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Smart Cities in Future Energy System Architecture

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ABSTRACT

The article analyzes new technologies, which establish modern trends for future electric power systems operation and development, and their impact on production, storage, transmission, distribution and consumption of electricity. The article also studies trends and approaches to urban planning with an emphasis on energy infrastructure, where success in "smart city" and "smart grid" concepts implementation is considered as overarching question. The general requirements for smart power supply system are defined, problems that need to be solved are formulated, and a number of general recommendations are given for future development.

Keywords: Energy System, Smart Grid, Smart Cities
JEL Classifications: L94, Q42, Q48, H54

1. INTRODUCTION

In many countries, energy sector enterprises are undergoing a period of reformation. The ongoing processes of mergers, acquisitions and changes in management structure, the boundaries of the sphere of activity and the territorial presence make many former monopolies look for new models of value creation. Inevitably, the targets of the companies and their business processes change, and so do the markets for public services provision, as new market mechanisms are being introduced, requiring for technological changes that meet the current development needs of the industry. Although all these changes differ depending on the location and type of activity of a certain energy company, innovations inevitably lead to transformation of the entire sphere of public services (Tadviser, 2018).

Regularities and common factors of changing conditions for development and functioning of electric power systems (EPS) lead to significant transformations in their structure, as well as modes of their operation. These transformations are caused by a number of objective factors that shape the future EPS architecture, namely:

- Increase of EPS scale, expansion of territories they serve, and regional cooperation that leads to formation of interregional and interstate energy associations;
- Development of large cities' agglomerations, conditioned by the formation of state and economic management centers, and concentration of high-tech industries, financial resources, creative groups, scientific and educational cluster;
- Trend for de-urbanization of urban settlements, including the removal of industrial production off cities' limits, and development of individual low-rise construction.

All this will lead to an ever-widening dispersal of electricity consumption throughout the territory, parallel to profound electrification of industry and everyday life to ensure growth of quality of life and labor productivity (Voropai and Stennikov, 2013).

Societal development in high-developed states with established social institutions is currently being considered as an overarching target to ensure well-being. Moreover, the latter is tested against not only aggregate income, but also against metrics that encapsulate social issues and reflect on the quality of life in general. Against the background of rapid technological development and social advancement, groundwork for practical implementation of actions, leading to improvement of the population quality of life, is laid.

Social and technological development pillars are closely interlinked and have a composite impact on socio-technical systems. EPS might be considered as an illustrative example. Interconnected relations among social and technical components of EPS are primarily reflected in electrical power supply management (centralized or decentralized), modes of cooperation for innovative projects' (either systemic or non-systemic) delivery, etc.

The increased attention of modern society to the interests and needs of the individual, contributes to the formation of customer-oriented power supply systems with an emphasis on the quality of service to end-users. In general, the task of improving the quality of life in the context of intensive urbanization is formulated primarily applicable to large cities and big urban centers.

The experience of managing territorial development at the national and regional levels, as well as planning the harmonious development of urban agglomerations, is gaining momentum globally (Zhang et al., 2006). The development of urban environment is an alternating stage in the growth of problems and post-crisis transformation. At the same time, modern experience shows that the successful development of cities, including their development as centers of regional importance, is directly related to the existence of a program of interaction between actors, and the use of a distributed type of management.

2. LITERATURE REVIEW

The themes of the city's intelligent energy systems, active-adaptive networks, digitalization of power systems and substations are increasingly being raised for discussion on thematic venues, forums and meetings at various levels.

Since the beginning of the XXI century, territorial development is being associated with the concept of "smart city." This concept represents the development of a "quality of life approach" in accordance with the criterion of sustainable development, which links the current needs of society with the limitations on the ability to meet them both at the present time and in the future (Styczynski et al., 2011). The concept of sustainable development includes socio-economic and technological development, as well as environmental protection. A distinctive feature of the smart city is the widespread use of information and communication technologies (Muromtsev, 2017).

