The introduction of intelligent electrical networks in Russia

I P Mikhnev¹, N A Salnikova¹*, N Y Orudjev², E L Shestopalova²

¹Volgograd Institute of Management - branch of the Russian Presidential Academy of National Economy and Public Administration, 8, Gagarin Street, Volgograd, 400066, Russia
²Volgograd State Medical University, 1, Pavshikh Bortsov Square, Volgograd, 400131, Russia

E-mail: ns3112@mail.ru

Abstract. The article analyzes the development of modern energy. From the analysis should be the most promising area of development is the modernization of energy by reducing losses in power systems. Technically, this problem can be solved with the help of intelligent networks (Smart Grid). An example of the creation of intelligent electrical networks in the Russian Federation.

1. Introduction

Most energy transmission and distribution companies (as well as water supply, gas transmission and gas distribution companies) are facing serious problems today.

These include the aging network infrastructure, the investment risk, increasing peak loads, the massive proliferation of the new technologies for generating electricity (distributed generation, alternative energy sources), the need for priority asset replacement, the need to modernize the network under pressure from regulators, the need to improve the service quality for the customers, the need to maintain a constantly high level of network reliability, the need to build an effective management system by company tags [1]. These problems can be solved by introducing smart grids (Smart Grid) into the power system in a number of Russian regions.

The smart grid is a new frame of reference for the role of technology in renewing energy infrastructure, in rethinking our responsibility as energy consumers and, ultimately, in saving the environment and vital energy resources.

Intelligent networks (IN) are a set of technical tools that automatically detect the weakest and most dangerous parts of the network, and then change the characteristics and the network circuitry in order to prevent accidents and reduce losses.

In addition, the intelligent network should have the functions of self-diagnosis and self-healing and include advanced sensor, communication and control technologies to increase the transmission efficiency and energy distribution [2].

Thus, an intelligent network is an automatically balancing and self-controlling energy system capable of receiving energy from any source (coal, sun, wind) and converting it into a final product for consumers (heat, light, warm water) with minimal human participation. From the above-mentioned definitions and problems to be solved, it follows that the main technical means of IN are digital
control systems that monitor, control and solve artificial intelligence problems. The consumption systems’ computerization will allow control over energy consumption by the systems that are more accurate and efficient [3].

Obviously, such a complex system should use the capabilities of modern information technology, which significantly increases the level of “intelligence” and makes it possible to solve the system optimization problem.

The aim of this work is to develop a comprehensive assessment of the environment’s climatic parameters and take into account the environmental aspects of alternative power plants to solve the problem of choosing the solar-wind power facilities’ location in the settlements’ territories to increase the municipal entities’ energy supply efficiency. Based on the developed methodology, a geographic information module is designed to automate the design of power plants using alternative (solar, wind) energy sources.

2. The benefits of intelligent networks

The advantages of intelligent networks are in the following points [4):

- operational efficiency - reducing the amount of electricity theft and improving the collection of payments using the automated meter reading systems;
- correct response - reduction of peak loads with the help of smart metering devices, allowing to introduce tariffing depending on the consumption time;
- network reliability - consumption forecasting to optimize the network configuration in real time, which will allow equipment to operate in full force of its actual capabilities;
- modern communication technologies - the ability to integrate the intelligent functions into the entire infrastructure of the power grid: from the substation to subscriber equipment. The structure of intelligent networks:
- an intelligent power grid combines the functions of power grid monitoring and generating capacity monitoring with the aim of load balancing, protection and measurement and also ensures the safe and efficient electricity delivery;
- renewable energy sources;
- intellectual exchange of information combines the two-way exchange of data from the sensors and counters located throughout the network;
- intellectual consumption and accounting provide increased reliability, security and network efficiency by automating demand management and emergency response [5]. Digital substations are one of the basic elements of an intelligent network. They implemented modern solutions and technologies for monitoring power grid equipment. Economic factors and business benefits of digital substation automation:
- decrease in current expenses. The substations of new generation allow to reduce the operating costs by combining several control and monitoring systems into one IP network, which will ensure the highest priority for control data and operational data traffic;
- lower capital costs. As the demand for electricity continues to grow, the power industry needs to find the ways to generate energy to meet this demand at peak times. One of the ways to automate a substation can be the use of technology for large-scale peak load reduction and demand management, which will reduce the number of additional power plants to meet the demand at the times of maximum load on the grid;
- ensuring distributed intelligence. Since the functions of intelligent network management are available not only within the control center, but also for the substations, there is the possibility of developing the new applications that allow implementing the distributed functions of protection, control and automation of equipment;
- improved power system protection. The task of ensuring information security of the power system includes not only the substation perimeter protection, but also the creation of a fully protected architecture that will allow to get the best possible view of the entire network, devices and events.
3. Worldwide experience and solutions

