

# Development and simulation of the Institute of ionosphere measuring complex energy consumption

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**Abstract** – The work is devoted to solving an urgent problem - the development of a computer model of the energy consumption system of the Institute of the ionosphere of the National Academy of Sciences and the Ministry of Education and Science of Ukraine in order to solve the problem of increasing the energy efficiency of the measuring complex. The power supply system of the complex is described, a generalized structural diagram of the loads - powerful consumers of electricity is presented. The graphs characterizing the energy consumption of individual powerful loads are presented, the problem of compensating the reactive power of loads is shown. The adequacy of the developed model is confirmed by the coincidence of the shape and values of the experimentally obtained characteristics on loads with the characteristics of the model. The model adequacy was assessed by the variance of feedback deviations from the system mean. The results obtained confirmed the possibility of using the developed Matlab-model of the energy consumption system of the measuring complex for creating and testing on the model of an energy-efficient power supply system, which will ensure the stable operation of scientific equipment for the implementation of research programs of the NAS of Ukraine.

**Keywords** – power supply system, power consumption, energy efficiency, average power consumption.

## I. PROBLEM STATEMENT

The Institute of ionosphere is one of the world's largest research institutes that studies the ionized part of the atmosphere [1]. The research part of the institute consists of transmitter channels, distribution network, three pavilions, the main load of which consists of: distillers, heating boiler, STS stabilizer, pumps of distiller and raw water circuits, converters, antenna, receiver.

Ionosphere studies are conducted at intervals of two to four studies per month. One test takes five days in a row. In summer, the consumption for one test is about 16060 kW, and in winter about 18720 kW. Due to the high cost of 1 kW of electricity, the annual research costs the institute a considerable amount.

In today's world, in order to save electricity, there is a tendency to abandon the use of electricity in favor of alternative sources such as sun, wind, water. Due to their geographical location and temperate continental climate, Ukraine and Kharkiv have a total annual level of solar radiation at the level of 1200 kWh / m<sup>2</sup>.

The Institute of Ionosphere territorially has free space that can be used to accommodate solar panels and wind turbines, with their subsequent integration into a smart SmartGrid power system. The use of solar panels, as well as batteries with a large number of charge / discharge cycles with the ability to return energy to the industrial network can increase the energy efficiency of the system [2–4].

## II. PURPOSE AND OBJECTIVES OF THE RESEARCH

The purpose of the work is the development of a computer model of the Institute of ionosphere energy consumption system of the National Academy of Sciences and the Ministry of Education and Science of Ukraine in order to solve the problem of increasing the energy efficiency of the measuring complex.

## III. PRESENTATION OF THE BASIC MATERIAL

The model of the Ionosphere Research Institute consists of three pavilions, a cooling circuit, and a transmitter. Pavilion 1 contains an ionosonde, a heating system, computers, workplaces and air conditioners. Pavilion 2 – heating system, receiver, full swing antenna motors, air conditioning unit. In pavilion 3 there are distillers, a stabilizer, household appliances, a heating system, pumps for distiller circuits. The cooling circuit consists of raw water pumps, cooling water fans. The transmitter includes 5 channels, each of which has a power of 50 kW. During the tests, only 2 channels out of 5 are switched on simultaneously. A 1MW transformer with a voltage of 10 / 0.4 kV is used at the entrance to the system. In parallel, a 560 kW transformer with a voltage of 10 / 0.4 kV is connected to it, which is used as a safety net if the main transformer is faulty. Each channel of the transmitter uses

its own separate transformer with a power of 250 kW and a voltage of 10 / 1.2 kV on the windings.

The electrical indicators of the devices are given in table 1.

The structural scheme of connection of energy consumers of the Institute is shown in the Fig. 1.