Currently there are numerous definitions that seek to describe smart grids (SG), with the most relevant compiled and presented below (United Nations, 2015):

1. International Energy Agency: "A smart grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users. Smart grids co-ordinate the needs and capabilities of all generators, grid operators, end-users and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimising costs and environmental impacts while maximising system reliability, resilience and stability."
2. European Commission (EC): "Smart grids are energy networks that can automatically monitor energy flows and adjust to changes in energy supply and demand accordingly. When coupled with smart metering systems, smart grids reach consumers and suppliers by providing information on real-time consumption. With smart meters, consumers can adapt – in time and volume – their energy usage to different energy prices throughout the day, saving money on their energy bills by consuming more energy in lower price periods. Smart grids can also help to better integrate renewable energy. While the sun doesn't shine all the time and the wind doesn't always blow, combining information on energy demand with weather forecasts can allow grid operators to better plan the integration of renewable energy into the grid and balance their networks. Smart grids also open up the possibility for consumers who produce their own energy to respond to prices and sell excess to the grid."
3. United States office of electricity delivery and energy reliability (USA OE): "Smart grid generally refers to a class of technology that people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries. They are beginning to be used on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers - mostly seen in big improvements in energy efficiency on the electricity grid and in the energy users' homes and offices."
4. International electrotechnical commission (IEC): "The general understanding is that the Smart Grid is the concept of modernizing the electric grid. The Smart Grid comprises everything related to the electric system in between any point of generation and any point of consumption. Through the addition of Smart Grid technologies the grid becomes more flexible, interactive and is able to provide real time feedback. A smart grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies. A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to: facilitate the connection and operation of generators of all sizes and technologies; allow consumers to play a part in optimizing the operation of the system; provide consumers with greater information and choice of supply; significantly reduce the environmental impact of the whole electricity supply system; deliver enhanced levels of reliability and security of supply."
5. Japan Smart Community Alliance (JSCA): "In the context of Smart Communities, smart grids promote the greater use of renewable and unused energy and local generation of heat energy for local consumption contribute to the improvement of

energy self-sufficiency rates and reduction of CO_2 emissions. Smart grids provide stable power supply and optimize overall grid operations from power generation to the end user."

Definitions can also reflect national or regional electricity system development needs. For example, in China initial emphasis was placed on the "Strong Smart Grid," reflecting technology development and infrastructure needs in transmission networks. In May 2009, the State Grid Corporation of China officially launched the study and construction of the "Strong Smart Grid" system, to be completed by 2020, noting that this has not precluded efforts by China in distribution technologies. The years 2011–2015 mark the construction stage, when rollout of ultra high voltage links will be accelerated and urban and rural distribution networks built out (IEEE, 2011).

Despite the absence of a single terminology, there are generally several main areas in the formation of a "smart city": Smart economy, smart environment, smart management, smart habitat, smart communication, and smart people (Allee and Tschudi, 2012). These are summarized in Table 1.

With an integrated approach, a growing number of life-supporting spheres fall into the field of attention of civil planners: Energy supply and utilities, transport and logistics, real estate and construction, business and finance, health and education, public safety, waste utilization, etc. Particular attention is paid to the organization of smart urban management in general, which establishes a large closed-loop cycle – from the production of necessary forms of energy, products and services to ensuring social and environmental sustainability.

The European pioneer in the field of smart cities is Amsterdam (Netherlands), which started implementation of relevant programs in 2009. At present, more than 40 different projects are being implemented in the city aimed at social and economic development of the city, increasing energy efficiency and reducing the burden on the environment thus decreasing ecological stress. After Amsterdam, other cities followed, including Malaga (Spain), Evora (Portugal), Madrid (Spain), Freiburg (Germany), etc., (Patterson, 2012).

An indispensable component of smart city projects is the energy supply sector, which is being intensively transformed primarily due to the implementation of large-scale governmental programs to support the introduction of distributed generation based on wind and solar energy, as well as smart metering systems for consumers. A number of long-term mega-projects in the European Union and the United States – Green eMotion, ECOGRID, Pacific Northwest Smart Grid, Houston's Smart Grid, etc., – are of the nature of research projects and test sites, where new approaches to the organization of energy supply are being developed.

