Power Grid Infrastructure Modernization by the Implementation of Smart Grid Technologies

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1 Introduction

The power grid sector is one of the basic sectors providing the development of the national economy. This branch has a great impact on the development of other sectors and economy in general, and it means that ensuring reliable and high-quality power supply is an essential factor of economic and social stability.

The main questions faced by power grid companies, nowadays, are:

1. Current condition of grid infrastructure
2. Crucial problems demanding solution and expansion
3. Technical solutions that may be applied for current or future problems

The choice of appropriate technologies is the key aspect of giving the answers. Modern technologies of power grid infrastructure management are united by a catch-all term Smart Grid, the main elements of which are presented in Fig. 1. Various elements of Smart Grid technologies are relevant for different countries. These elements are determined by certain characteristics of power grid infrastructure of the given countries (Table 1).

Management of renewable energy sources that demands advanced technologies in regard to dispatching automated and remotely operated control is relevant for Europe. In the USA, much attention is paid to demand response, and smart metering prevails there. In BRICS countries, acute problems are outdated equipment and

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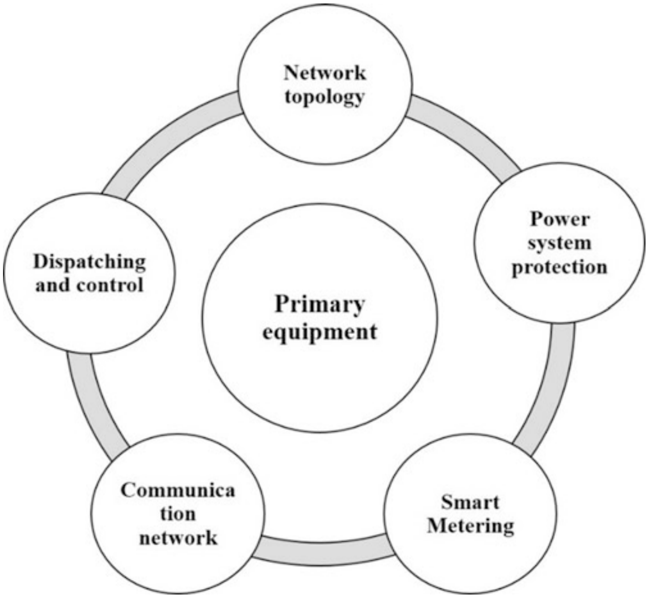

Fig. 1 Smart Grid key elements

Table 1 Characteristic features of Smart Grid technologies for different regions

Region	Characteristic features	Relevant Smart Grid technologies
Europe	Renewable sources Circular cable systems Widespread distributed generation CO_2 emission abatement	Medium and high voltage systems automation (hereafter MV and HV) GIS (geographic information systems), OMS (outage management systems), DMS (distribution management systems) Variable-delivery transformers for medium-voltage system Microgrids; smart metering
USA	Demand response Radial grids with overhead lines Unbalanced load Renewable sources	Microgrids; smart metering Demand response DMS, OMS, GIS High-voltage systems automation SCADA (supervisory control and data acquisition system)
BRICS countries	Outdated equipment Business losses Single-point large-volume generation	Medium- and high-voltage systems reconstruction and automation; SCADA for medium- and high-voltage substations DMS, OMS, GIS Smart metering

energy losses; therefore, comprehensive grid modernization could be the method of solution.

Realization of one or another Smart Grid technology is designed to achieve the key purposes of power grid companies, in particular, to ensure [1]:

- Security of supply and energy quality
- Flexibility in the context of response to the network failures

To determine what Smart Grid means for the Russian Federation, it is necessary to thoroughly analyse the characteristic features of power grid infrastructure in Russian cities.

2 Performance Review of Distribution Systems of Large Cities in Russia and the CIS

A typical condition of city electrical grid in Russia and the CIS is described below through the example of the network in Ufa, Bashkortostan:

- Ufa's electricity supply is carried out by electricity networks of several voltage levels, 110/35/10/6/0.4 kV. Supply centres are 51 high-voltage substations (35, 110 kV). The overall number of 6–10 kV transformation stations is 2178.
- The network of 6–10 kV is mainly a simple open radial scheme, based on underground cables.
- Operational monitoring of power facilities parameters (power, currents, voltage levels) and switching off devices positions at substations of 35 kV and higher are implemented with an operational information complex (OIK – Dispatcher) in real-time regime. However, observability and remote control do not exist in 6–10 kV transformation stations and 0.4 kV network.

