

Development of intelligent energy systems: the concept of smart grids in Uzbekistan

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Abstract. In the process of energy reform, liberalization and deregulation of the electricity market, a number of features have been identified that are related to the fact that in the conditions of market relations, the economic benefit and the price of electricity for consumers become a priority. There is certain isolation of networks and power lines from generation facilities; attention is lost to such an important problem as the reliability and safety of power supply. In this situation, the load on the power elements of the electric network increases, there is a need to create appropriate reserves of generating capacities, to increase the throughput of electric networks. All this involves increasing the role of system operators and improving supervisory control systems. The strategic goal of this study was to analyze the development of the electric power complex by the creation of smart grid systems as a platform for market, managerial and technological innovations that provide a transition to a new level of development of the electric power industry in Uzbekistan.

1 Introduction

In the last decade, the Smart Grid concept, which means an intelligent power system, has been actively discussed and developed abroad. In the USA and the European Union, it is considered as a technological concept of the electric power industry of the future [1-3] and it is, in fact, the state policy for the technological development of the electric power industry of the future.

There are various points of view on the concept of intelligent networks [4]. This explains the fact that, despite the relative similarity of the main factors in the development of intelligent networks in different parts of the world, the priorities are different. For example, in the EU, the priorities are the problems of integrating renewable energy sources, energy efficiency, as well as integrating the EU markets within the framework of a carbon-free economy, while for the United States, such problems as disruption of energy supply, situations of peak power consumption and aging of production facilities are priority. In China, the rapid development of the energy system, the need to unite large wind farms in the northern regions and create links between different provinces is the most urgent priorities.

The most general and technically complete definition of the concept of Smart Grid was formulated by scientists from the Institute of Electrotechnic and

Electronic Engineers (IEEE). So, according to their definition,

Smart Grid is a fully integrated self-regulating and self-renewing electric power system with a network topology that includes all generation sources, trunk and distribution networks and all types of electricity consumers, which are controlled using a single network of information and control devices and real-time systems. In fact, an intelligent electric network unites not one, but two networks – an electric and information-control network, which closely interact with each other and function simultaneously. Moreover, the management and control of each device of the electric network are carried out using the necessary “intelligent” devices, combined into a single information-control network.

Despite the existence of a number of definitions of the concept of intelligent energy systems, they can be generalized by defining an intelligent energy system as a combination of energy infrastructure and embedded / distributed information and communication technologies (software, automation, information processing). The combination of two infrastructures provides the necessary “intelligence”. This intelligence can be represented at different levels of the network (generation, network software, consumption, monitoring and control). Three basic principles of Smart Grid can be distinguished: security, standardization, integration.

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The reasons for the transition to Smart Grid are as follows: reduced predictability of demand behavior; the emergence of consumer generating ability and the need to return electricity back to the network; low energy efficiency and environmental friendliness of a grid built on analogous principles and technologies; digitalization of management of individual network elements and the risk of reducing their ability to mutual integration; the problem of the stability of hierarchical energy systems.

The main competitive advantages of smart grid technologies are: local measurement and monitoring; remote measurements and control; multi-information measurements and monitoring; controlled measurements and monitoring; general improvement in the quality of electric energy; low operating costs; minimization of expensive visual inspections of the system; automatic recording of time and operating parameters of specific equipment for timely preventive repairs; reduction of electric energy losses, improvement of environmental conditions, minimization of light and noise pollution; the best level of reliability and security; quick response to changes in external conditions; quick and easy access to the system database. The development of Smart Grid technologies also means a fundamental reorganization of the market for electric energy services [1, 2, 5-8].

Already today, the world has developed the understanding that a quick transition to the ideal Smart Grid model is impossible. In this regard, three generations of Smart Grid have been singled out, which make it possible to gradually move towards the target model: Smart Grid 1.0 – state of the electric power infrastructure, in which individual devices and system objects can be connected to the network without using common digital standards; Smart Grid 2.0 – the state of the electricity infrastructure, in which the connection of any system nodes is possible only if it is switched to a single IP protocol and included in a single integrated IP network; Smart Grid 3.0 is a flexible energy system that is based on the principles of decentralized management and equal rights for consumers and suppliers.