Electric cars and houses with solar collectors on the roofs, which are the mini-generators, caused the emergence of “smart” networks (Smart grids). Since the 70s of the last century, the experiments with the creation of “smart” distribution electrical networks have been conducted in Europe and the USA.

They make it possible to create a balance between numerous producers and electricity consumers. In the EU countries, along with large power plants, there are also numerous small energy producers, up to the so-called “active” houses, which return unused electricity back to the grid. On the other hand, the number of electricity consumers is constantly growing. According to the creators of “smart” systems, in the future, the consumers will have a significant amount of various electricity sources - from the power plants operating on various media to the power plants operating on renewable energy sources.

Obviously, such a complex system should use the capabilities of modern information technology, which significantly increases the level of “intelligence” and allows solving the system optimization problem. It should be noted that smart networks are able to contribute to solving climate problems. Experts believe that more than a billion tons of CO₂ emissions can be reduced with the help of “smart” networks by 2020 [6, 7].

And this is against the background of the fact that according to the research of Siemens concern, the need for electricity of all mankind will double by 2030, despite the measures taken to improve energy efficiency. It is enough to mention here that the installations developed by the EU commission imply a reduction in energy consumption in the EU countries precisely by increasing the energy efficiency level by 9% by 2020.

The European Union is developing the concept of the European Electric Grid of the Future. The concept of “smart” networks has already been implemented at the local level, such as, for example, the energy supply of individual buildings or regional networks that can cover entire areas and even the small states, such as Denmark.

In general, the potential of “smart” networks extends much wider, and it is already becoming quite real systems that, guided by the messages from millions of individual meters, raise or lower tariff rates hourly, depending on the network load. In some situations, the meters even react to energy shortages, ordering “smart” home appliances to temporarily stop working until the energy balance is restored.

The American consulting firm Cisco predicts that the potential market of “smart” networks should be 100–1000 times more than the Internet, and the level of future investments will be more than 100 billion dollars in it.

The US government has made the topic of “smart” networks one of the gravity centers of the state investment program and adopted a program in the amount of $ 4.5 billion aimed at restructuring the infrastructure of the electric power industry in February 2018.

In Europe, Siemens is actively involved in “smart” networks. The firm plans to receive orders of at least 6 billion euros to create such networks.

As part of a pilot project, Cisco and Yello Strom plan to connect 70 residential houses and enterprises to the local power transmission network and energy sources via an intelligent IP network [8]. Using the Yello Sparzähler smart meter, the users will receive real-time information about energy consumption online, and energy management systems installed in houses will allow using the “smart connectors” to configure home appliances to automatically turn on during their minimum load hours [9].

Cisco’s network technology strategy includes building a well-protected integrated electrical infrastructure that makes it possible to manage the entire power supply network — from generating the stations to the house and corporate consumers — as a single, holistic system. Due to the built-in intellectual functions, such a network will be able to actively recognize fluctuations in supply and demand and promptly respond to them, increasing the security and reliability of the electricity delivery and optimizing running costs. At the core of the Smart Grid network are innovative communication technologies. The idea of intelligent electricity delivery without them would be a complete utopia.
Electric current management is very similar to information flow management; therefore, the principles of the Smart Grid networks’ operation are similar to those of the Internet. The only difference is that electrical networks include much more network nodes. Here it is possible to apply the experience of integration and processing of important information and optimize energy consumption.

The studies have shown that such technologies can reduce electricity consumption by 10%. Moreover, the savings can reach 15% or more, if the household appliances are included in the most profitable periods of time.

The pilot projects on the “intelligent networks” use appeared in the United States, China and Europe. The Accenture consortium of smart cities has become a global platform for cooperation and promotion of “intelligent technologies” through the knowledge exchange, experience and the ideas based on the principles of active action, synergy and use of advantages.

The long-term goals of the European Union include:

- 20% reduction in CO2 emissions;
- 20% energy savings;
- 20% renewable energy.

