ATLANTIS PRESS

Atlantis Highlights in Computer Sciences, volume 1

International Conference on Digital Transformation in Logistics and Infrastructure (ICDTLI 2019)

Experience in the use of intelligent systems and digital technologies in the energy sector of emerging economies

Ecaterina Resniova
Saint-Petersburg Minimg University
Department of Organization and Management
Saint-Petersburg, Russia
reshniovakate@gmail.com

***Abstract*—The energy sector of developing countries faces a large number of modern challenges that contribute to the formation of a new stage of its development as the most important infrastructure of the economy. On the one hand, powerful technological and digital progresses have led to the active development of distributed energy technologies. On the other hand, the development of a competitive environment in the wholesale and retail market, together with the growing differentiation of consumer requirements for reliability, quality and cost of energy supply, change the ideology of interaction with the consumer, who becomes an active participant in technological and commercial interactions. Thirdly, technological development in the field of information and communication technologies (ICT) has created an opportunity for the development and implementation of digital technologies. They increase the efficiency of analysis and forecasting of situations in the energy sector, and decision-making based on the processing of large arrays and data flows, which allows in practice to move to flexible management of the electricity market.**

It should be noted that the necessity for innovative development of the energy sector is directly related to such existing problems as: the exhaustion of primary energy resources and, as a consequence, their scarcity in many countries of the world; the instability of energy safety of the countries; the issues of ecologization of energy production. In this regard, energy companies pay great attention to energy management and the development of modern technologies in this sector.

The article considers digital technologies and Smart grid, identifies their main advantages, and concludes on the economic efficiency of innovation in the energy sector of developing countries

Keywords - Smart grid, innovative technologies, digital technologies, digitalization, energy of developing countries.

I. INTRODUCTION

The problems of development and modernization of energy systems are the same for most countries - the issues of energy efficiency and energy security in the field of energy generation, distribution and consumption are addressed. There are several trends on the energy market of developing countries. The increase the efficiency of energy production which includes both the introduction of a combined cycle and the development of alternative energy is the main trend in the generation market. The reduction of technological losses in bearers, transmission and distribution of energy, reduction of peak loads are the trends in network business. But, despite the similarity of tasks, the solution of which digital technology and Smart Grid are help to achieve, there are differences related to the history of the formation of the energy system, geographical location, availability of energy or alternative energy sources in each of the country.

Thus, the importance of using digital technologies and Smart Grid is explained by the fact that in the world with an annually growing demand for energy the necessity to optimize asset management, to create distributed generation resources, to completely satisfy the needs of each consumer, is an important element of guaranteed and high-quality functioning of the energy sector.

The main purpose of this paper is to highlight the main advantages of the implementation of digitalization and Smart Grid technology in the energy sector of developing countries.

The main objectives of the article are as follows:

1. To show the main ideas of digital technology and Smart Grid;
2. To highlight the main advantages of the intelligent power system;
3. To analyze the economic efficiency of the implementation of these modern technologies;
4. To make a conclusion about the possibilities of implementation of digitalization and Smart Grid in emerging economies.

II. THE MAIN PART

The most specifically from the point of view of functional and technical part of the idea of Smart Grid is reflected in the definition of IEEE (The Institute of Electrical and Electronics Engineers): "smart grid is a concept of a fully integrated, self-regulating and self-healing power system having a network topology and includes all generating sources (including alternative), transmission and distribution networks and all types of consumers of electric energy-driven integrated network of information and control of devices and systems in real-time [1]."

In the modern and future society, the energy within the framework of the concept of Smart Grid is considered as a

source (tool or means) that provides a person with a certain level of life benefits and comfort.

In the concept of Smart Grid developed by DOE (Department of Energy USA), the variety of requirements is reduced to a group of key values/key goals new electricity, formulated as:

1. Accessibility - providing consumers with electricity without restrictions depending on when and where they need it, and depending on its quality, paid by the consumer;
2. Reliability - the possibility of confrontation between the physical and informational negative impacts without total shutdowns or high-cost recovery work is, fast recovery (healing) efficiency;
3. Efficiency is the optimization of electricity tariffs for consumers and reduced system-wide costs;
4. Productivity - maximizing the efficient use of all resources, technologies and equipment in the production, transmission, distribution and consumption of electricity;
5. Organic interaction with the environment — the maximum possible reduction of negative environmental impacts;
6. Safety - prevention of situations in the electricity industry that are dangerous for people and the environment.