Currently, in the ranking of smart cities in Europe, according to a study by Bearing Point, the leading are Vienna (Austria), Amsterdam (Netherlands) and Barcelona (Spain). At the same time, Vienna has been leading the list of the best cities for quality of life for several years. The smart city project there includes such areas as development

Table 1: Key elements for "smart city" formation

Element	What is entailed in the term
Smart economy (competitiveness)	Path-breaking, innovative spirit Entrepreneurism and commercial endeavor Trade marks Productivity and effectiveness Labor market flexibility Engagement in international processes Capacity for transformational change
Smart environment (natural resources)	Force of natural conditions attraction Environmental protection Sustainable resources management
Smart management (partnerships)	Involvement in decision-making Public and social services Transparent governmental actions and administrative procedures Political strategies, road maps and long-range plans
Smart habitat (quality of life)	Quality of housing services Social cohesion Educational facilities and services Public health services Personal security Cultural facilities Tourist attraction
Smart communication (transport and communications)	Environmentally sound, innovative and safe transportation systems Information and communication technologies infrastructure Availability, accessibility and affordability at local, national and international levels
Smart people (human capital)	Skill and expertise level Commitment to continuous learning Social and ethnic diversity Flexibility Creativity Ex-territoriality (cosmopolitism) Community involvement

Source: Adapted from (Voropai and Stennikov, 2013; Allee and Tschudi, 2012)

of renewable energy resources (including those derived from garbage processing) and increased use of "clean energy," energy efficient traffic lighting system, electric public transport and charging stations, open access to data, insurance services, etc.In the United States, projects are known in the cities of New York, San Francisco, Boston, Seattle, etc. In Asia, projects can be identified in Yokogama (Japan), Dubai and Masdar (OEA), New Sondo (Korea), and in India, where the "100 smart cities" program is launched, and China, where about 200 pilot projects of smart cities are in the implementation phase. An example of successful international cooperation (particularly, in terms of smart cities development) might also be the Covenant of Mayors, which is aimed at (including, but not limited to) fulfilling the indicators of sustainable energy development.

All smart city projects are implemented in close interaction of a wide range of participants and stakeholders, including:

Representatives of the authorities of all levels, business, energy companies, power equipment manufacturers, telecommunications sector companies, scientific organizations, universities and academic institutions, developers and city residents. This underlines the interest of different communities in achieving common goals, as well as the need to combine their efforts to solve a set of interrelated tasks, including territorial planning, development of the urban management model, carrying out scientific research, development, deployment and mastering of new technologies, training and building capacity of specialists and wider community, etc.

3. ANALYSIS OF EPS DEVELOPMENT TRENDS

In order to understand what is the intelligent energy systems of cities with an actively adaptive network, a broader look at the issue might be applies, posing a question: What are the intellectual systems of cities in general, without binding only to energy? To answer it, it is necessary to imagine a future, in which all these systems already exist. In this future, intelligent electric networks, intelligent heat networks, water and gas supply networks, intelligent ground and underground transportation, intelligent emergency services, intellectual services, even buildings, – are created and made operational. All these urban areas exchange relevant information with each other through a single city management system in real time. For example, a failure in the work of the subway automatically affects the scheme and intervals of ground transportation, and the disconnection of the power line leads to an automatic change in the scheme of power supply of the district. From the same city management system, the city government and the population receive topical information, the first – to improve management efficiency, the latter – for timely information and services.

In general, the work of such a system leads to the existence of a self-regulating city network, in the life of which both the government and residents participate in real time. Receiving feedback from the public makes it possible to make timely adjustments to the algorithms of self-regulating systems, thus continuously increasing the efficiency of city services.

The electrical network of such a city is also actively adaptive, that is, it can change and adapt to the processes taking place in it, in order to maintain uninterrupted power supply in optimal modes. Mutually supplementing participants of this network are sources of generation (both traditional and renewable), backbone and city electric networks with their substations, as well as consumers, both with their own generation sources, capable of delivering excess power to the network, and without them. For the automatic operation of such a network, in addition to a city control center that introduces control commands at the global level, local (node) control centers are necessary, on which the day-to-day operation of individual network segments depends.

Active-adaptive electric network – SG – is a self-regulating power supply system of the city. It provides analysis of energy consumption of individual consumers and groups; accumulation of energy with excess output and output to the network in case of power shortage, automatic reconfiguration of the power supply network in case of emergency situations; automatic reconfiguration of protection and automation devices depending on regimes, informing adjacent systems of current events in the network.

The power supply decentralization trend is developing in the electricity production due to the expanse of distributed generation sources connected to the nodes of the distribution grid. This tendency is due to the emergence of new high-performance electricity generation technologies, which are able to customize EPS to the uncertainty of electricity demand. Renewables also contribute to distributed generation system.

