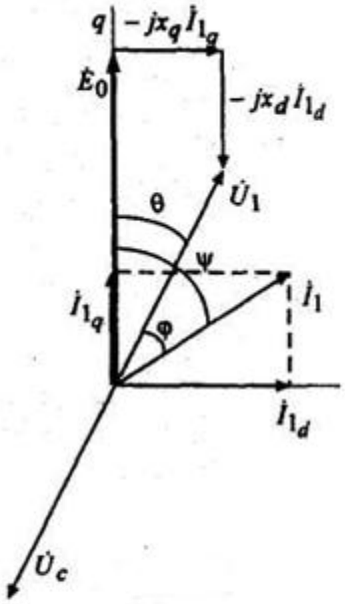


Figure 4.6 Vector diagram

4.5.3 the Order of execution of work

1) Collect the scheme presented in the work No. 4 in accordance with figure 4.5.

2) Enable the generator to parallel work with the network (to carry items to 2.. 14 according to methodical instructions for the laboratory work №5).

3) Set the rated current of the excitation synchronous generator 1A.

4) Gradually increasing the control voltage of the drive motor to remove the dependence of the active power of the synchronous generator from its load angle R{d). Attention! When you reach the limit of the static stability of the generator switches to asynchronous moves. Long stay (more than 10 seconds) in this mode is not allowed, so, in the case of buckling it is necessary:

- to reduce the voltage of the control drive motor as long as the generator is not drawn into synchronism;
- if resynchronization has not occurred, it is necessary to disconnect the three-phase network (SB2 synchronization module), remove the excitation of the

generator (potentiometer RP1 module excitation), to adjust frequency of rotation of the rotating Assembly (potentiometer RP1 module frequency Converter) to the rated value and re-synchronization of the generator with the network .

5) Set the value of the excitation current corresponding to the idling speed of the generator (about 0.8 A).

6) Gradually loading the generator (increasing setpoint chastnogo Converter) to remove the dependence of the active power of the synchronous generator from the load angle P(S) , to determine the time of buckling and the corresponding value of the active power of the SG.

7) Set the excitation current value slightly below the value corresponding to the idling mode of the generator (i.e., transfer the generator to the reactive power consumption mode).

8) Smoothly load the generator (increasing the setting of the frequency converter) to remove the dependence of the value of the active power of the synchronous generator on its load angle P (q), determine the moment of loss of stability and the corresponding value of the active power of the SG.

9) Compare the results obtained and draw a conclusion about the effect of the excitation current of a synchronous generator on its static stability.

10) Disconnect the stand in accordance with the STOP TERMINATION PROCEDURE, presented in paper No. 5, process the results and issue a report on laboratory work.

4.5.4 Test questions

1. Purpose of the laboratory stand and describe the modules used.
2. What is the purpose of laboratory work?
3. What is a synchronous generator?
4. What is the definition of the electrical network?
5. Describe the electrical circuit and the purpose of the elements used in laboratory work?
6. What kinds of transformers exist and describe the scheme of connection of windings?
7. How much and what experiments are carried out in the laboratory?
8. What is a potentiometer and its purpose in laboratory work?
9. Describe the implementation procedure in the laboratory work?
10. How to order the shutdown of the laboratory installation?

4.6 Investigation of the influence of the parameters of the elements, the circuit and the regime of the electrical system on its stability.

The purpose of this work is to investigate the effect of the parameters of the elements, circuit and mode of the electrical system on its stability.

4.6.1. Work assignment

- to determine the effect of the length of the transmission line (its equivalent resistance) stability of SG in the nominal mode;
- determine the influence of the power transmission voltage on the limit of static stability of the SG in the nominal mode.

4.6.2 Theoretical information

In the steady-state mode of a real system, its parameters are constantly changing, which is due to the following factors:

- load variation and response to these changes in control devices;
- normal operational changes in the system switching circuit;
- switching on and off of individual generators or changing their power.

Thus, in the steady-state regime of the system, there are always small perturbations of the parameters of its regime, for which it must be stable.

Static stability is the ability of the system to restore the original (or close to the original) mode after a small perturbation.