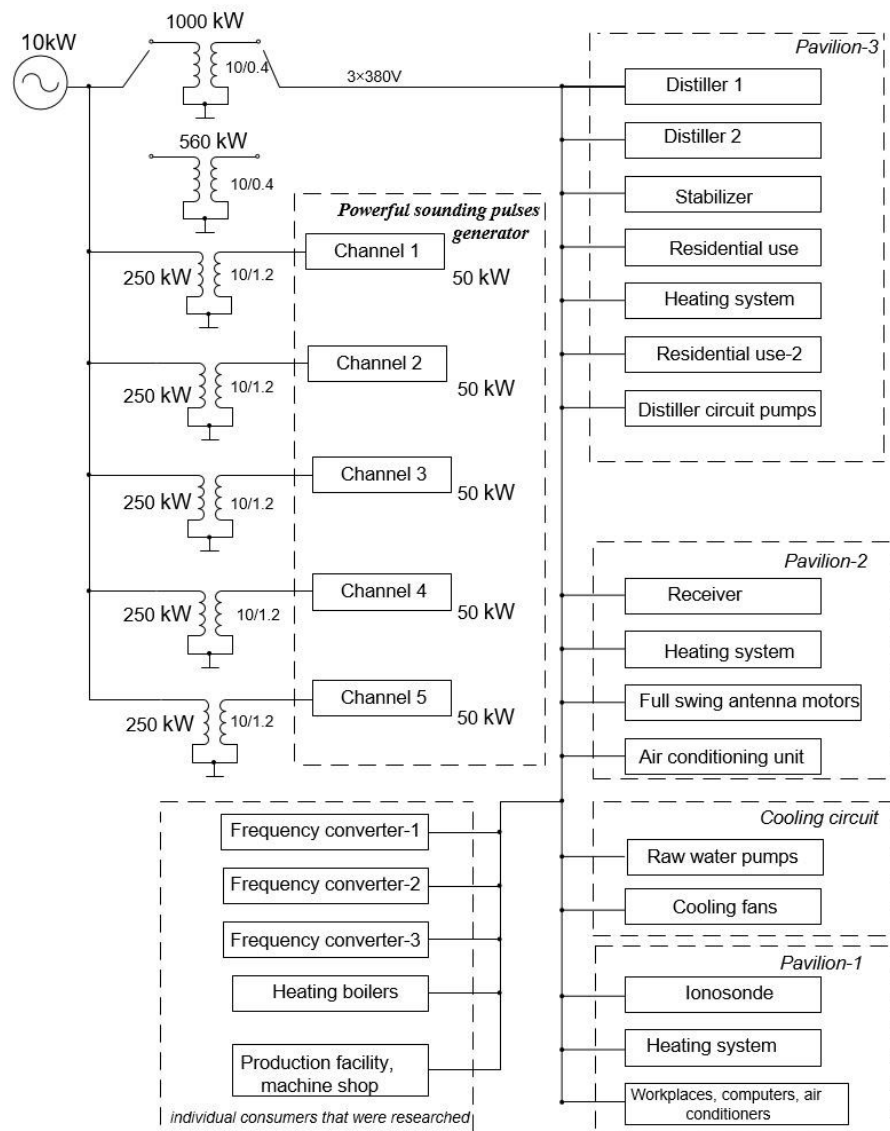


Fig. 1. The structural scheme of connection of energy consumers of the Institute of ionosphere

The meter-range radar radio transmitter (shaper) generates, amplifies and transmits powerful probing pulses and is built on a two-channel circuit, each channel of which is a pulse transmitter that generates high-frequency probing pulses at a frequency of 158 MHz. The main parameters of the shaper (Channels 1 - 5):

- pulse power at the output  $P_i > 2$  MW,
- the length of the emitted pulses  $T_i = 800$   $\mu$ s,
- pulse repetition frequency  $F_i = 24.4$  Hz.

The modulation device is designed to power the transmitter device and provides pulsed anode voltage to the following channels and blocks of the transmitter device: III stage, II stage, I stage, preamplifier and oscillator frequency generator. The modulation device provides a

pulse power of 4.26 MW at a voltage of 29 kV at an equivalent load of 200 ohms. When working on the generator, the modulation device provides the following maximum voltage values:

- III cascade - 29 kV;
- II cascade - 23 kV;
- I cascade - 7.5 kV;

Based on the structural diagram and initial data, a model has been developed, which consists of a supply unit, pavilion 3, a transmitter, a cooling circuit, converters, pavilion 2, pavilion 1 (Fig. 2).