New high-efficiency technologies are increasingly being used for large-scale power sources. The future EPS generation structure should comprise relatively large generating sources for the supply of electricity to large electric consumers and a sufficiently high share of distributed electricity generation.

The expanse of distributed electricity units in EPS induces certain peculiarities. Many small generating units based on gas turbine technology operate at a higher frequency than the industrial one and are connected to the system via reversible converter units. Similar connection is provided by wind turbines, which differ in the stochastic nature of the generated power. As a result, the frequency characteristics of the generation in the EPS are significantly changed, the regulatory effect of the generation in frequency is reduced.

Distributed generation units have smaller rotor inertia and simplified control system, comparing to traditional units, what creates problems with EPS stability.

Connection of distributed generation units to the distribution grid radically changes its properties, creating problems of stability, forming the need for significant development and fundamental reconstruction of relay protection and automation systems at this level.

Electricity network will change due to the drift in power generation and consumption. Considering new technologies in converter units based on power electronics, cost reduction, reliability improvement and high controllability of DC power transmission, these technologies will significantly develop in the transmission network. At the same time, the widespread use of devices that form flexible AC power transmission (FACTS), will radically increase the controllability of the AC transmission network. New technologies, including the use of FACTS units, will significantly increase the reliability and controllability of distribution grid. The power consumption growth and the dispersion of generating sources and consumers on the territory will lead to the increase in the transmission density and distribution networks. Considering these factors, future EPS will increasingly assume properties of infrastructure systems (a kind of "electric Internet"). Theoretically, this may provide consumer with the proper quality electricity in certain place at the acceptable price.

Another factor is the emergence of active consumers, who will independently manage their power consumption depending on the price conditions in the retail electricity market by transferring electricity consumption by some power receivers from periods with a high price of electricity to periods with a low price. This independent management of line load creates problems for the management of the EPS modes due to the uncertainty of power consumption of active consumers. Therefore, the interaction between the EPS and consumers on the joint management of the system modes using the regulatory capabilities of consumers is promising.

A significant change in the properties of future EPS will occur as a result of the mass expanse of electric energy storage systems, whose technologies are already in industrial use (Zhang et al., 2006). Electric energy storage systems are characterized by the presence of high-performance control systems, which may contribute to the flexibility of EPS. A large share of electric energy storage is expected to be on the basis of electric vehicles, which will significantly change the layout and modes of operation of future power plants. These new characteristics of consumers, drives and generation of future power plants will significantly change the properties and flexibility of systems.

In the concept of a smart city, energy supply system retains an important infrastructural role in urban economy and is characterized by a new level of development, for which the term SG is used. The smart power supply system of the city unites three main systems: electricity, heat and gas supply. At the same time, the unified energy supply system can be represented in the form of integrated energy units, including sources and consumers of different types of energy, and complex energy links that ensure the transfer of different types of energy resources.

Such a complex presentation is primarily due to the desire to optimize the use of energy in smart city as a whole. Secondly, it is necessary to take into account of the interrelatedness of the operating modes of the systems, which is manifested, for example, in the available capacity of thermal power plants, the reliability of natural gas supplies, partial interchangeability of electricity, heat and gas during heating, etc. Thirdly, places and routes for energy infrastructure in the city are limited, which requires a comprehensive approach to the design and operation of power facilities, including their placement in a single corridor.

At the smart city facilities' level, an integrated approach to energy supply(for example, of large buildings), allows to obtain an additional effect when taking into account constructive and technological solutions in construction aimed at energy saving and energy efficiency. Should the electric transport infrastructure and the power supply system be considered jointly, it is possible to ensure optimum charging of the load in the overall load schedule of the power system with a mutual benefit for consumers and the power system. The urgency of this task increases with the development of fast charge and discharge technology.