Emergency modes in the electrical system occur during faults, emergency trips of loaded aggregates or lines, etc. Under the influence of large perturbations, abrupt changes in the regime arise.

Dynamic stability is the ability of the system to return to its original (or near) state after a large disturbance. When after a large disturbance the synchronous mode of the system is violated, and then after a permissible break is restored, then the resultant stability of the system is indicated.

Proceeding from the definition of the static stability of the system, we can conclude that there is a regime in which a very small increase in loads causes a violation of its stability. Such a regime is called the limiting mode, and the system's loads are the maximum or maximum loads under the conditions of static stability.

Restriction of loads can be caused by other circumstances, for example, heating elements of the electrical system (generators, transformers, etc.). In this case, one speaks of limiting loads by the condition of heating and also establishes the maximum lifetime of the regime.

Limitations of loads by voltage levels in nodes, crown stress, etc. are possible. The capacity of a system element is called the maximum power that can be transmitted through this element, taking into account all the limiting factors (heating, stability, voltage in the nodes, etc.).

The concept of bandwidth is also valid for dynamic stability. In this case, one speaks of the power transmission limit according to the conditions of dynamic stability at faults at any point, switching off the line, and so on.

Stability with respect to the electrical system is the ability of the system to return to the initial or new steady state after elimination of the disturbing effect without the occurrence of an asynchronous rotation of the rotors of the system generators. If the magnitude of the disturbance is small (for example, a smooth change in the load of the system), then one speaks of static stability. With a significant disturbance in the system, for example, in case of a short circuit, they speak of dynamic stability.

Accidents associated with a breakdown in the stability of parallel operation in electrical systems are the most severe, leading to a breakdown in the electricity supply of large areas and cities.

The efficiency of measures used in power systems is largely determined by the speed of the switches, relay protection, emergency control, automatic excitation control of generators (ARV), etc.

In the absence of ARV, the generators of the power plant do not have a sufficient margin for static stability, in contrast to the regime when ARVs are installed. With ARVs proportional, generators have less static stability than with strong ARV.

This effect of ARVs on the stock of static stability is due to the generator replacement circuit, which is included in the final network replacement scheme. The peculiarities of alternator replacement circuits for various ARV systems are caused by real physical models of these ARV systems and their action features. Analyzing what was written above, one can explain the desire of companies producing generators to install ARVs on them with a strong effect.

This will not only help maintain the nominal voltage level at the generator terminals to ensure the proper operation of all equipment connected to this stage, but will also significantly increase the static stability margin.

Roughly speaking, installing an ARV of a strong action contributes to the better functioning of the generators, not only with electromagnetic, but also with electromechanical transients.

Also, the amount of static stability is affected by the nominal voltage of the power line connecting the electrical station to the system. The higher the line voltage class, the greater the static stability margin the power plant generators have.

4.6.3 Procedure for completing the work

1) Collect the diagram presented in work No. 5 in accordance with Figure 4.7.

2) Switch on the generator for parallel operation with the network (follow steps 2 .. 14 according to the guidelines for laboratory work No. 5).

3) Set the rated excitation current of the synchronous generator 1A.

4) Smoothly increasing the control voltage of the drive motor to determine the value of the static stability limit of the synchronous generator. ATTENTION! When the static stability limit is reached, the generator will go into asynchronous stroke mode. Long stay (more than 10 seconds) in this mode is not permissible, therefore, in case of loss of stability it is necessary:

- to reduce the magnitude of the drive motor control voltage until the generator is retracted;
- if the resynchronization does not occur, it is necessary to disconnect the connection with the three-phase network (SB2 button of the synchronization module), remove the excitation of the generator (potentiometer RP1 of the excitation module), adjust the speed of the electric machine (potentiometer RP1 of the frequency converter module) to the nominal value and re-synchronize the generator with network (see clause 2).

5) Determine the static stability limit of the generator at a different value of the line resistance (determine the influence of the transmission line length on the stability of the parallel operation of the SG). To do this, turn off the stand (see STAND TERMINATION procedure in laboratory work No. 4), set switch SA1 of the power line module to position 2, repeat execution of points 2..4, compare the results with those obtained earlier and draw conclusions.