4. Renewable Energy

In a number of Russian regions there are all conditions for the distributed generation’s growth. It is about the potential of wind energy and solar energy. Renewable energy can play a significant role in solving the problems of energy security, environmental degradation and climate change [10].

In order to stimulate the electric energy production by generating the facilities operating on the basis of the renewable energy sources use, it is necessary to approve the methodological guidelines for calculating tariffs for electric energy produced at renewable energy facilities and purchased in retail markets in order to compensate for losses in electric networks.

The analysts of Bloomberg New Energy Finance had prepared a report on the normalized cost of electricity. According to the company, the figure for the solar and wind energy is very close to the figures relating to the coal and gas power generation [11]. In some countries, the normalized cost of energy derived from the renewable sources, has already caught up with the price of power generated from fossil fuel.

At the same time the construction technology of solar and wind power generators is becoming more affordable, which makes a further decline in prices for alternative energy resources.

According to the report of the World Energy Council “Integration of renewable energy systems in 2018”, 286 billion dollars were invested in the development of renewable energy sources in 2017, ahead of the investment in traditional energy. It is expected that by the end of 2020 the world’s solar power capacity will reach 95 GW, increasing to 43%.

Russia has a huge potential for the development of energy-saving technologies and alternative types of energy: 40% of energy can be produced using the renewable sources.

In 2016, production of solar cells based on semiconductor heterostructures started in Russia.

The potential of wind energy (72 TW or 54 billion tons of oil equivalent) exceeds the current energy consumption in the world at least five times. At the same time only the places with an average annual wind speed in excess of 6.9 m/s at a height of 80 m were taken into account. As the chairman of the company, Anatoly Chubais at REENCON international congress “Renewable energy is the 21st century: energy and economic efficiency” informed, Rosnano plans to invest more than 10 billion rubles in the wind energy projects’ development. According to the Rosnano, by 2024 the cost of wind energy in our country will become equal to the fossil energy cost.

In addition to the above-mentioned reasons, another important problem exists: the problem of electrification of long distanced settlements. To solve this problem, the selection methodology of the solar-wind power objects’ placement was proposed, there are still the areas without a centralized power supply in the Lower Volga region along with unfavorable ecological situation.
The developed methodology for choosing the location of solar-wind energy facilities, which allows to solve the following tasks, is aimed at solving these problems: to carry out the functional and resource zoning of urban development; to perform an environmental impact analysis of the solar-wind power on the environment compared to the CHP power plant, nuclear power plant; a qualitative assessment of the architectural design the most suitable land in the urban areas to accommodate the objects of the solar-wind energy; to create e-cards for the high-rise buildings and placing terrain solar-wind power plants; to provide an economic assessment of investment in the development and construction of solar and wind power plants in residential areas in comparison with traditional energy sources; to develop a methodology for selecting the type of solar-wind turbines, depending on the environment and high-rise buildings’ parameters, as well as to implement a program module for calculating the alternative sources’ energy efficiency.

5. Automated system of power plants accommodation places’ choice
At present, the studies on the solar-wind power stations optimal placements’ selection use the data on the average annual wind speed and the possible capacity of the station. Also, the location of individual power plants should be taken into account. WAsP and PARK software can be an effective tool for this purpose.

These two computer programs are designed to determine the energy performance of single sources as well as for the power plants production capacity calculation. When placing the power generating objects, these programs allow taking into account the generalized climate regime, the influence of topography and obstacles, the performance of alternative energy sources.

For these programs’ application in the energy performance study of a certain area the digital maps should be input including the data on conditions of all sorts of changes in the wind flow obstacles (terrain, grass, trees, power lines, bridges, residential buildings, industrial zone).

6. Intellectual geo-information system of efficient placement of alternative energy sources
In carrying out this project the geoinformation module “Alternative” for calculating the efficiency of wind farms and automating the process of alternative power (solar, wind) energy sources designing, was worked up [12]. The module allows accurately determining the amount of generated electric power, the number of days of inactivity, the amount of required batteries, the parameters of the alternative power plants’ accommodation. It also allows planning the project taking into account the existing risks and opportunities as well as constantly monitoring the situation and responding to the emerge changes and deviations to achieve the project objectives within the set time, budget and quality.

The automated system is characterized by the following features:
- continuous and comprehensive predictive planning, taking into account the prevailing situation at a given moment of time;
- continuous monitoring of the project’s progress;
- maintaining base for manufacturers of alternative power plants, environmental information parameters (climate, terrain, options surrounding buildings);
- formation of reporting on the construction project’s effectiveness.

