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Potential of Energy Saving as a Tool for Increasing the Stability of Electrical Supply of the Kaliningrad Region

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ABSTRACT

The Kaliningrad region remains to be energetically dependent on neighboring states, since the reliability and continuity of its power supply depends on transit flows of capacity and energy, as well as international relations with transit countries. In this regard, the sustainability of electricity supply is becoming a priority task for ensuring the livelihood of the Kaliningrad region. The basis for the sustainability of electricity supply for the region is the planum implementation of a set of technical and technological measures for optimal control of power consumption. One of the key procedures for optimal control of power consumption is the potentization procedure. It consists in determining the energy-saving potential, the amount of which can be reduced in the given time interval by the energy consumption of the region without affecting its normal functioning. Energy Saving Potential is the absolute difference between the energy consumption of a region's objects obtained without the implementation of energy-saving procedures, on the one hand, and the power consumption corresponding to the lower boundary of the variable confidence interval, on the other. The purpose of the article is to substantiate the need to implement a scientifically based approach to determine the energy saving potential of the Kaliningrad region to ensure the sustainability of the region's electricity supply. This approach will allow to reduce the power consumption and to cut costs on the necessary time interval without affecting the normal functioning of the region.

Keywords: Stability of Electrical Supply, Energy Saving, Optimal Power Management, Power System
JEL Classifications: O25, Q43, Q48

1. INTRODUCTION

The energy intensity of Russian products is three to four times higher than in the developed European countries and the United States, and seven times higher than in Japan. In the last 10-15 years, this indicator continues to deteriorate from year to year. It seems that the situation will not change if the development of the Russian energy sector does not follow the path previously accomplished by the US, Germany, Japan and other countries since the beginning of the energy crisis of the 70s of the XX century when research on the electrical supply of large electro-technical complexes was put into practice (Federal Service of State Statistics, 2017; Kolesnikov and Tolstoguzov, 2016; Merkulov et al., 2012). The stability of the region's electricity supply is understood as the state of the region that determines its ability to reliably supply the economy's needs with electricity of acceptable quality and affordable price in full volume, the ability at any time to counteract the negative impact of constantly evolving internal and external threats, and the ability of the system to self-development and improvement. Realization of scientifically grounded methods of research on stability of electric supply of large electro-technical and electric power complexes and systems is impossible without calculating the energy saving potential, the increased attention to which is typical for the last decade around the world.

The introduction of modern energy-saving technologies and distributed energy plays a crucial role for the sustainability of electricity supply to the regions, and is equivalent to the production of energy resources, and often it is a more cost-effective and environmentally responsible way to meet the growing demand for energy. Denmark is a particular example of the leaders in the implementation of energy-saving technologies. Since the middle of the last century, a great amount of work has been carried out to introduce energy efficiency in the housing sector and in industry.

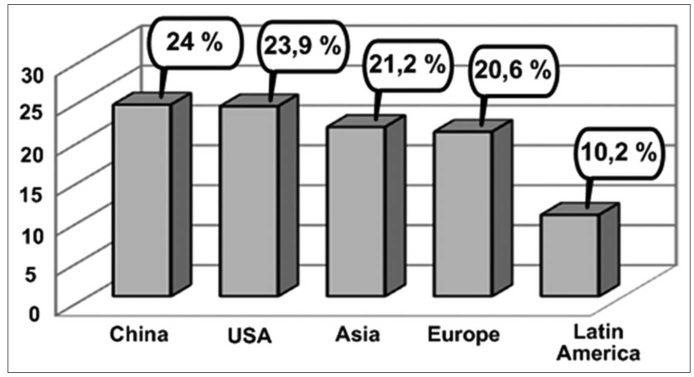
Denmark's first energy plan was published in 1976. The main ideas of this plan were to strengthen the guarantee of energy saving by creating a very flexible and diverse energy system, in stimulating energy efficiency and in organizing scientific and technological development on the basis of state support (Gnatyuk et al., 2007).