6) Investigate the effect of the power transmission voltage on the stability of a natural synchronous generator. To do this, turn off the stand and transfer the power line module to the 127V branch lines in accordance with the diagram shown in Figure 4.7.

7) Perform paragraphs 2-4, compare the results with those obtained earlier and draw conclusions.

Disconnect the stand in accordance with the STOP TERMINATION procedure in laboratory work No. 4, process the results and issue a report on laboratory work.

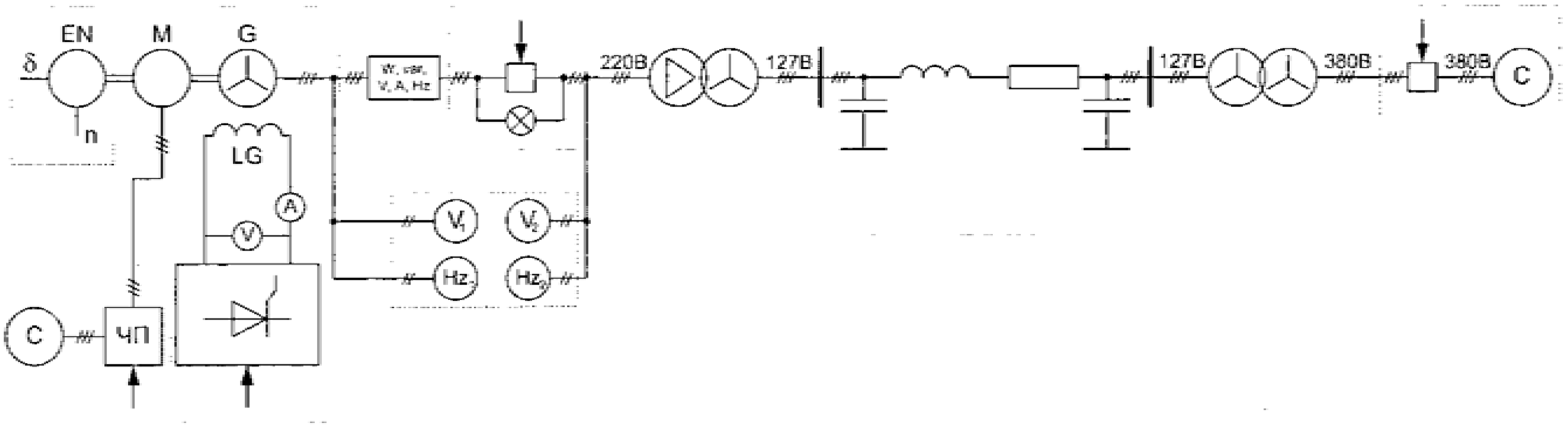


Figure 4.7 - Diagram of laboratory tests

4.6.4 Control questions

1. What needs to be investigated in this laboratory work?
2. What modules are involved in the implementation of experimental studies?
3. Outline the procedure for performing laboratory work.
4. Describe the elements of the scheme of the laboratory installation.
5. How is the value of the statistical stability limit of a synchronous generator determined?
6. What do the terms "synchronism" and "resynchronization" mean?
7. What is the limit of the static stability of the generator?
8. How is the influence of the power transmission voltage on the stability of a non-synchronous generator synchronized?
9. What are the conclusions of the pilot studies?
10. What does the term static stability of the generator mean?

4.7 Investigation of the effect on static stability of a natural synchronous generator of the short-circuit type in the electric power system.

Objective: to investigate the effects on the static stability of a natural synchronous generator of the short-circuit type in the electric power system.

4.7.1. The task to work is

to investigate the influence of the excitation current on the static stability of the synchronous generator for the listed types of short circuits.

- Investigate the effect on static stability of a natural synchronous generator of single-phase, two-phase and three-phase short circuits.

4.7.2. Theoretical information

The static stability of a synchronous machine operating in parallel with the network is the ability to maintain synchronous rotation (n2 = n1) with a change in the external torque or braking torque Mvn applied to its shaft. Static stability is ensured only at angles q <qcr, corresponding to the electromagnetic moment M <Mmax.

Assume that the synchronous generator operates at some external torque of the Mvn transmitted to its rotor from the primary motor. The axis of the rotor poles is shifted by some angle q relative to the axis of the total flux Φ and the machine develops the electromagnetic moment M, which can be considered equal to the braking torque (points A and C in the figure).