In the European Union, key values include [2]:

1. Flexibility in terms of responding to changing consumer needs and emerging problems with electricity supply;
2. Availability of electricity to consumers, in particular renewable energy sources and high-efficiency local generation with zero or low emissions;
3. Reliability of electricity supply and quality of electricity while ensuring resistance to hazards and uncertainties;
4. Efficiency through innovation, effective management, rational combination of competition and regulation [3].

Fundamentally the new here is that all of the stated key requirements (values) are proposed to be considered as equal, but their degree of priority, the level and ratio are not common, normative for all fixed and can be defined for each subject of power relations (power company, region, city, household, etc.), basically and individually.

The practical application of the Smart Grid concept is positioned as a means of solving a range of problems in the electricity industry, such as reducing the damage of economic entities by improving the reliability and quality of electricity supply, the integration of renewable energy into the energy system, increasing competition in the electricity industry through active consumer behavior on the market, the integration of energy systems and the unification of markets. The effect of application is also an innovative impulse for the entire economy as a whole, due to the mass demand for research and development work in power engineering, electrical engineering, information and communication technologies, without which it is impossible to achieve a qualitatively new level of automation, control and management in the electric power industry [4].

Digital technologies and Smart Grid give a tangible economic effect in the form of reducing the cost of operation and development of the power system in the complex. At the same time, the purpose of such complex solutions is to achieve the same level of requirements for the reliability and quality of electricity supply at lower additional costs for extensive expansion of additional reserving capacity. A number of innovative solutions can be used for this purpose, including new generation control algorithms, new information processing and computing technologies, network condition monitoring systems, power supply centers and consuming devices, providing a qualitatively new level of automation and responsiveness to changes in power supply parameters in real time.

The promising solutions are the formation of micro-networks among consumers with the widespread implementation of new types of storage devices and the ability to manage their modes of operation as part of the power system and in Autonomous mode in the case of violations of centralized power supply. The global trend of liberalization of electricity markets, the development of competition first at the wholesale level, and then at the level of active penetration into retail trade makes it increasingly urgent to increase the activity of consumers in the formation of economically justified electricity prices. Management of volumes and modes of electricity consumption is a complex task that requires joint consideration of technical capabilities and economic incentives of the consumer when changing their behavior [5].

The dynamism of competitive prices and the expansion of opportunities for the development of their own generation motivate consumers to change their behavior patterns, but at the same time increases the risk of losing control of such a large centralized trading system. Efficiency and activity reaction - are two new qualities that the consumer should get on the basis of digital technologies and Smart Grid. The transition to dynamic pricing requires replacing the previous electricity metering systems with progressive real-time load measurement and control systems, including smart meters, which provide network subscribers with the ability to respond quickly to changes in the price situation.

The integration of power systems into larger power units, the formation of a single technological space with a common system of dispatching power plants will create significant economic effects due to such factors as improving the modes of capacity utilization and associated fuel economy, optimizing the volume of reserve capacity, their placement and transmission capabilities within the power unit, reducing the volume of additional construction of power plants and network facilities to ensure balance and regime reliability in individual power systems. The strategy of integration of power systems and markets on the basis of Smart Grid and digitalization will allow increasing capacity and intelligent methods of power transmission and flow management in a single network. The obvious systemic benefits make integration as a natural stage of evolution in the electricity sector of developing countries [6].

In terms of reducing losses in electrical networks, increasing the mutual responsibility of consumers and operators for the transmission and distribution of electricity,

Smart Metering technology is being developed and planned to be implemented as a component of Smart Grid, which includes digital technologies.

Smart Metering is a modern complex of hardware and software based on the latest world scientific and technical achievements, with the help of which it is possible to provide a qualitatively new level of reliability [7]:

1. Measurement of energy resources;
2. The control and management of their supply, transportation and consumption;
3. Automated transmission, processing and presentation of resource consumption information;
4. The formation of situational databases on energy consumption with the elements of information support for energy consumption management tasks.