The purpose of the article is to substantiate the need to implement a scientifically based approach to determine the energy saving potential of the Kaliningrad region in order to ensure the sustainability of the region's electricity supply. The procedure for determining the energy saving potential implies modeling the absolute difference between the power consumption of the Kaliningrad region without implementing energy saving procedures and the power consumption corresponding to the lower boundary of the variable confidence interval for a given time interval. The power consumption of the Kaliningrad region is calculated as an integral between zero and infinity under the curve of the rank parametric distribution (or under the boundary of the interval). The energy saving potential possesses structural properties. Thus, there is a certain potential level, the boundaries of which is stable over time and is determined by the probabilistic patterns of the system. The given approach enables to reduce power consumption and reduce costs at the required time interval without affecting the normal functioning of the region.

2. TRENDS IN THE DEVELOPMENT OF THE ELECTRIC POWER INDUSTRY IN RUSSIA AND THE KALININGRAD REGION

The analysis of the global trends in the development of the electric power industry demonstrates that in the coming years it will face such challenges as the moral obsolescence of the infrastructure and the need to integrate distributed energy facilities while preserving the reliability of energy supply, as well as simplifying the processes of technological connection to power networks (Enrgominimum, 2016; Gaines and Kohout, 1977; Palmowski, 2013; Rosseti, 2016; Yantarenergo, 2017). It is projected that by 2025 a gradual transition to a new type of grid organization – the Smart Grid, will take place throughout the world. Undoubtedly, this type of organization is a global trend in the development of innovation technologies in the field of electricity distribution networks (Rosseti, 2016). According to the "GTM RESEARCH" company, the total capacity of the global Smart Grid market will reach 400 billion US dollars by 2020 with an average of "CAGR 4" at 8.4% level (Figure 1).

Figure 1: The forecast of the global "Smart Grid" market by 2020



Source: Rosseti (2016)

With that, the largest market remains to be China (24%), followed by the USA (23.9%), the countries of the Asia-Pacific region (21.2%) and Europe (20.6%). The markets of Latin America are projected at the level of 10.2% (Rosseti, 2016). Analysis of the development priorities for the technologies in the energy sector of Russia, reflected in government policy documents, road maps of national technology platforms, and strategic documents of development institutions confirm that the development of transmission and distribution of electricity will be carried out through technologies and means of remote monitoring, accompanied by the development of control systems, automation and security, the introduction of new materials (superconducting materials, composite materials) and increasing the efficiency of energy transmission and wide use of electric power storage devices (Rosseti, 2016). Among the existing priority innovation technologies in Russia are: Intelligent systems on electricity metering and improving the quality of customer service; advanced technologies for distributed generation and its integration; digital substations and reactive power compensation technologies; electric vehicles and network power storage systems.

In accordance with the instructions of the President of the Russian Federation following the meeting of the Commission under the President of the Russian Federation for Modernization and Technological Development of the Russian Economy of January 31, 2011, the Government of the Russian Federation of November 07, 2015, the road map of the Energy NET association, as well as other governing documents the Program of innovative development of Russia's largest energy company Rosseti was approved for 2016-2020 with a perspective up to 2025 (Kivchun et al., 2016; Rosseti, 2016). A comprehensive analysis of this program shows that the main directions of innovative development of Rosset, its subsidiaries and dependent companies in terms of technological innovation are generally in line with the trends of global industrial innovation development and are oriented towards solving intersecting tasks in the field of electricity transmission. However, an increased emphasis has to paid for the development of new technologies given the specifics of some regions, especially in terms of their geographical location. One of such regions is the Kaliningrad region (Gaines and Kohout, 1977).

The innovative development program of Rosseti includes the creation of automation system for 15 kV distribution networks of Yantarenergo company (Rosseti, 2016). The framework of this project implies the implementation of the basic subsystems of Smart Grid, including the distributed automation of emergency modes and automation of substations; the intelligent electricity metering system; the integrated DMS/OMS management system that assists the decision making on the distribution network of 15 kV undertaken by the Yantarenergo company.