If the moment Mvn increases, the generator rotor accelerates, which leads to an increase in the angle q to the value $(q + \Delta q)$. When the machine is operating at point A, increasing the angle q causes an increase in the electromagnetic moment to the value $(M + \Delta M)$ (point B). As a result, the balance of the moments acting on the rotor shaft is restored and the machine continues to operate at a synchronous speed after some oscillatory process.

A similar process occurs when the Mv is reduced. In this case, the angle q and the electromagnetic moment M decrease. Consequently, the equilibrium of the moments is also restored.

However, if the machine operates at $qcr < q < 1800$ (point C), increasing the angle q with increasing MW causes the electromagnetic moment to decrease to a value $(M - \Delta M)$ (point D). The equilibrium of the moments acting on the rotor shaft is violated. The rotor continues to accelerate, and the angle q increases, which can lead to two results:

1) the machine goes to the point of stable operation (similar to point A) on subsequent positive half-waves of the angular characteristic;

2) the inertial rotor skips stable positions, while the loss of synchronism occurs, i.e. the rotor starts to rotate at a frequency different from the rotational frequency of the stator magnetic field.

Fallout, from synchronism is an emergency mode. At the same time, the armature current increases, since the EMF of the generator E and the voltage of the network Uc in this mode can be added along the "generator-network" contour, and not subtracted, as in normal operation.

If the external moment at the work of the machine at point C decreases, the angle q decreases, the electromagnetic moment increases, which leads to a further decrease of the angle q and the transition to work at the stable point A.

If the machine operates in a steady state at some angle q, then a small deviation Δq from this angle is accompanied by the appearance of the moment $\Delta M = (dM / dq)\, \Delta$, which tends to restore the initial angle q.

This moment is called synchronizing. It corresponds to the concept of synchronizing power $\Delta PЭM = (dPЭM / dq)\, \Delta q$.

Derivatives dM / dq and dEM / dq are called the specific synchronizing moment and the specific synchronizing power, respectively. The specific synchronizing moment has a maximum value at $q = 0$. As q increases, it decreases, and at $q = qcr$ it is zero, so synchronous machines usually work with q = 20-30 °, which corresponds to approximately two times the reserve by the moment.

4.7.3 Procedure for performing the work

1) Collect the scheme of laboratory tests Figure 4.8. Here, the three-phase circuit breaker Q is used as a short-circuit. The figure shows the variant of assembly of the circuit for carrying out the three-phase short circuit test in the middle of the transmission line (2 power transmission modules are used). Changing the circuit of connections of one of the sides of the switch, you can get all kinds of short circuits. To ensure sufficient single-phase short-circuit current, the neutral of the transformers from the power line side and the neutral of the power line itself must be combined. The transverse components of the transmission lines must be switched on (switches SA2 and SA3 in position 2).

2) Switch on the generator for parallel operation with the network (follow steps 2 .. 14 according to the guidelines for laboratory work No. 5).

3) Set the initial mode of loading the synchronous generator, approximately equal to half of its nominal power (adjusting the setting of the frequency converter).

4) Adjust the excitation current to transfer the generator to the reactive power output mode (controlling the excitation current of the synchronous generator).

5) Carry out a short circuit test (turn on switch Q and turn it off after a few seconds) while observing the operation mode of the SG.

6) In case of loss of stability, perform actions to re-synchronize the generator with the network.

7) Repeat the experiment with the following types of short circuits: single-phase, two-phase, two-phase on the ground. The excitation current must remain unchanged (iB = const).

8) Repeat the experiments for other values of the excitation current (more and less than the initial value). Disconnect the stand in accordance with the order of the STOP TERMINATION of work No. 5. Compare the findings and draw conclusions. Issue a report on laboratory work.