The described situation has significant drawbacks in comparison with the world's leading practices of the power grid management, and it is typical for the majority of large cities in Russia and the CIS. The average number of disconnected consumers and average outages duration in the network of "Bashkirenergo" exceed the corresponding figures in European countries [2] (Fig. 2). Alongside this, energy losses in Russian cities figure up to 10–15%, suggesting a significant potential for reduction (Fig. 3).

Benchmarking results show a significant gap between the operating efficiency of Russian and the CIS power grid companies and industry world leaders in the field of power grid infrastructure management.

Alongside this, depreciation of the equipment obsolescence also takes place. According to many positions average performance standards of the installed substation equipment of "Bashkirenergo" correspond to the equipment that was run in advanced countries 30 years ago.

To sum it up, a conclusion could be drawn that power grid infrastructure of big cities in Russia and the CIS has four characteristic system problems:

1. Poor reliability due to tough topology, which makes hard to identify a point of fault, fault condition spreads over large grid sections and loss in reliability due to cross-linking bonds

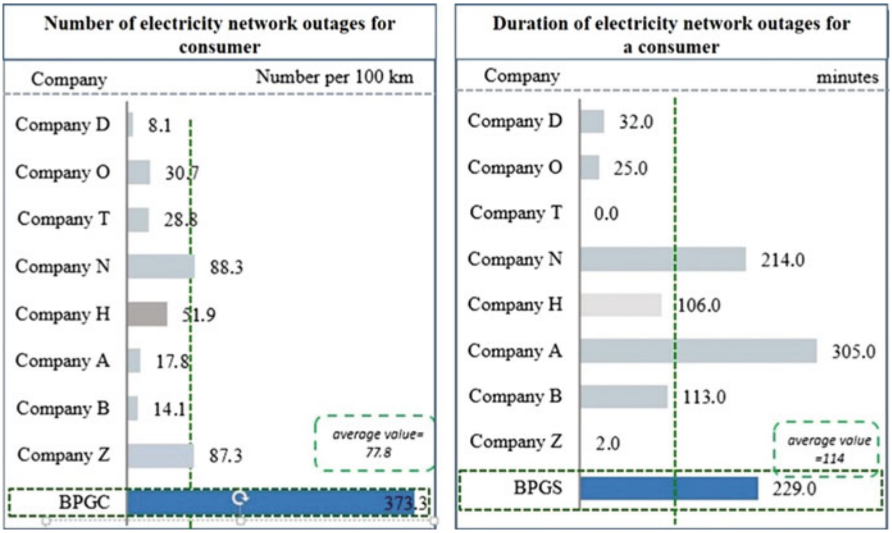

Fig. 2 Number of electricity network outages and outages duration as compared to European countries [3]

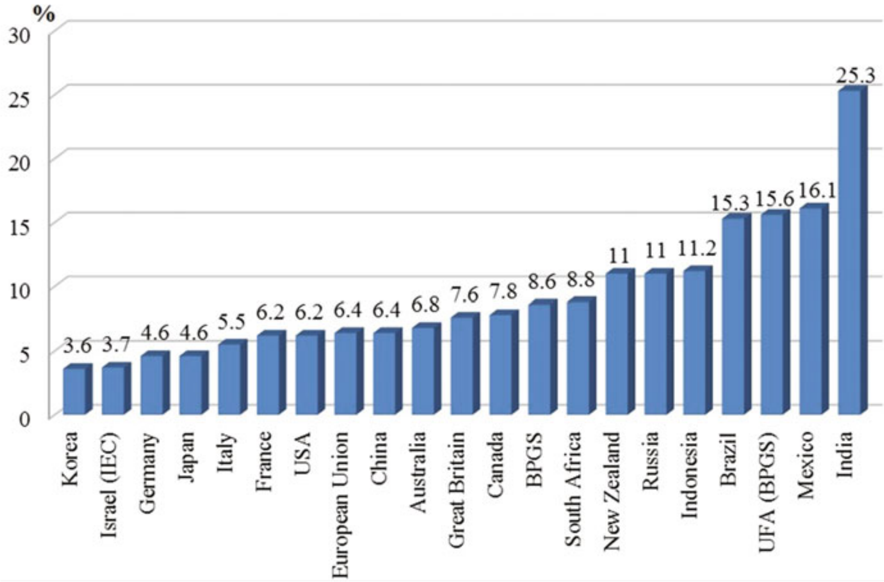

Fig. 3 Energy losses in different countries [4]

2. Poor manageability: absence of remote control and impossibility of control standardization
3. Relatively high energy losses and equipment depreciation

Taking into account the system problems stated above, the following elements of Smart Grid technologies are proposed to be relevant for the Russian Federation: network structure optimization by modern switching equipment; automation of network control, including its observability and remote control providing; automation of dispatching control; building the system of smart metering; and establishing cybersecurity of power facilities.