Each sub-system, being an element of the integrated energy supply system, forms a branched hierarchical structure, starting from local energy supply systems of individual consumers to high-level backbone networks. First of all, the energy infrastructure is most developed at the level of distribution and consumption of energy due to a number of factors: the growth of distributed generation and its integration, including energy storage, at the grassroots level of hierarchy into the public network, deep automation of interface connections of consumers with power system, implementation of local power systems technologies, when the distributed sources of generation on the consumers' side can work sustainably and ensure the quality and balanced power supply during power outages, and secure capability to adapt to reverse energy flows of the distribution network, etc. At the same time, in the structure of the power system, the consumption sector boundary is diluted due to the large-scale development and integration of different power sources in consumers' energy in residential, industrial and business sectors. Local power systems, such as microgrid and multimicrogrid, capable both of synchronous operation in the composition of the power grid, and autonomous operation, form fractal structures in the power system, increasing its resistance to disturbances and facilitating recovery from accidents (Wei and Kundur, 2012).

The unifying role in the management system of the energy infrastructure of smart city is carried out by information and communication technologies, which ensure the exchange of information and control signals both inside the systems and between them. At the same time, a significant increase in the volume of information requires the use of new principles of information processing and decision-making in management systems. A qualitative change in the automatic control of a complex system is the transition to distributed control with the possibility of maximum processing of information and decision-making on the ground, based on the multiagency principles. The new task is to organize the management of local power systems, which ensures their stable operation as part of a large EPS and, if necessary, reliably allocates for isolated work with the balancing of own consumption and energy sources to ensure life support of critically important consumers.

Distributed management of the SG is built on a hierarchical basis and includes several levels of energy management systems (EMS): a system for the housing development cluster of the city (Home EMS); business and social activity – large business centers, entertainment buildings and the hotel sector (Building EMS); industrial plants and technology parks (Factory EMS); etc. General management of different types of clusters, including the electric vehicle (EV) charging infrastructure, is carried out in the territorial EMS (Community EMS) with information support from supervisory control and data acquisition (SCADA) system regarding the collection of data from metering devices and consumer participation in demand management. Such a management system for a smart city's power system is being developed, for example, within the framework of a major Yokohama Smart City project in Japan.

4. DISCUSSION

In general, the distinctive features of smart energy supply system are: efficient use of energy, reliable operation and adaptability to changing conditions, which includes the possibility of flexible participation of market actors, including consumers, in regime and emergency control in accordance with their individual characteristics.

Among the basic requirements for the smart power supply system, it is necessary to distinguish the following (Voropai, Stennikov, 2013):

- Optimal choice of the composition of generating sources, including distributed generation, and energy management that approaches the real-time mode;
- Integration of diverse sources of electricity, including renewable and low-power sources, and energy storage into the energy system;
- Automatic assessment of the risks of violations, detection and elimination of the consequences of violations in the operation of the power system at all hierarchical levels;
- Two-way communication with consumers via intelligent metering systems and power management;
- Resistance to the impact of security threats (physical, informational and resource);
- computer-aided design of the power system, including power facilities, and the information and communication system in conjunction with the cities' infrastructure;
- Optimal use of the equipment life, and timely (including preventive, based on risk-management) maintenance of assets.

Which objects do participate in an active-adaptive energy network? Which – among them – exist in traditional networks, and are they ready (in their existing form) to work as part of an actively adaptive network? All participants of the active-adaptive network may be divided into three groups, according to their degree of presence in traditional networks and the level of readiness for work in the active-adaptive network (Litvinenko and Glebov, 2017).

1. The first group is traditional generation, intersystem and backbone networks. The participants of this group are an integral part of current electric network and have a high degree of readiness to work in the active-adaptive network. At the facilities of this group, such systems as emergency response and technological automation, telemechanics and SCADA, relay protection and automation have been operating for a long time already and actively.
2. The second group is consumers without sources of generation, and urban networks that feed these consumers, and here it is possible to include the nodal control centers. This group also exists in today's networks, but its elements are not fully or partially ready for work in the active-adaptive network. This is due to the fact that city electric networks have always been built on the basis of simple and inexpensive equipment. On the low side of the city substations, protection, as a rule, was built on fuses, so it is impossible to talk about remote control and automatic change of some parameters of the operation of city networks in the existing form. Therefore, only by equipping the city substations with intelligent devices is not limited here - requires a comprehensive reconstruction with the replacement of basic electrical equipment for supporting remote and automatic control. Almost the same situation on the side of end-users: the maximum that is now transmitted to the power supply organization in an automated form is the indication of commercial accounting data. Therefore, today, consumers have no opportunity to influence the operation of the supply network, depending on the processes that occur in the consumers themselves.
3. Renewable generation, consumers that include sources of mini and microgeneration, as well as the City Management Center, are the third group of participants in the actively adaptive network, which is practically non-existent today. Solar and wind power plants being built in Russia today are not equipped with energy storage systems, so they are unable to accumulate energy during peak hours and give it out to the grid in the event of a failure, and consumers with small solar panels or "windmills" do not have a legal the ability to produce surplus production in the network. These aspects do not allow the construction of decentralized active-adaptive power supply systems operating on the basis of energy block technology, a system that manages several trade agreements between consumers that buy surplus electricity generated directly from the original producer without additional costs and trade margins that operatively change the cost of this electricity in dependence from the needs and volumes of surplus. Thus, the cornerstone in this group of participants in the actively adaptive network is the storage of electrical energy, or rather their absence as part of renewable generation.