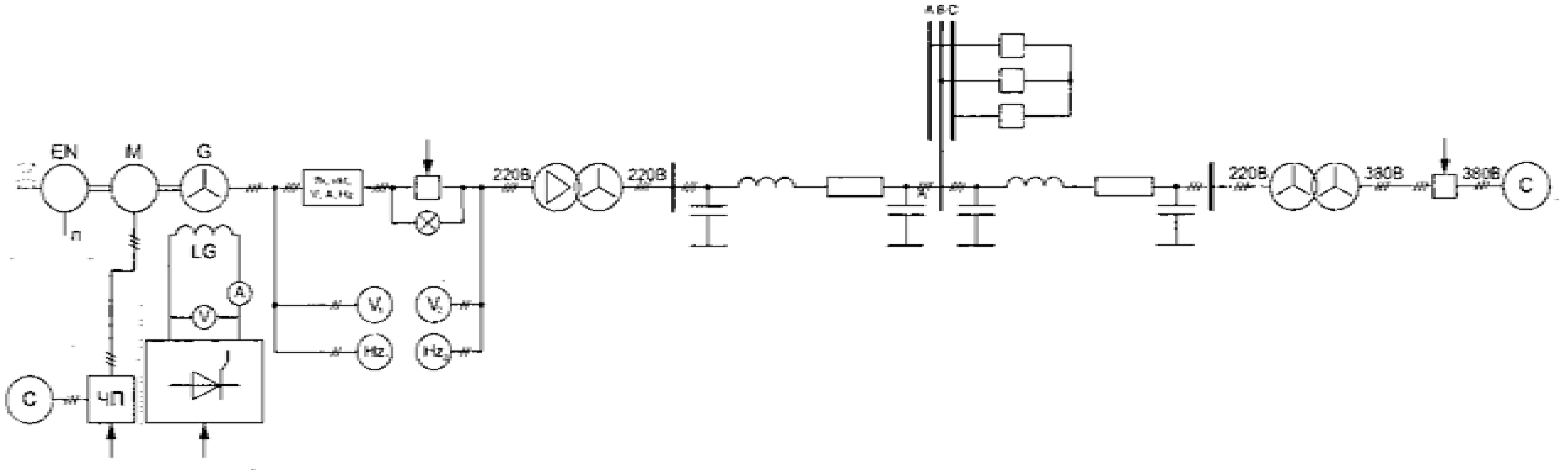


Figure 4.8 - Diagram of laboratory tests

4.7.4 Test questions

1. Define "short circuit and what kinds exist".
2. What does it mean to investigate the influence of the magnitude of the excitation current on the static synchronism of the synchronous generator?
3. Explain the procedure for conducting laboratory work.
4. How many and which modules are involved in this lab work?
5. What types of short circuits are investigated in this laboratory work?
6. What does the term "turn on the generator for parallel operation with the network" mean?
7. How do I set the initial mode for loading a synchronous generator?
8. Why is it necessary to control the excitation current of a synchronous generator?
9. Explain all the elements used in the circuitry given laboratory work.
10. What experimental data have been compared and what conclusions have been obtained?

4.8 Investigation of the influence on the dynamic stability of a natural synchronous generator of the duration of a short circuit in the electric power system.

Objective: to study the effects on the dynamic stability of a natural synchronous generator of the duration of a short circuit in the electric power system.