Smart Metering technologies have proven advantages. For consumers, it is a decrease in payments for energy and power used, for energy companies - a decrease in consumption peaks and a decrease in investment in the build-up of peak generating capacity. Such systems allow the collection and remote transmission of all necessary data for operational control and commercial calculations of electricity consumption.

According to research by Zpryme Research & Consulting in some states of the USA due to the introduction of Smart Grid decreased peak load on the grid, about 10% decreased electricity bills, while the cost increased by 15%, and the use of Smart Grid technologies by 2020 will save about 1.8 trillion dollars by reducing energy consumption and improving the reliability of energy supply [8].

In Europe for the next 30 years the funding of programs on intelligent networks in the amount of 750 billion dollars is provided According to Cleandex Agency [9]. In Germany, Smart Grid was introduced into the systems of electric meters, and in 2010 GE Energy was engaged in the implementation of a pilot project for the installation of smart meters that collect information about energy consumption and use of utilities in individual households with its subsequent transfer to utility companies. Now, thanks to this, municipalities consume energy more efficiently, as well as reduce the negative impact on the environment. Also in 2010, GE Energy launched a modern center to demonstrate the capabilities of smart grids in China, demonstrating equipment that can improve energy efficiency in an emerging economy and reduce the negative effect of carbon dioxide emissions. According to the study of environmentalists, the use of intelligent networks will prevent emissions of more than 1 billion. tons of carbon dioxide into the atmosphere by 2020.

In the modern energy strategies of many developing countries, the development of digital technologies and Smart Grid is one of the key objectives, the achievement of which will lead to the sustainable functioning of the country's energy system. For example, in the Republic of Moldova, the Energy strategy 2030 presents goal No. 3, which is related to the introduction of intelligent electrical networks in the "green energy". Due to the fact that the distribution of renewable resources on the territory of the Republic of Moldova is scattered, and this is one of the weighty arguments in favor of the implementation of an intelligent network for the integration of these distributed resources, in cases of solar and wind energy fluctuations [10].

Economic estimates of the effects of Smart Grid development in developing countries in terms of demand management, power losses, large and distributed generation, reliability and quality of energy supply are expressed in a decrease:

1. Capital expenditures for the construction of new generating facilities, based on reduced capacity requirements;
2. Capital expenditures for the construction of power grid facilities, based on increased network capacity and reduced peak capacity;
3. Operating costs in generation and networks, primarily fuel costs, due to changes in input volumes and loading modes of thermal power plants.

Countries around the world pay great attention to the ecologization of energy production. According to NREL (National Renewable Energy Laboratory USA), USA carbon emissions will increase from 1,700 million tons per year in 2008 to 2,300 million tons by 2030. In this regard, NREL shows that companies through the implementation of energy efficiency and renewable energy programs can not only stop this growth, but also have the opportunity to reduce carbon emissions to below 1000 million tons of carbon by 2030 [11].

The implementation of digital technologies and the concept of Smart Grid in the energy sector will reduce carbon emissions by:

1. Increase the response to the demand or load management in order to minimize the use of expensive peak electricity, for which power units with relatively low fuel efficiency are used;
2. Promotion of energy efficiency by means of notification the consumers in the implementation of outreach information programs and pricing options;
3. Reducing the variability (volatility) of renewable energy productivity;
4. Integration of electric vehicles, distributed energy sources powered by wind and solar energy, and other forms of distributed generation.

Further development of energy systems in developing countries supposes three major stages: the increase in automation, which is characterized by high speed of the reaction of technical devices and control systems, as well as market entities to changing external conditions; improving the informatization and digitalization, this is due to the new level of observability and control status, control of operating modes of certain technical devices and the grid in General, information transparency mechanisms of the competitive market; increasing intelligence at all levels of control systems of the power system, which provides not only “response to the actual state”, but also “reaction to the forecast”, based on the assessment of likely changes in the state of individual devices, objects, systems, as well as market conditions.