The implementation of national strategies for the development of SG technologies and smart metering in various countries of the world pursues a number of key goals.

For energy companies, these pursued objectives include:

- Reduction of energy losses;
- Increase of timeliness and completeness of payment for consumed energy resources;
- Control of the unevenness of the electrical load schedule;
- Increasing the efficiency of asset management of energy companies;
- Improving the quality of integration of renewable generation facilities and distributed generation into the power system;
- Increasing the reliability of the functioning of the power system in the event of emergency situations;
- Increase visualization of the operation of energy infrastructure facilities.

The key objectives of energy resources consumers are:

- Improving consumers' access to energy infrastructure;
- Increase of reliability of power supply of all categories of consumers;
- Improving the quality of energy resources;
- Creation of a modern interface between energy consumers and their suppliers;
- Opportunity for the consumer to act as a full participant in the energy market;
- Expanded opportunities for consumers to manage energy consumption and reduce payments for consumed energy.

Governments and regulators of the energy industry – through development of SG technologies – are striving to achieve the following:

- Increase in the level of satisfaction of energy consumers with the quality and cost of energy supply;
- Ensuring the sustainable economic situation of enterprises in the energy sector;
- Ensuring the modernization of the fixed assets of the energy industry without a significant increase in tariffs.

The transition to smart power supply systems in the cities is associated with the gradual transformation of the existing infrastructure in the course of implementing complex projects aimed to create a new urban environment in a certain territory, including the reconstruction of industrial areas – gentrification.

At the same time, the goal of introducing new technologies requires solving the issues of organizational interaction, financing, regulatory support, etc. Implementation of, and delivery on, smart city projects requires a wide involvement of energy companies, equipment manufacturers, residents, large consumers under the auspices of city authorities under a single project management system. In addition, in the field of information support, it is necessary to develop and implement a wide range of educational and training programs in the field of energy efficiency and environmental protection, as well as programs on integrated smart city project management using alife-cycle approach.

From a technical point of view, and taking into account the mentioned tendencies of increasing distribution of electric receivers and electric energy storage systems feeding on direct current through converter elements, a transition to the formation of direct current feed distribution networks at the location of common converter installations from alternating current to constant at feed substations might be expected.

Moreover, these new load characteristics of consumers, storage devices and generation within the future EPS will significantly change the properties and controllability of systems. The existing principles of regime control in traditional EPS are based on the use of the regulating effect of the load and the frequency characteristics. Due to these effects, modern EPSs have internal self-sustainability, and control systems affect the regime parameters only subject to their violation of certain limits. In connection with the change in the properties of future EPS, a large transformation regarding their internal self-sustainability might be expected, resulting in a fact that the traditional principles of EPS regimes' management would require significant modification and further development.

Practically all the countries have introduces state policies that support technological development of electric power industry and future EPS, in which the concept of creating intellectual power systems – SGs – is widely declared. This concept is based on the integration of several innovative directions in all segments from production to consumption of electricity, namely:

- Innovative technologies and installations for the production, storage, transmission, distribution and consumption of electricity;
- Highly effective means and technologies for measuring, collecting, processing, storing, transmitting and presenting (visualizing) information;
- Progressive information and computer technologies;
- Highly effective methods of monitoring and management based on modern approaches and practices of management theory;
- Active consumers.