3. SUSTAINABILITY OF ELECTRICITY SUPPLY IN THE KALININGRAD REGION

Despite the relatively low pace of introduction of new innovative technologies for the sustainability of electricity supply in the Kaliningrad region, the very content of the energy strategy requires a radical revision (Gnatyuk, 2010; Kivchun et al., 2016). First of all, it is necessary to single out the object of this strategy, which can be understood as the power system of the Kaliningrad region that is part of the single North-Western unified energy system. The power link of the region with the integrated power system of Russia is carried out through the electrical networks of the energy systems of Estonia, Latvia, Lithuania and the Republic of Belarus (Kretinin et al., 2016). The closest energy system on which the Kaliningrad region depends is the Lithuanian energy system. Electricity flows from the territory of Lithuania to the power plants of the region pass through three air lines (i.e., overhead lines) of 330 kV, three overhead lines of 110 kV, and two overhead lines of 10 kV (Beley, 2009; Beley, 2010; Governor of the Kaliningrad Region, 2016).

Dispatch management of the operation of the Kaliningrad energy system is carried out by the Baltic Regional Dispatch Office (RDO) - the unified energy system subsidiary. The superordinate dispatching center in relation to the Baltic RDO is the North-Western branch. The "LITGRID AB" dispatch center of Lithuania is the adjacent dispatch center for the Baltic RDO. According to the current list of dispatching facilities, the power transmission lines and equipment of substations with voltage of 60–110–330 kV are located in the operational dispatch and operational-technological management of Baltic RDO (Governor of the Kaliningrad Region, 2016).

Electricity production in the Kaliningrad region is carried out at the power plants of "Inter RAO-Electrogeneratsiya," "Kaliningradskaya generiruyushchaya kompaniya," as well as at power plants of industrial enterprises. In case of a shortage of their capacity the electricity supply is carried out from the unified energy system of Russia through the electrical grids of the energy systems of the Baltic States, which are members of the European Union, primarily Lithuania, as well as the Republic of Belarus. The total installed capacity of power plants of the power system of the Kaliningrad region as of February 2016 is 951.293 MW. The maximum power consumption of the power system of the Kaliningrad region in 2015 was 741 MW (Governor of the Kaliningrad Region, 2016).

Back in the late 1980s it became apparent that the regional energy system, being 90% energy deficit, is in an extremely unsatisfactory condition in terms of capacity balance. Over the past few years, the regional and national authorities, as well as the UES management have been searching for ways to resolve the region's energy problem. A large number of options were considered, but now everything has come down to the work of Kaliningrad's second thermoelectric plant (Gnatyuk, 2010). At present, construction of gas thermal power plants has begun. The capacity of the future Pregol TPP in Kaliningrad will be 440 MW, Mayakovskaya TPP in Gusev and Talakhovskaya TPP in Sovietsk – 156 MW each. Their launch is planned in 2018. The construction of a 195 MW seaside Primorskaya TPP will begin later, and the launch of the station is scheduled for 2019. Whether these measures will be enough to ensure uninterrupted power supply in isolated mode remains to be questionable (Gnatyuk, 2010).

For the period of 20130–2015 the electricity consumption in the Kaliningrad region increased by an average of 5.19%. The average annual growth rate for the period under review was 1.38%, while in 2014 there was a slowdown in the growth rate of electricity consumption, and in 2015 there was a decrease in electricity consumption by 0.9% (Governor of the Kaliningrad Region, 2016). The regional maximum power consumption in the power system of the Kaliningrad region in 2015 amounted to 741 MW, demonstrating a decrease of 102 MW or 12% compared with 2014. At the same time, the number of hours of using regional maximum values in 2015 reached its maximum value for the entire period under review and amounted to 5901 h (Beley, 2009; Governor of the Kaliningrad Region, 2016).