Hence, this study aims to present possible list of stages of the concept for creating smart grids in Uzbekistan by analysing the development of the electric power complex via creation of smart grid systems as a platform for market, managerial and technological innovations that provide a transition to a new level of development of the electric power industry.

2 Construction features and components of intelligent control systems

Today, the complexity of managing the electric power system is so high that fully centralized management becomes ineffective due to the presence of huge flows of information, when too much time is spent on transferring it to the center and making decisions [4, 6, 8, 9, 10, 11-13]. Control systems include a number of subsystems with different functional characteristics and interacting with various specialists, remote from each other. Therefore, some elements of organizational management

should be transferred from the center to the periphery with a clear delineation of rights and information access. The management system of the UES of the upper level should be a coordinating information management system that operates on the basis of appropriate standardized protocols and interaction interfaces.

The construction of a traditional control system of the unified electric power system (UEPS) is carried out according to the hierarchical principle with allocation of zones of responsibility for managing a certain level of the hierarchy [11-13].

A calculated union of groups of nodes that have “strong” connections with each other into one “equivalent” node with a total generation and consumption in this node takes place at the highest levels of the control hierarchy, and control is carried out by “weak” connections between these nodes for the output of parameters characterizing their work outside of normal mode. For each of the control levels, the processes of normal functioning are determined when disturbances in control node do not lead to an imbalance between consumption and production, and also do not cause disturbances in the connections operation between the nodes. In this case, the control carries out the process of transition from one stationary state to another, optimizing the current processes (modes) of the power system.

Power system objects are owned by various organizational structures with various commercial interests; therefore, when organizing the management process of such a complex object, it is necessary to take into account the market nature of relations between them, solving problems of resolving a conflict of interest. Therefore, commercial agents also function at each level. The infrastructural limitations associated with the insufficient bandwidth of many communications dictate the need to divide the common electric power system into electric power segments of UEPS.

Reliability issues in modern power grids are becoming increasingly problematic. The factors that determine the occurrence of these problems [9-13]:

- increased network congestion due to uncertainty, diversity and distribution of energy supply, taking into account environmental concerns and sustainable development; real-time electricity flows can significantly differ from those imposed during design or on-line analysis;
- increase in the number of powerful power lines over long distances contributes to the growth of instability and reduce the margin of safety; this phenomenon is reinforced by energy markets;
- the network is managed from one “end” from various locations and often taking into account the “lack” of investments and the restriction of land allocation; increase in energy consumption and peak demand creating a “conflict” with limited transmission capabilities; infrastructure aging; maximization of asset utilization thanks to modern technologies for monitoring, analysis and regulation;
- a consolidation of operator companies contributes to an increase in “area (covered by networks)” with more complex problems and requires more accurate

information and shorter time to make decisions; this problem is exacerbated by a lack of qualified personnel due to aging staff.

Under ideal conditions of demand management, energy storage and electric vehicles will be closely coordinated with other resources, so the total energy consumption will be almost uniform. This suggests that the network will be operated according to the conditions of near-peak load for almost the entire time. First, a decrease in total power consumption led to an increase in reliability by reducing the peak. However, over time, in the face of an increasing load, opportunities for optimal transmission and use of distribution assets, total energy consumption will approach the ultimate capabilities of the power system. Thus, a system will be close to the "limit" much more often, which leads to a greater likelihood of failures and exacerbation of reliability problems, respectively, the need for intelligent networks will increase.

The implementation of the Smart Grid concept provisions for a construction of an intelligent electric power system (IEPS) requires ensuring reliability through the use of modern information and communication technologies (ICT) in order to create an infrastructure that would ensure the coordination of monitoring and regulation throughout the network. Such an IT infrastructure should ensure trouble-free and almost instant two-way interaction between all devices - from individual loads to network control centers, including all basic equipment at the transmission and distribution level. This requires the processing of a significant amount of data for analysis and automation, which is associated with a high-performance infrastructure capable of delivering highly intelligent local pre-second reviews coordinated with higher-level global analysis to prevent or contain rapidly occurring adverse events. The centralized system was too slow for this kind of task. Distributed architecture allows you to create a high-performance infrastructure with a local intelligent pre-second response using modern technologies, which is based on the following:

- advanced telemetry: using PMU technologies for faster, time-stamped, clearer, second-second scans to provide up-to-date information about the network status;
- devices for faster regulation: using powerful electronics for faster automatic regulation, voltage and power flow control at the level of transmission and distribution;
- more robust regulation: actively adaptive regulation of protection and control for a wide area of monitoring and regulation, including an international division of UEPS;
- embedded smart devices: in order to prepare for the use of adaptive intelligent control: diagnosing equipment level failures and poor-quality data identification; operations within the limits are remotely reported by the system operator or regulatory centers; "Intelligent" RAS / SPS etc .; automatic equipment recovery; automatic local regulation; integrated and secure communication systems: distributed and comprehensive communications based on open standards, which allow creating flexible network configurability for the purpose of trouble-free monitoring, automation, two-way communications between all operators and agents;

- use of computer capabilities: trouble-free and secure systems for reliable analysis in order to support the decisions of the operator and stand-alone functional agents controlled by a geographically and time-coordinated hierarchy in IT infrastructure of the network;

- Internet technologies: internet protocols to simplify the exchange of data, a regulatory process and cyber security for implementation of a distributed architecture based on standards with open interfaces.

The hierarchy of control levels in an intelligent electric power system reveals the concept of "smart grids" as a combination of energy and information and communication technologies, representing the possibility of more efficient management of UEPS through the exchange and management of technological and marketing information.

3 Intelligent forecasting in IEPS

The development data of recent years is focused on the development of predictive approaches based on algorithms and methods of artificial intelligence: neural network technologies, expert systems, machine learning models, fuzzy calculations, etc.

Despite the advantages of intelligent forecasting algorithms, indicated in a number of articles of recent years, many researchers believe that the issue of high efficiency, for example, artificial neural networks (ANNs) or fuzzy systems, in solving the problem of predicting aircraft is still open. An intelligent solution to the above cases is the use of hybrid approaches and models, when the combination of various intelligent and traditional models allows you to get the most effective solutions, first of all, guaranteed forecast accuracy. The following combinations can be attributed to promising hybrid models at this stage: fuzzy systems and ANN, expert systems and ANN, Hilbert-Hung transformations with ANN models, etc.

The concept of intelligent monitoring includes the following actions [12-15]: collecting data that is fed to data pre-processing systems that determine the most important and critical data that affect the development of the regime; classification (clustering) of EEC states - the purpose of this procedure is to determine how dangerous a particular state of the system is; interpretation of the resulting clusters (states) so that an operator can develop and implement preventive measures.

For operational dispatching control of the International Electrotechnical Commission (IEC) modes, new means of measuring the regime's parameters of power systems (Phasor Measurement Units, digital measuring instruments) and controlling them (FACTS, energy storage, etc.) should be used, which radically increase the observability and controllability of power systems, modern means of communication, new information technologies and methods of artificial intelligence, high-performance computer tools. They fundamentally change the processes of collecting, processing, transmitting, presenting (visualizing) and using information, and on a new basis, they can

significantly increase the efficiency of operational dispatch control of modes. The development of operational dispatch control methods is associated with IEPS improving information support, automating the preparation of operational solution options, automating management, increasing a share of automatic control in the tasks of regulating and limiting mode parameters, automating the calculation of optimal modes, implementing them, etc., while maintaining control from operational dispatching staff in the required amount [16-19].

Today, the problems of constructing intelligent distribution networks relate mainly to their development on the basis of modern telemechanics and telecontrol facilities, as well as data transmission channels. However, the basis for the optimal functioning of the intelligent network should be provided by control algorithms and software.

The source of information for the operational control system can be the telemechanics devices of the main step-down substations. Distribution network power centres usually have the following telemetry: tire voltage, total active and reactive load, and current load of feeders. If there are reclosers in some feeder branches, the one can additionally obtain information about the current of the site and the voltage of the node at a place of its installation. The recloser at the point of opening the network allows you to control the voltage of the nodes, the difference of which allows evaluating the current efficiency of installed breaks. The observed mode parameters with a fixed operational scheme allow us to estimate the magnitude of nodal loads, using, in addition to telemetry, statistics regarding the loading of transformer points.