5. CONCLUSION

The development of future EPS on the technological basis of the intelligent power system will largely neutralize the listed and discussed potentially negative trends in the changing properties of EPS. At the same time, new problems arise (and they would only grow in scope in the future) due to the need to strengthen the coordination of EPS regimes' management of at various levels, in order to improve management efficiency, and to ensure the reliability of the very management system. Moreover, in terms of monitoring and managing EPS, the issues related to ensuring information and cyber security acquire special urgency. Nevertheless, the security of such networks in the energy sector remains. We must understand that the simpler the system, the more reliable it is. Therefore, the addition of new elements - all new sensors, all new devices for monitoring - does not make it more reliable. Nevertheless, in general, the energy system with the advent of IoT technologies becomes more reliable precisely because the effect is achieved due to greater control, the use of additional controls and other methods. But it is worth noting that the security of the Internet of things (IoT) is a serious and urgent issue, which has not yet been fully explored.

All mentioned above requires serious in-depth research into the properties of future EPSs, the development of principles and methods for their formation, taking into account changing conditions, the management of their regimes in normal and emergency situations, as well as dispatching and automatic control systems for future EPS modes.

In the context of the development of the IoT, talk about a variety of devices that can send collected data via the Internet. On hearing examples of household devices, for example, for "smart home." However, there is another large segment of the application of IoT technologies - energy. Gathering the parameters of energy networks can help increase the reliability of all their elements, optimize the load on the infrastructure. As a result, due to sensor networks and data processing from them both operational costs and repair costs (due to remote monitoring systems, self-diagnosis systems) will be reduced.

In the description of IoT applications in power engineering, one can often hear the phrase "intelligent networks." This is a small speculation with the term "intellectual," but in this case it is justified. In general, intellectual can be called only what has intellectual behavior. Levels of intelligence, of course, are different. But there are basic things: the ability to reason, goal-setting, the ability to adapt to changing conditions and so on. In the electric power industry, rather, it is not about intelligence as such, but about the ability of networks to automatically inform about their state, that is, the amount of energy consumed, its distribution, emergency or emergency situations, and so on. In other words, the network performs part of the work that the maintenance staff used to do before. Basically it concerns data collection.

This system has several levels. Generator level "digitized" can be all the parameters of the generating capacity, including fuel reserves, the need for planned repairs and maintenance, load, and so on. This allows you to switch the power in time, better to plan maintenance and repairs, which, undoubtedly, reduces costs, and also facilitates control over unauthorized connection and theft.

The second level is the architecture of the network itself, which becomes more decentralized. Such a wireless network works in the same way as, for example, conventional computers or mobile devices are combined into a network. In addition, there is a technology for transferring data directly through power cables, but this may require replacing the equipment with power lines, which is not always easy to do.

At the level of opportunities for consumers of energy, new services are emerging. Most of them are related to the fact that consumers have the opportunity to monitor the consumption of electricity in real time and with maximum detail, up to a specific device. If we talk about large consumers, such as enterprises or business centers, then they can track dishonest tenants. For example, you can identify those who sort out with electricity, connect more powerful devices than allowed. It is also possible to more accurately determine peak loads. And end users will be able to plan for a more even use of energy, avoiding the simultaneous inclusion of several powerful devices, and automatically switch equipment to work at cheaper rates at night.

Flexibility of power systems and consumption accounting, which allows to come to large data analytics, allow the inclusion of a large number of distributed sources of energy generation into the network. Therefore, the penetration of IoT into the energy sector will also spur the development of small-scale power and the connection of alternative energy sources. For example, several small energy producers (say, substations collecting energy from windmills) will be able to unite in a virtual station and offer energy to households.

Operational management of infrastructure is crucial. Energy companies are faced with the need to introduce new standards of operation and maintenance to continuously improve the balance between reliability of power supply and costs. Another key task in the energy sector is the maintenance and repair of equipment. This is due to the huge number of pieces of equipment distributed over large areas and requiring regular maintenance and repair. Consolidation of information about the state of equipment in a unified management system with the ability to provide it quickly to various consumers on the ground can reduce downtime for repairs, reduce costs for spare parts and materials, optimize logistics and staff utilization.

Consumers are also no less important driving force for the changes that are taking place. There has been a tendency to shift from a process-oriented approach to a client-oriented approach. Increased requirements of consumers to the level of services inevitably lead to an expansion of the range of services provided by energy companies, the introduction of new financial and payment mechanisms.

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