As announced, the commissioning of new stations and the operation of Kaliningrad thermoelectric plant-2 will ensure the sustainability of electricity supply in the Kaliningrad region, which has no direct links to the Russian energy system and incurs losses due to the desire of the Baltic countries to raise tariffs for energy resources to the European level (Beley, 2009; Gnatyuk et al., 2007; Gnatyuk et al., 2009; Gnatyuk, 2010; Kudrin, 2015; Zaymenko and Gnatyuk, 2010). It should be noted that thermoelectric plant-2 is one of the few compact heat and power plants in Russia with a combined-cycle plant that uses such a valuable fossil as natural gas. The station complies with environmental requirements, has a modern monitoring and control system, consists of two power units with a total electric capacity of 900 MW, and a thermal capacity of 680 Gcal/h. However, despite the fact that Kaliningrad thermoelectric plant-2 and new power plants formally close the deficit of electricity generated in the region, the issue of sustainability of the region's electricity supply remains topical due to a number of reasons (Beley, 2009; Gnatyuk et al., 2007; Gnatyuk et al., 2009; Gnatyuk, 2010), which are: An excess of generating capacity; lack of a reserve generating complex in the region; the need to modernize the transport and grid complex; high probability of interruptions with gas supplies from mainland Russia; low energy efficiency of industry, housing and communal services of the Kaliningrad region; clearly insufficient use of renewable clean energy sources; low innovation and scientifically sound level of energy system's management of the Kaliningrad region; significant difficulties in connecting new consumers in the region; high energy losses (especially in the sphere of housing and communal services); low level of automation of metering of electricity. Given the problems identified, it has been established that one of the approaches for eliminating some of them is the implementation of scientifically based methods of calculating the energy saving potential.

4. POTENTIATION - A PROCEDURE FOR MANAGING THE ENERGY SAVING POTENTIAL OF THE KALININGRAD REGION

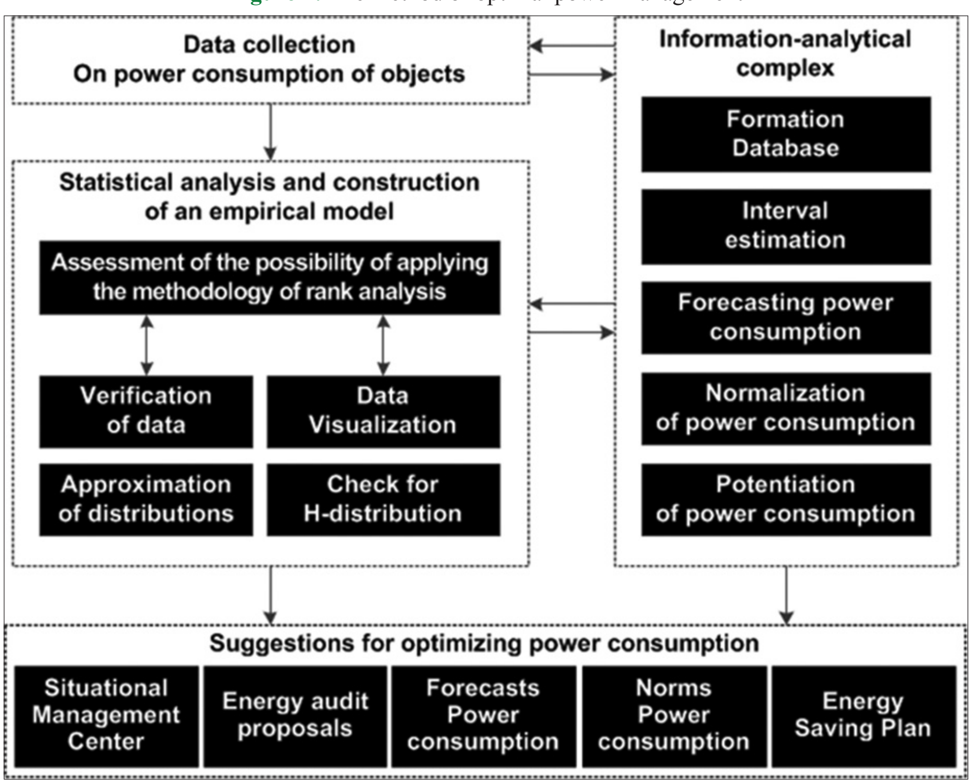
A number of scholarly researches have shown that for the effective development of the regional energy system managers at all levels need to implement scientifically based approaches to managing the energy saving potential (Gnatyuk et al., 2007; Gnatyuk et al., 2009; Gnatyuk, 2010; Kudrin, 2015; Naumov, 2000). One of such approaches is the implementation of the method of optimal control of power consumption. As studied by (Gnatyuk et al., 2017; Kosharnaya, 2016; Kudrin, 2015; Lutsenko et al., 2015; Vasilev et al., 2012), the main procedures of this method are the following: The formation of a database, interval estimation, forecasting and rationing. It is proposed to supplement them with one more key procedure – potentiation (Kudrin, 2016; Lutsenko et al., 2014) (Figure 2).