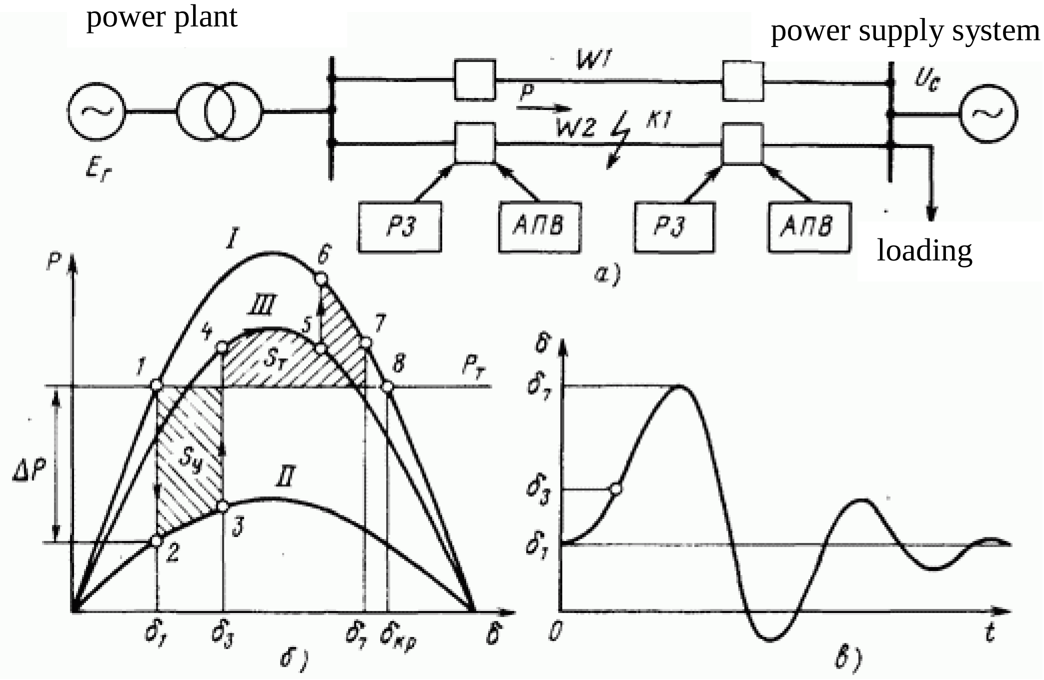
4.8.1 Task to study

-the effect of the duration of a two-phase short circuit on the dynamic stability of a full- synchronous generator;

- determine the influence of the excitation current and the load of the synchronous generator on the maximum duration of the emergency mode, which does not lead to a loss of stability.

4.8.2 Theoretical information

Dynamic stability is understood as the ability of the power system to maintain synchronous parallel operation of generators in case of significant sudden perturbations occurring in the power system (short circuit, emergency shutdown of generators, lines in transformers). To estimate dynamic stability, the area method is applied. As an example, consider the mode of operation of a two-circuit power transmission linking a power station to a power system, with a fault on one of the lines with the disconnection of the damaged line and its successful reclosure (Fig. 4.9, a). The initial power transmission mode is characterized by a point 1 located on the angular characteristic I, which corresponds to the initial power transmission scheme (Fig. 4.9, b)



a - power transmission scheme; b - angular characteristics of power transmission; c - change in the angle δ in time

Figure 4.9 - Qualitative analysis of dynamic stability at K3 on the power line

At K3 at the point K1 on the line W2, the angular characteristic of power transmission occupies position II. The decrease in the amplitude of the characteristic II is caused by a significant increase in the resultant resistance Xrez between the points of application Er and Uc. At the moment K3, the electric power is reset by □P due to the reduction of the voltage on the buses of the station (point 2 in Figure 4.9, b). The discharge of electrical power depends on the type of K3 and its location. In the limiting case, with a three-phase K3 on the station buses, the power is reset to zero. Under the influence of excessive mechanical power of turbines over electric power, the rotors of the station generators begin accelerate, and the angle δ increases. The process of power change follows characteristic II. Point 3 corresponds to the moment when the faulty line is disconnected from both sides of the RZ relay protection devices. After the line is disconnected, the transmission mode is characterized by a point 4 located on characteristic III, which corresponds to a power transmission scheme with one disconnected line. During the time of angle change from δ1 to δ3, the rotors of the station generators acquire additional kinetic energy.

This energy is proportional to the area bounded by the PT line, characteristic II and ordinates at points 1 and 3. This area is called the acceleration site Sy. At point 4, the process of braking of the rotors starts, since the electric power is greater than the power of the turbines. But the process of inhibition occurs with an increase in the angle δ. An increase in the angle δ will continue until all the stored kinetic energy is converted into a potential one.

The potential energy is proportional to the area limited by the PT line and the angular characteristics of the post-accident regime. This area was called the ST brake site. At point 5, after a certain pause after the line W2 has been disconnected, the recloser is activated (a three-phase high-speed reclosing with a small pause is assumed). If the reclosure is successful, the process of increasing the angle will continue along characteristic I (point 6) corresponding to the initial power transmission scheme. The increase in the angle stops at point 7, which is characterized by the equality of the Sy and ST sites. At point 7, the transient process does not stop: due to the fact that the electric power exceeds the turbine power, the braking process will continue along characteristic I, but only with decreasing angle. The process is established at point 1 after several oscillations near this point. The character of the change in the angle δ in time is shown in Fig. 4.9, c.