TABLE I. INFORMATION ON MODELED COMPONENTS

Component name	Power, kW	Phase shift angle
<b>Pavilion 1</b>		
Ionosonde	0.3	10
Heating system	6	0
Workplaces, computers, air conditioners	0.5	10
<b>Pavilion 2</b>		
Heating system	6	0
Receiver	5	20/0/10
Full swing antenna motors	20	30
Air conditioning unit	10	0
<b>Pavilion 3</b>		
Distiller 1	55	0
Distiller 2	55	0
Stabilizer CTC 63/0.5	63	55.5/30/30
Appliances for residential use 1	4.2	40
Heating system	60	0
Appliances for residential use 2	3.8	20
Distiller circuit pumps	10.5	0
<b>Cooling circuit</b>		
Raw water pumps	23	20
Cooling fans	9	54
<b>Converters</b>		
Converter 1	30	60
Converter 2	30	60
Converter 3	50	60
Heating system 1	6	0
Heating system 2	6	0
<b>Transmitters</b>		
Channel 1	50	53
Channel 2	50	53
Channel 3	50	53
Channel 4	50	53
Channel 5	50	53

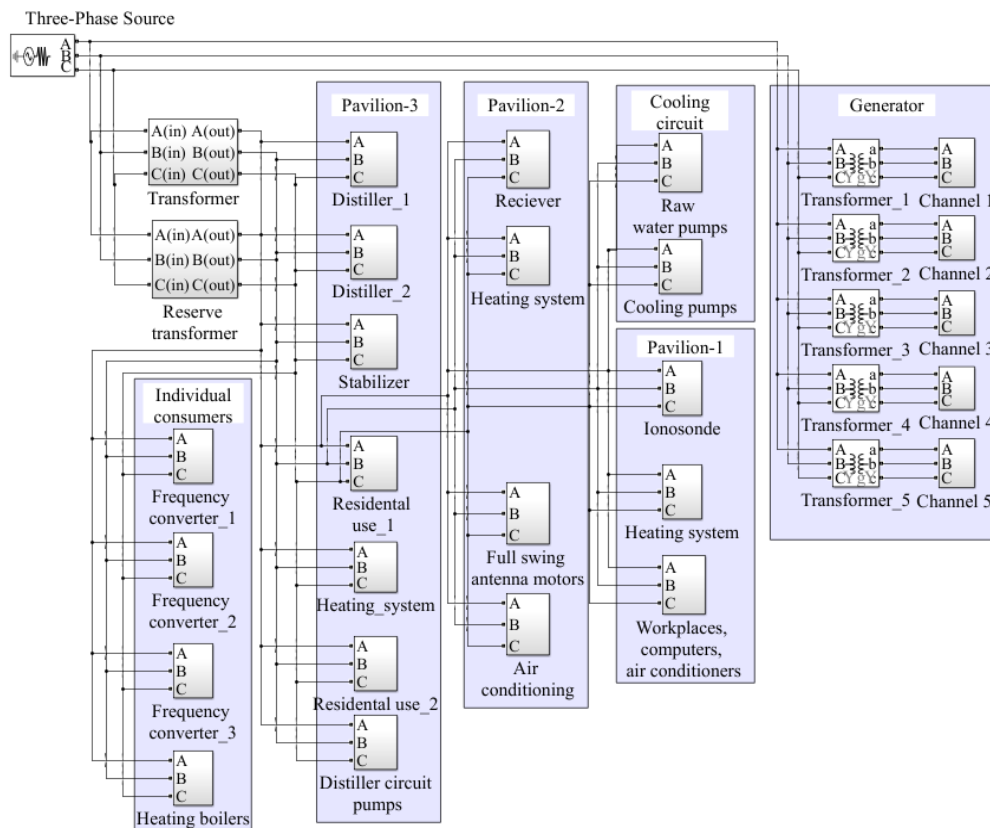


Fig. 2. The Matlab-model of connection of energy consumers of the Institute of ionosphere