Potentiation is generally considered as the procedure for optimal resources management of the region, which consists in determining the integral amount of the resource by the amount of which the resource consumption should be reduced for the given period without affecting the systems' normal functioning (Kudrin, 2015; Lutsenko et al., 2015; Vasilev et al., 2012). Obviously, with regard to electricity, the potentiation procedure is reduced to the definition and subsequent use in the process of managing the energy saving potential. Thus, the methodology of optimal power consumption management implies potentiation as the procedure of determining the energy saving potential, by the amount of which the electric power consumption of the region should be reduced without affecting the normal functioning of the consumers in the given time interval (Kudrin, 2015; Lutsenko et al., 2015; Vasilev et al., 2012). Let us define the concept of energy saving potential for it being the key element in the potentiation procedure. The energy saving potential (or system potential of energy saving) is the absolute difference between the power consumption of a technocenosis (in kWh) without the implementation of energy saving procedures calculated a period of time, on the one hand, and the power consumption corresponding to the lower boundary of the variable confidence interval, on the other (Figure 3). The power consumption of a technocenosis is calculated as an integral from zero to infinity under the corresponding curve of the rank parametric distribution.

The calculation unit taken is either the curve obtained for the empirical values of the power consumption, or the lower boundary of the variable confidence interval. The estimated time interval is determined, on the one hand, by the depth of the database on electricity consumption in the past, on which the variable confidence interval is based, and on the other hand by the required horizon for modeling the potential in the future (Kosharnaya, 2015; Kudrin, 2015; Lutsenko et al., 2015). It should be noted that the proposed approach is fundamentally different from the traditional approach, when the potential for energy saving is understood as the sum of the differences for each electrical installation between the actual power consumption and a certain hypothetical value of the power consumption of this installation, which could occur if some best indicators of energy efficiency would be achieved.

At the same time, nowhere in the available literature do we disclose the following important points: Firstly, on what basis is the conclusion made that the potential for energy saving in the technocenosis has the additive properties, i.e., can be calculated as the sum of the potentials of energy saving of individual electric receivers; secondly, what are the 'best energy efficiency indicators' and how to interpret them; thirdly, how to account and evaluate the degree of availability of the best energy efficiency indicators

Figure 2: The method of optimal power management

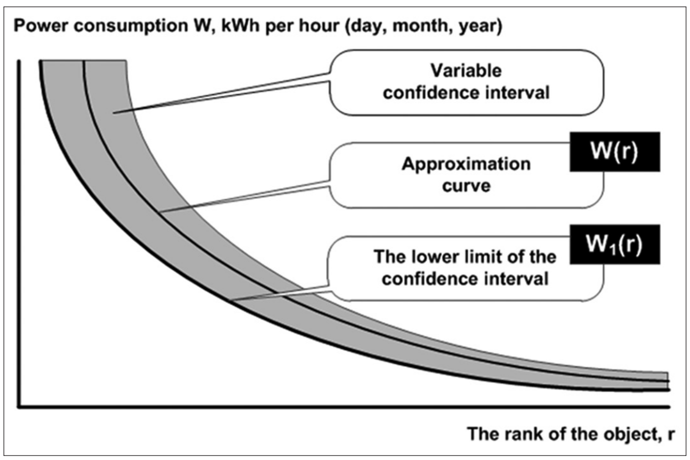


Source: Gnatyuk (2017)