In order to simplify the analysis, the power of the turbines of the RT during the transient process is unchanged. In fact, it varies somewhat due to the action of the turbine speed governors. Thus, the analysis showed that under the conditions of this example, the stability of parallel operation is maintained. A necessary condition for dynamic stability is the fulfillment of static stability conditions in the post-accident regime. In the example considered, this condition is satisfied, since the turbine power does not exceed the static stability limit.

The stability of the parallel operation would be disrupted if, in the transient process, the angle δ crossed the value corresponding to point 8. Point 8 limits the maximum stopping area to the right. The angle corresponding to point 8 is called the critical δcr. When this boundary is crossed, there is an avalanche increase of the angle δ, i.e. loss of generators from synchronism.

4.8.3 Procedure for performing the work

1) Collect the scheme of laboratory tests drawing in accordance with Figure 4.8. Here, the three-phase circuit breaker Q is used as a short-circuit. The figure shows the variant of assembly of the circuit for carrying out the three-phase short circuit test in the middle of the transmission line (2 power transmission modules are used). Changing the circuit of connections of one of the sides of the switch, you can get all kinds of short circuits. To ensure sufficient single-phase short-circuit current, the neutral of the transformers from the power line side and the neutral of the power line itself must be combined. The transverse components of the power lines must be switched on (switches SA2 and SA3 in position 2).

2) Turn on the generator for parallel operation with the network (follow steps 2..14 according to the guidelines for laboratory work No. 4).

3) Set the initial mode of loading the synchronous generator, approximately equal to half of its nominal power (adjusting the setting of the frequency converter).

4) Adjust the excitation current to transfer the generator to the reactive power output mode (controlling the excitation current of the synchronous generator).

5) Conduct a two-phase short-circuit (turn on the Q switch and turn it off after a few seconds) while observing the operation mode of the SG.

6) In case of loss of stability, perform actions to re-synchronize the generator with the network.

7) Investigate the effect of the duration of the short-circuit regime. To do this, conduct a series of two-phase short-circuit experiments with a duration of 0.5 s (turn on and immediately turn off) and duration 2., 3s. In this case, choose the ratio of generator load with active power (frequency converter control) and excitation current (excitation module control) at which the short-time fault mode does not violate the stability of parallel operation of the synchronous generator, and a longer fault mode leads to loss of stability.

8) Disconnect the stand in accordance with the order of the STOP TERMINATION of work No. 4. Compare the findings and draw conclusions. Issue a report on laboratory work.

4.8.4 Test questions

1. What does it mean to investigate the impact on the dynamic stability of a full-scale rotator?
2. What is a full-scale synchronous generator?

3. What types of sustainability exist and are being investigated in this laboratory work?

4. What kinds of switches are available in networks above 1000V?

5. What do you mean by the terms "reliability" and "selectivity"?

6. How is the initial mode of synchronous generator loading regulated?

7. Why is it necessary to control the excitation current of a synchronous generator? 8. When is it necessary to perform actions for resynchronizing the generator with the network?

9. How is it necessary to investigate the effect of the duration of the short-circuit regime?

10. Describe the modules and elements involved in this lab work.

4.9 Conclusions on the chapter

The chapter shows the practical application of the electric system model in the discipline "Transient processes used in the electric power industry".

The research is carried out in the following areas:

- Analysis of transients in three-phase short-circuit in an electrical network, powered by a source of infinite power;
- Analysis of transient processes with asymmetric short-circuits in an electrical network powered by a source of infinite power;
- Analysis of transients in single-phase short circuits in networks with isolated and deaf earthed neutral;
- Investigation of synchronization process of a natural synchronous generator with a network and regulation of its active and reactive powers;
- Determination of the angular characteristic of a synchronous generator;

The purpose of all the works is:

- to learn to analyze transients in electrical networks;
- Investigate the dependence of the magnitude of the short-circuit current on the type of damage in electrical networks;
- to study the process of synchronization of the full-scale synchronous generator with the network;
- to investigate the effect of the parameters of elements, schemes and regimes on the stability of the system;
- carry out an analysis of the effect on the dynamic stability of a natural synchronous generator of the duration of a short circuit in an electrical system.