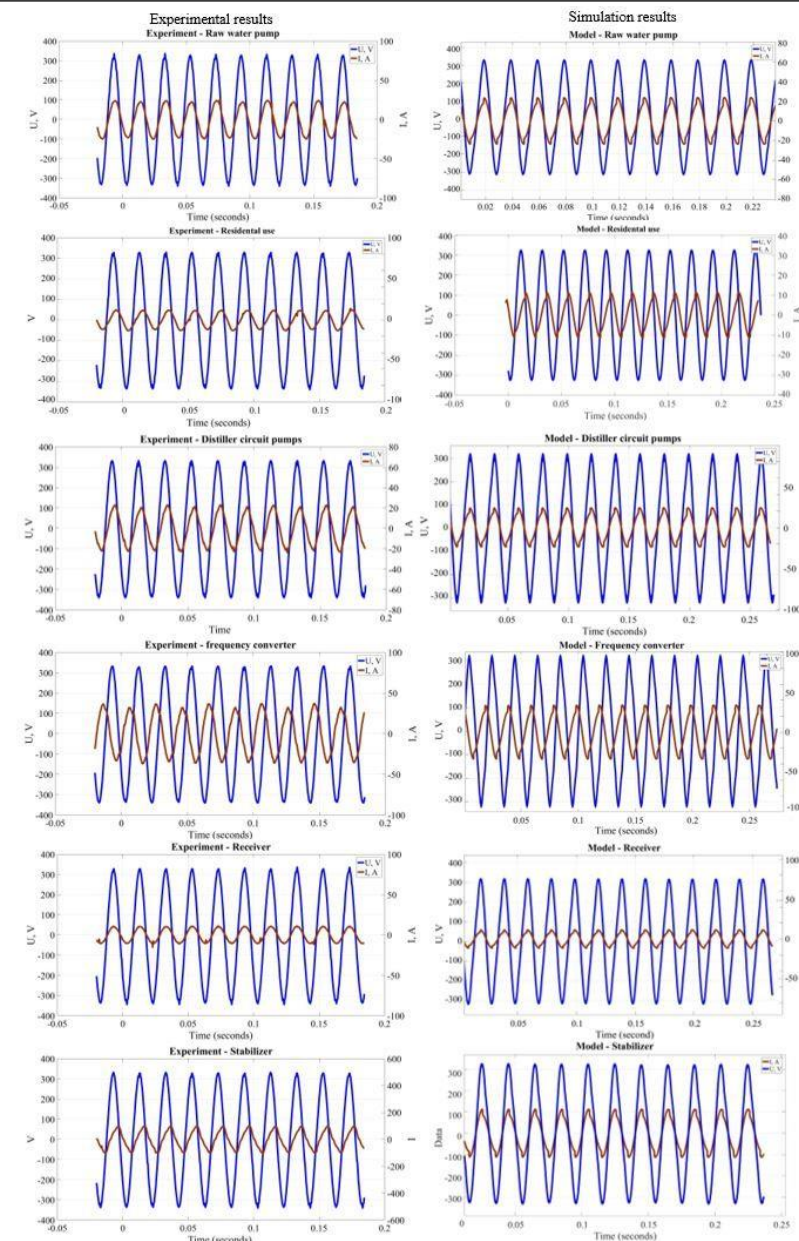


Fig. 3. Experiment and simulation results

Experimental data were taken at the connection points of each consumer. The oscillograms of currents and voltages of some consumers are shown in Fig. 3. The data of the graphs given on the oscillograms allow to estimate the adequacy of the developed Matlab-model of the power supply system of the measuring complex. The procedure for assessing the adequacy of the developed model is based on the comparison of measurements on a real system of experimental results on the model, which is carried out on the average values of the responses of the model and the system. The given data testify to a considerable share of reactive power in the mode of inclusion of the radio equipment. Irregular energy consumption, the presence of a significant share of the reactive component of energy consumption make such facilities commercially unattractive to energy companies, in modern conditions can lead to either significant fines or even shutdown.