In conclusion, it should be noted that the formation of the modern energy system is to implement intensive scenario of the industry development, which is accompanied

by a change in the functionality, i.e. transformation of existing or emergence of new properties in different structural segments and the energy system as a whole. Unlike previous approaches to energy development, the transition to an intelligent energy system is more efficient to start from the bottom up, from consumers and local power supply systems, creating distributed clusters of new energy, a new market environment in the industry. The experience of the world's largest energy systems shows the success of such initiatives in the framework of pilot projects, which are growing as individual technologies are developed, scaled up and integrated into complex technical solutions. This approach is both economically and technically feasible for developing economies.

III. CONCLUSION

1. The idea of creating and implementing digital technologies and Smart Grid in the energy sector is to operate an integrated, self-regulating and self-healing energy system that satisfy all the needs of consumers, is informative, transparent and easily controlled in real time;

2. The transition to an intelligent energy system in developing economies is attractive from an economic, technical and innovative point of view, because it helps to solve a wide range of problems in the energy sector, and forms a huge domestic market for new products and integrated services with significant export potential;

3. Flexible demand management, reduction of power losses, large and distributed generation, reliability and quality of power supply are reflected in the energy efficiency from the implementation of intelligent power system;

4. In many developing countries, there is no clear and formalized strategy of the state in terms of systemic support for such a transition as a priority direction of energy development. In this regard, the possibility of a faster and more successful transition to Smart Grid technologies in the energy sector becomes difficult, and the timing of their implementation increases. It should be noted that the magnitude as the required investment and the expected effects of a program of intellectualization and digitalization of energy in emerging economies show the need for extensive reformatting of the management system development in the energy sector with a strengthening of central role of the state as the main investor, ensuring, through the economic mechanisms of coordinating the innovation activities in the energy sector.

REFERENCES

[1] Smart Power Grids - Talking about a Revolution. IEEE Emerging Technology Portal, 2009.

[2] European Commission Directorate-General for Research Information and Communication Unit European Communities: «European Technology Platform Smart Grids, Vision and Strategy for Europe's Electricity Networks of the future», European Communities, 2006

[3] European Technology Platform SmartGrids. Strategic Deployment Document for Europe's Electricity Networks of the Future. April, 2010.

[4] Doronichev D. A., Gusak G. Yu. Current trends in improving the efficiency of the electric power industry: from restructuring to innovation.// Bulletin of Nizhny Novgorod state University. N. I. Lobachevsky, 2012 No. 2 (2),p. 86-94.

[5] Kobets B. B., Volkova T. O. Innovative development of electric power industry based on the concept of Smart Grid. - Moscow: Energia, 2010. - 208 p.

[6] Zaitsev A. I. Development of electric power systems based on the concept of Smart Grid / / Electrotechnical complexes and control systems, № 1 2013. - p. 71 - 76.

[7] Report of the Ontario Smart Grid Forum: "Enabling Tomorrow's Electricity System".

[8] Electric Power Research Institute, Electricity Sector Framework for the Future Volume I: Achieving the 21st Century Transformation / Washington, DC: Electric Power Research Institute.

[9] Vincenzo G., G. Flavia, Gianluca F. (JRC-IE), Manuel S. J. (DG ENER)/ Smart Grid projects in Europe: lessons learned and current developments//Luxembourg: Publications Office of the European Union 2011 -118 p.

[10] Energy strategy of Moldova until 2030, approved by Government Resolution No. 102 of 05.02.2013.

[11] National Renewable Energy Laboratory, Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs — FY 2008 Budget Request, 2007.

[12] Fedorov, M. P., Okorokov, V. R. Okorokov, R. V. Energy Technologies and World Economic Development: Past, Present, Future. Saint-Petersburg, Nauka, 2010 - 412 p.

[13] Kupriyanovsky VP, Dolbnev AV, Volkov SA, SA Sinyagov, Seleznev S. P.

Intelligent substations as the basis for a strong intelligent grid / V. P. Kupriyanovsky // ArcReview. -2012 - No. 2 (61). - P. 137-149.

[14] Michele de Nigris, Francesca C., Rainer, B., Marie L., José T./ Synergies and complementarities of European and International initiatives towards energy transition - March 2019, 165 p.

[15] ledin S. S., Ignatichev A.V. Development of industrial standards for intra-and inter-system data exchange of intelligent energy systems / / automation and IT in energy, 2010, No. 10.