Based on the results of an operational assessment of the state of each feeder, it is possible to search for optimal control actions using well-known methods for analysing the modes of electric networks. Today, these methods, as a rule, are developed on the basis of an iterative solution of systems of nodal nonlinear equations and are focused on calculating the modes of multiple closed networks. Unlike the backbones in distribution networks, the design diagram is open in accordance with the operational position of the working openings, the graph of which is represented by a set of branches forming a tree and chords corresponding to disconnected branches.

One of the control tasks in distribution networks is to find the optimal operational circuit and mode parameters when changing loads, supply voltage, etc. Optimization criteria for the hourly step of the graph are power loss, quality and reliability. Often, they are contradictory; therefore, a search for the optimal solution is carried out in the Pareto region. However, such multicriteria problems can be reduced to one criterion. Reliability can be taken into account as a restriction on the acceptable parameters of the mode and fixing some openings in the network to provide power to responsible consumers from two sources.

The quality criterion can be estimated by the minimum release of energy at voltages that go beyond

the permissible region, which can be individual for each characteristic consumer.

Independent parameters for optimizing the parameters may include: voltage level in the power centre, which is determined by the number of a soldering regulation under voltage, a reactive power of small generation plants and the position of the cuts on the full network graph.

4 The development of smart grids concept in Uzbekistan

World experience shows that smart grids can be built in several stages. The first stage is the development of the concept of building a smart grid. The second and third stages can be implemented in parallel: work on the creation of interfaces that can connect the modernized facilities of the main electric grid economy with generation and consumers which is simultaneously carried out with the development of pilot projects, within the framework of which technologies are being developed for the creation of intelligent power system (IPS). Fig. 1 highlights the basic concept for smart grid development in Uzbekistan.

Possible list of stages of the concept for creating smart grids in Uzbekistan:

1. New solutions and technologies (breakthrough and improving): new types of electrical equipment, including new systems for monitoring the condition of equipment, self-recovering, relay protection and emergency automation, energy metering systems.

2. Information interaction and control systems: the creation of information infrastructure, its integration with the electric grid, information support and optimization systems for managing all processes in the electric network.

3. Regulatory aspects: a new range of services that is provided by electric power industry entities; normative distribution of roles in the interaction of electric power industry entities in the new conditions, including the development of network rules.

4. Creation and implementation of pilot projects (energy clusters): integration of electric grid and information infrastructure, integration of all types of generation, energy storage systems; creation of an all-regime management system with full-scale information support, optimization management systems; selection of zones for the implementation of pilot projects, assessment of technical, economic, environmental and social effects.

5. Duplication of results, cluster consolidation, creation of intelligent energy systems in Uzbekistan, replication of the successful results of pilot projects, integration of energy clusters into a single electric power system.

Expected results from the implementation of Smart Grid:

- 1) the most efficient use of energy resources;
- 2) removing the network economy from the crisis by replacing obsolete equipment;
- 3) reduction of electricity losses, its significant savings;

- 4) reduction of emergency shutdown time; increasing the efficiency of loading electrical equipment;
- 5) increase in volumes of electricity transit by 15–20% without the construction of new network facilities;
- 6) reduction in energy production costs;
- 7) reduction in the cost of utilities;
- 8) the use of alternative energy sources;

- 9) reduction of the environmental impact of energy facilities (reduction of CO₂ emissions in the atmosphere);
- 10) providing a model of two-way communication with the consumer;
- 11) identification of a theft of electricity, equipment damage and their timely elimination.