The next step is to propose a methodology to increase the commercial attractiveness of research facilities such as the Institute of ionosphere, which aims to reduce the difference in energy consumption during the experiment and a simple and significant reduction in the reactive component. The proposed technique will be based on the construction of a mathematical model of the energy complex of the radio range and the study of its dynamic, frequency and energy properties. The methodology provides for such steps as the division of all consumers in the facility into permanent (conditional), and those that operate in pulse mode. For the latter group of consumers, it is proposed to use rechargeable batteries as a damper, which is an active load for the energy supplier, connected at night, and for the equipment - a provider of continuous action during the experiment. In works [5 - 8], devoted to the decision of problems of improvement of electric power quality of a power supply network, the basic principles and approaches to the decision of a problem of quality of the electric power of a power supply network are formulated.

At the same time, the analysis of scientific works shows that a number of problematic issues need further study, there is a need to improve existing scientific and methodological approaches to determining the effectiveness of the operation of various types of measures that apply to a particular object.

#### IV. CONCLUSIONS

After obtaining experimental data and analyzing the energy consumption of the measuring complex of the Institute of ionosphere of the National Academy of Sciences and the Ministry of Education and Science of Ukraine, a model of the energy consumption system of the complex was developed. The obtained modeling results indicate the adequacy of the developed model and the possibility of using the model in the development of methods to improve the efficiency of operation of the whole complex. According to the results of the analysis of the nature of the loads, it is determined that the loads include a reactive component, which can be eliminated through the use of filter-compensating devices.

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## Розробка та моделювання системи енергоспоживання вимірювального комплексу Інститута іоносфери

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Роботу присвячено вирішенню нагальної проблеми - розробці комп'ютерної моделі системи енергоспоживання Інституту іоносфери НАН та МОН України з метою вирішення проблеми підвищення енергоефективності вимірювального комплексу. Описано систему електропостачання комплексу, представлено узагальнену структурну схему навантажень - потужних споживачів електроенергії, описано характер навантаження з точки зору якості електроенергії. Визначено, що найбільш потужний споживач електроенергії вимірювального комплексу - формувач потужних зондуючих імпульсів, який здійснює генерацію, посилення і передачу потужних зондуючих імпульсів і будується за дво- або чотириканальною схемою, кожен канал якої є імпульсний передавач, що генерує високочастотні зондуючі імпульси. Експериментальні дані, представлені у роботі, показали, що режим електроспоживання Інституту іоносфери характеризується значною сквапністю. Представлено графіки, що характеризують споживання енергії окремими потужними навантаженнями, показано проблему компенсації реактивної потужності навантажень. Адекватність розробленої моделі підтверджується збігом форми та значень експериментально отриманих характеристик на навантаженнях з характеристиками моделі. Адекватність моделі оцінювалась за середнім значенням відгуків моделі і системи. Отримані результати підтвердили можливість використання розробленої Matlab-моделі системи енергоспоживання вимірювального комплексу для створення та випробування на моделі енергоефективної системи електропостачання, що забезпечить стабільну роботу наукового обладнання для впровадження дослідницьких програм НАН України. Зроблено висновки щодо можливості підвищення якості електроенергії живлення потужного споживача за допомогою фільтрокомпенсуючих пристроїв, що дозволяє зменшити втрати енергії та поліпшити електромагнітну сумісність вимірювального комплексу Інститута іоносфери з мережею живлення. Проаналізовано літературу щодо створення та застосування багатофункціональних енергоефективних компенсаторів неактивних складових повної потужності, що дозволяють успішно вирішувати задачу компенсації реактивної потужності, що генерується або споживається навантаженням, фільтрації вищих гармонік струму.

**Ключові слова** – система електропостачання, енергоспоживання, енергоефективність, реактивна потужність.