for a particular equipment of a particular technocenosis taken into account?; fourthly, where the lower limit of power consumption, below which it is simply impossible to drop in technocenosis without disrupting the normal technological process; fifthly, how can the energy saving potential calculated by summing up the indices of individual electric receivers can be used in the everyday process of power consumption management; sixthly, how can one define the reliable single-stage determination of the power consumption of hundreds of thousands (or even millions) of individual electric receivers (from a mobile phone charger or a kettle to a converter or a blast furnace) with a certain degree of certainty, which, moreover, by ninety-nine percent do not have a system of individual metering of power consumption.

A quantitative assessment of the assessment results on the potential was carried out in the software and hardware complex for power consumption management in the Kaliningrad region for 110 kV substations of "Yantarenergo" using (Kosharnaya, 2015; Merkulov et al., 2012; Vasilev et al., 2012) data (Figure 4).

Figure 3: The concept of the system potential of energy saving in the region



Source: Gnatyuk (2017)

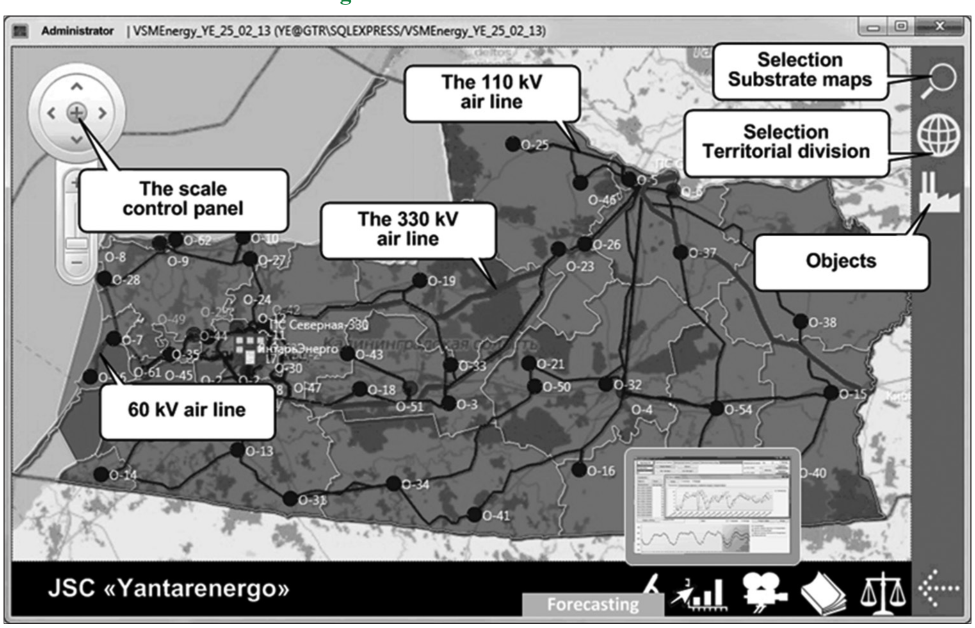
Information on the balance of electricity substations for each month from 2013 to 2016 was an initial data input. Using the data on the electricity balance at the substations of Yantarenergo, the boundaries of the variable confidence interval were calculated and the energy saving potential in 2016 was determined (Van Greet et al., 1995) (Figure 5).

The energy saving potential value was determined about 21% of the annual value of productive supply to the power grid. According to the data provided by "Rosseti" in 2016, the productive supply of "Yantarenergo" to the power grid amounted to 3389 million kWh per year (Efficiency of Russian economy; Yantarenergo). An average single-rate tariff for electricity in 2016 for the population was 3 rubles 72 kopecks (Enrgominimum, 2016). Taking into account the estimated value of the energy saving potential, approximate energy and monetary savings were calculated, which amounted to about 712 million kWh per year and 2649 million rubles per year respectively.