CONCLUSION

"Model of the electrical system" is intended for conducting laboratory and practical work on the courses: "Transient processes in the electric power industry", "Relay protection and automation", "Automatic design in the electric power industry", "Electrical networks and systems".

The stand allows to qualitatively simulate the established operating modes of electric power systems, electromagnetic and electromechanical transient processes with various kinds of short circuits, to investigate the factors influencing the static and dynamic stability of the parallel operation of synchronous generators, to investigate relay protection and automation devices.

A personal computer is one of the components of a laboratory stand. With the help of specialized software included in the stand, it is used for oscillography, data visualization, as a multichannel oscilloscope and recorder, as well as for controlling and protecting electric power objects in real time.

Students of electrotechnical specialties have the opportunity to study the innovative equipment "Model of the electrical system" in the following areas:

- For what measurements is this stand used;
- Features of the "Electric system model";
- Learn the basic characteristics, power consumption, operating temperature range, rated line voltage;
- Determine the purpose of the "Electromagnetic Unit";
- Possibilities for performing various types of laboratory work;
- To study the role, purpose and on what disciplines it is necessary to use this stand;
- Make an opinion on each performed laboratory work.

The chapter shows the practical application of the electric system model in the discipline "Electrical networks and systems".

The studies are conducted in the following directions:

- Measurement of the parameters of the steady-state mode of the electrical network with one-sided power;
- Losses of electrical energy in distribution networks;
- Voltage regulation by transverse compensation of reactive power by means of a capacitor bank;
- Determination of the influence of voltage deviation on the power consumed by the active load;
- Determination of the influence of the voltage deviation on the power consumed by the inductive load;
- Determination of the influence of the voltage deviation on the power consumed by the capacitive load;

- Study of static characteristics of active, inductive and capacitive loads;
- Measurement of the quality of electrical energy.

The purpose of all the works is to learn the following questions from students:

- to study the factors influencing the values of the regime parameters of the transmission line (active and reactive powers, currents and voltages);
- to study the methods for calculating the steady-state operation of networks with one-sided power;
- Investigate the effect on the parameters of power transmission lines (length, nominal voltage) and load parameters in individual nodes on the values of the regime parameters in the ring network (voltage at the nodes, overflows of active and reactive power, losses);
- determine the factors that affect the amount of active and reactive power losses in the distribution network;
- to study the dependence of power losses on the magnitude of the load and its nature;
- study the effect of the rated voltage of the distribution network on the amount of active and reactive power losses;
- to study the effect of transverse capacitive compensation on the magnitude of the voltages in the nodes of the distribution network;
- to study the influence of the magnitude of the voltage on the power consumed by the active load;
- study the procedure for determining the effect of voltage deviation on the power consumed by the inductive load;
- to study the effect of the voltage value on the power consumed by the capacitive load;
- investigate the dependence of active and reactive power on the voltage and frequency of the supply network for active linear and nonlinear loads, as well as inductive loads;
- study methods for measuring the quality of electrical energy; - carry out measurements of the main indicators of the quality of electrical energy, compare the results with the requirements of the state standard for the quality of electrical energy.

The chapter shows the practical application of the electric system model in the discipline "Transient processes used in the electric power industry".

The research is carried out in the following areas:

- Analysis of transients in three-phase short-circuit in an electrical network, powered by a source of infinite power;
- Analysis of transient processes with asymmetric short-circuits in an electrical network powered by a source of infinite power;

- Analysis of transients in single-phase short circuits in networks with isolated and deaf earthed neutral;
- Investigation of synchronization process of a natural synchronous generator with a network and regulation of its active and reactive powers;
- Determination of the angular characteristic of a synchronous generator;

The purpose of all the works is:

- to learn to analyze transients in electrical networks;
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- to study the process of synchronization of the full-scale synchronous generator with the network;
- to investigate the effect of the parameters of elements, schemes and regimes on the stability of the system;
- carry out an analysis of the effect on the dynamic stability of a natural synchronous generator of the duration of a short circuit in an electrical system.

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