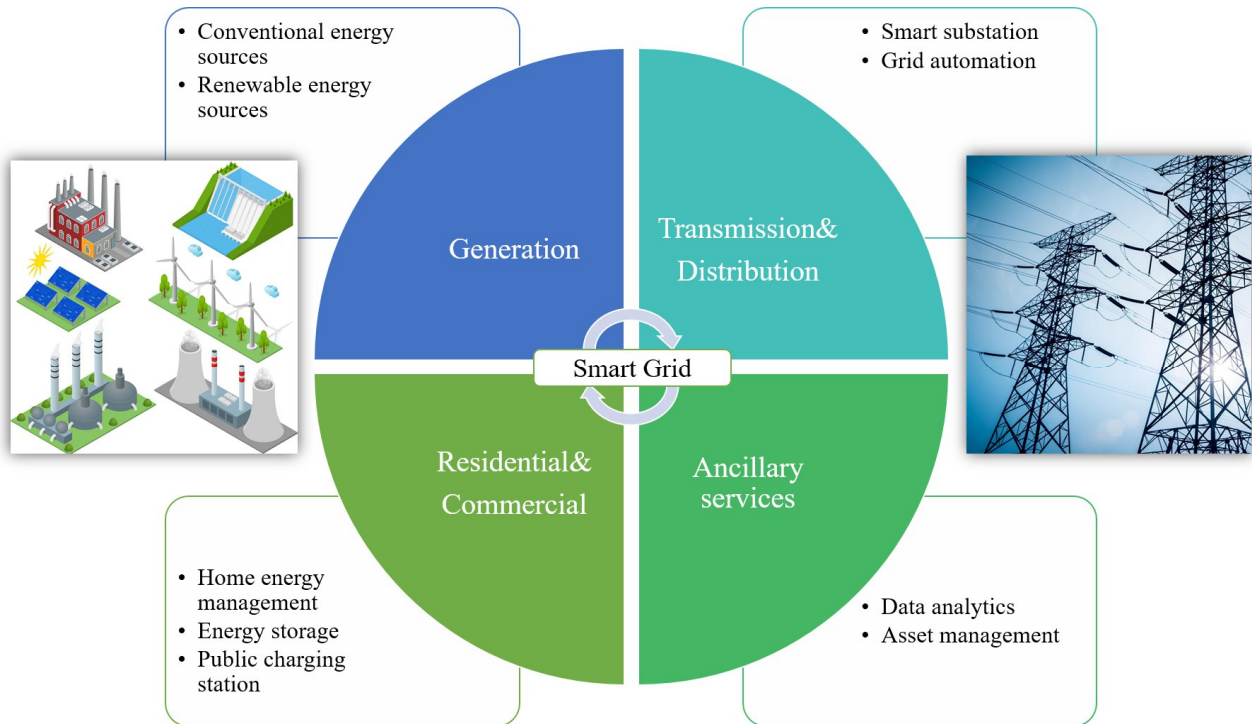


Fig. 1. The basic concept of smart grid development in Uzbekistan

Advancement of the Smart Grid concept requires a change in many elements of the power system. Their success depends not only on installing new meters and improving the efficiency of electricity supply but also long-term measures are needed, such as the development of power electronics and devices based on it, primarily various kinds of network-controlled devices (flexible AC transmission systems – FACTS) to increase line throughput and ensure stable operation of the power system under various disturbances, widespread development of distributed generation and renewable energy sources. It should be borne in mind that various technologies of the smart energy system are being introduced on the market and at different speeds.

Another obstacle to the comprehensive implementation of the concept of an intelligent energy system is the difficulty of reconfiguring the relationships between electric power entities, since the implementation of Smart Grid concerns all direct participants (individuals and legal entities of any form of ownership) of the processes of production, transmission, distribution, consumption, purchase and sale of electric energy.

Accordingly, the scope of such a project is commensurate with the scale of creation of a new electric power system, including the depth of elaboration and detailing for each individual power receiver.

The introduction of innovative technologies is connected with the solution of two critical issues that will allow a fresh look at the relationship between the consumer and the energy company: providing the consumer with two-way control technology that can help manage the declared peak power; an implementation of dynamic pricing in the retail electric energy market, stimulating consumers to change their usual load schedules.

5 Conclusions

Thus,

- the tasks of the electric power systems development were formulated,
- the main directions of the intelligent electric power systems development were evaluated,
- the necessary technological basis was described,
- the requirements for the areas of use of IEPS were sufficiently detailed,
- the construction features and the components of intelligent control systems were presented.

The introduction of Smart Grid leads to a change in the energy system's functioning technologies (direct consumer load management, dispatch modelling, real-time distributed system analysis tools, demand response analysis, system emergency recovery support, etc.), to a

change in the energy management system (new architecture program security, management system), to the formation and growth of new markets. It is possible that smart grids will not only contribute to the modernization of the Uzbekistan energy system, but will also help to create a new electrical base for the production of equipment.

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