7. Summary
The proposed project is located at the intersection of such high-tech industries as energy - design and deployment of alternative (solar and wind) energy sources - and information technologies - GIS modeling.

A promising market of the proposed methods of the effectiveness analysis of the alternative (solar and wind) energy sources accommodation is energy market based on the technological solutions, providing intellectualization and distributed the energy networks nature (smart Grid) - EnergyNet.

Thus, the development of this technique is an urgent need in most regions, especially in southern Russia. It helps to obtain the new technical solutions which can be applied not only in the
electrification of agrarian sector, but also in other sectors with geographically distributed hardware system in the Russian regions.

The proposed method helps to analyze the alternative energy sources’ placement effectiveness better and solves the problems by optimizing the energy alternative sources’ placement and also helps to determine the sanitary protection zone and calculate the impact on the environment.

Saving energy of all kinds is the task becoming more relevant in the modern world. Energy-saving technology recognized priority at the level of the state domestic policy in many countries and in Russia in particular. Energy-saving technology is developed on the basis of innovative solutions. These technologies should also be environmentally safe and do not change the course of society in general as well as each individual’s lifestyle.

References

[1] Kravets A, Skorobogatchenko D A, Salnikova N A, Orudjev N Y, and Poplavskaya O V 2018 The Traffic Safety Management System in Urban Conditions Based on the C4.5 Algorithm. Moscow. Workshop on Electronic and Networking Technologies, MWENT-2018. Proceedings. 8337254. IEEE. pp. 1-7.

[2] Kamaev V A, Salnikova N A, Akhmedov S A, and Likhter A M 2015 The Formalized Representation of the Structures of Complex Technical Devices Using Context-Free Plex Grammars Communications in Computer and Information Science 535 (CCIS, Volgograd, Russia Federation) 268-277.

[3] Orudjev N Y, Lempert M B, Osaulenko I, Salnikova N A, Kuzmichev A A, and Kravets A G 2016 Computer - Based Visual Analysis of Ecology Influence on Human Mental Health 7th International Conference on Information, Intelligence, Systems and Applications (IISA- 2016), IEEE 1-6.

[4] Kravets A, Shumeiko N, Lempert B, Salnikova N, and Shcherbakova N 2017 “Smart Queue” Approach for New Technical Solutions Discovery in Patent Applications Communications in Computer and Information Science 754 (CIT&DS 2017, Volgograd) 37-47.

[5] Shcherbakov M, Groumpos P P, Kravets A 2017 A method and IR4I index indicating the readiness of business processes for data science solutions Commun. Comput. Inf. Sci. 754 21–34.

[6] Kamaev V A, Mikhnev I P, and Salnikova N A 2016 Natural Radionuclides as a Source of Background Irradiation Affecting People Inside Buildings Procedia Engineering 150 1663-1672.

[7] Mikhnev I P, Salnikova N A, and Lempert M B 2017 Research of Activity of Natural Radionuclides in Construction Raw Materials of the Volgograd Region Solid State Phenomena 265 27-32.

[8] Mikhnev I P, Salnikova N A, Lempert M B, and Dmitrenko K Yu 2017 The Biological Effects of Natural Radionuclides from the Construction Materials on the Population of the Volgograd Region 8th International Conference on Information, Intelligence, Systems and Applications (IISA-2017) IEEE, 1-6.

[9] Mikhnev I P, Mikhneva S V, and Salnikova N A 2018 Studies of radon activity in civil engineering and environmental objects International Journal of Engineering & Technology 7 (2.23) 162-166.

[10] Kravets A G, Kanavina M A, and Salnikova N A 2017 Development of an Integrated Method of Placement of Solar and Wind Energy Objects in the Lower Volga International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM). IEEE 1-5.

[11] Mikhnev I P, Salnikova N A, and Lempert M B 2018 Modern Condition of Dose Loads from Construction Materials and Main Sources of Ionizing Impact on the Population of the Volgograd Region Materials and Technologies in Construction and Architecture, Materials Science Forum. 931 1007-1012.
[12] Kanavina M A, Kravets A G, Lempert L B, and Salnikova N A 2016 Certificate of state registration of the computer No 2016661339 from October 6, 2016 RF Module for calculating the efficiency of wind farms “Alternative”.