5. CONCLUSION

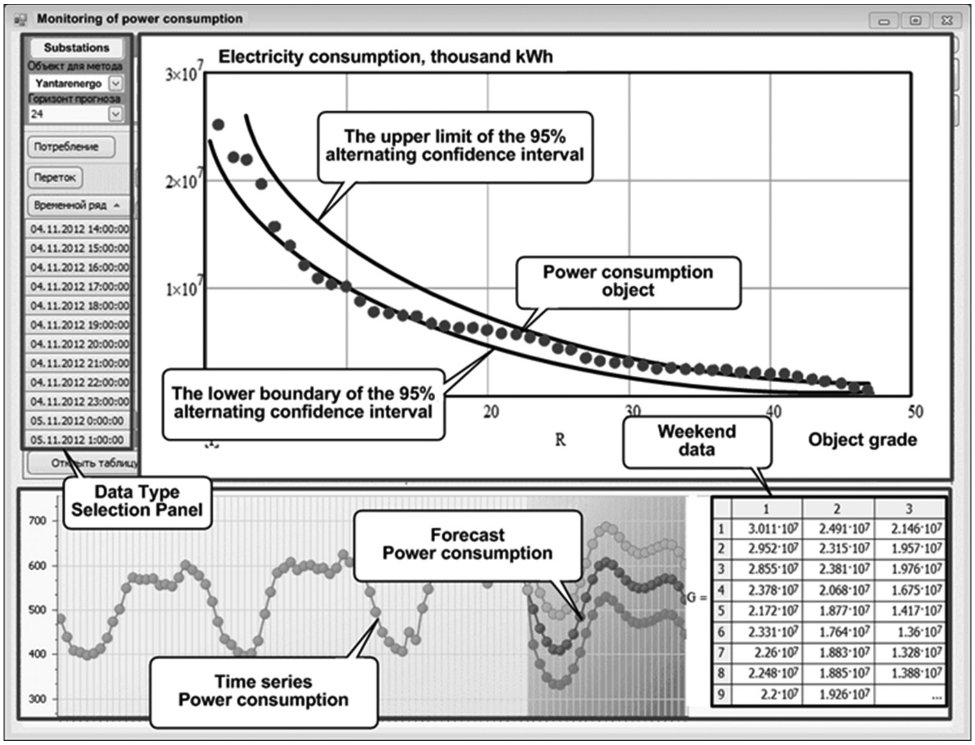
The obtained results on energy saving potential can significantly affect the sustainability of the electric power supply of the Kaliningrad region and will enable to:
- Increase the energy efficiency of the industry, as well as the housing and communal services of the Kaliningrad region;
- Create prerequisites for an increase in the innovative and scientifically sound level of management of the energy system of the Kaliningrad region;
- Reduce energy losses in the communal services sector;
- Increase the level of automation of the metering of electricity by introducing professional software for power consumption management in the Kaliningrad region.

Figure 4: The main software menu



Source: Merkulov et al. (2012)

Figure 5: Desktop for calculating energy saving potential



Source: Merkulov et al. (2012)

In addition, the scientifically based approach to calculating the energy saving potential presented in the article will make it possible to raise the basic socio-economic indicators of the region by:

- Creating an energy saving fund and subsequent tariff regulation (e.g., see Vakulo et al., 2003);
- Budgetary savings when adjusting the program for commissioning new capacities;
- Improving technical and economic indicators of the industry and communal services' sectors in the region, followed by attracting additional funds from the Federal budget and investments in the regional economy.

In accordance with the provisions of the UN Framework Convention of December 12, 2015 "on climate change regulating measures to reduce carbon dioxide in the atmosphere from 2020" (Federal Service of State Statistics, 2013; Karn et al., 2009), the results of the calculated potential may significantly affect the index of the physical volume of environmental expenditures in the Kaliningrad Region (Federal Service of State Statistics, 2013). Based on the methodological recommendations for calculating the index of the physical volume of environmental expenditures approved by order of the Federal State Statistics Service of October 21, 2013, the approximate savings would amount to 712 million kWh and 2649 million rubles a year due to implementation of the potential of energy saving. The index of physical volume of environmental expenditures can be improved by about 5.6%.

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