To determine Smart Grid technologies for future implementation, it is necessary to prepare a feasibility study for each city in review [2].

The work structure as defined within the feasibility study included:

1. Collection of initial data and modelling the city power grid
2. The analysis of grid current condition by applying the developed mode
3. Preparation of different scenarios of power grid perspective development, including the grid model and automation technologies offers for each scenario
4. Cost-benefit analysis for each scenario and selection of the preferred one
5. Plan preparation for the transition from the current situation to the power grid target model

The described approach is quite different from a traditional one applied for working out development programmes and schemes in the Russian Federation: to prepare the “as is” model, procedures both for providing projected increase in energy consumption and network topology optimization are offered. Moreover, this approach includes measures for grid automaton and power system protection improvement, for implementation of Smart Grid and connection systems.

In accordance with the results of feasibility study, “current power grid optimization and automation” and “building of electricity commercial metering system” measures turned out to be the best in the context of development prospects of Ufa’s power grid infrastructure.

3 Comprehensive Modernization Project of Ufa Power Grid Infrastructure

Within the framework of a feasibility study, a comprehensive plan of transition from the current situation to the target model with an activity progress chart and detailed estimation of capital investments required was worked out. The transition plan is intended for 5 years and includes the following stages: reconstruction and automation of 512 substations including observability and remote control and reconstruction of Ufa power grid management centre with implementation of SCADA-system, all related systems and 80,000 metering instruments setup.

The calculations showed that upon the transition from the current situation to the target model, the following effects will be reached:

- Business losses reduction by 80% from the current level
- Technical losses reduction by 30% from the current level

- Reduction of power outages duration owing to reduction of failures by 50%
- Economy of time for faults searching and switching by 70% due to grid observability and structure optimization
- Current equipment service life extension by 10%

That sort of a project is being implemented in Russia for the first time. Hence, to choose the best technical solution for the main project tailored for 5 years, JSC “BPGC” made a decision to execute a pilot project in Ufa in the following steps:

- Reconstruction of two distribution and five transforming substations of “Bashkirenergo” Ufa’s East Region Electric Power Grids
- Construction of the network management centre building (hereafter NMC)
- Creation of the automatic dispatch system of the network management centre, including PSI and multiple depiction system.

The sketch map of the pilot region network section and the entire Smart Grid project is presented in Fig. 4. The pilot project is being executed by “BPGC Engineering” – affiliated company of JSC “BPGC.” During the pilot project execution, JSC “BPGC” specialists worked out an innovative approach to the grid automation that provides complex observability and manageability while reconstructing only 25% of equipment.

Based on the data collected during the pilot project implementation, preparation for the main stage of the project is ongoing at the moment – Ufa power grid reconstruction is being designed. Also, it is necessary to point out that a number of problems occurred during execution of the pilot project.

Due to different approaches to grids manageability in the Russian Federation and western countries, difficulties in direct adaptation of western solutions and necessity to consider specific features of Russian cities’ network structure occurred while performing the feasibility study. It was essential to establish technical solutions for further extension at the stage of design and survey work. While addressing the issue, the decision was made to focus on modern standards instead of traditional solutions of automated technological process control system concerning data communication protocol, remote supervision and surveillance. Protocol 61,850 was chosen as the data communication protocol.

The following difficulties arose at the stage of the pilot project execution: dependence on the equipment manufacturer on the part of production time, delayed delivery of switchgears, difficulties in equipment installation due to its complexity and division of responsibilities between the customer and the supplier and significant cost overrun. As a solution, it was decided to launch own manufacturing of the power network equipment to downplay the problems stated above.

For implementation of Ufa power grid comprehensive modernization project with Smart Grid technologies applied, an assembly of smart distribution devices based on “Siemens” switching equipment started up on the territory of the Republic of Bashkortostan by virtue of the agreement between “Siemens” LLC and JSC “BPGC.” All secondary circuits are assembled by JSC “BPGC.”

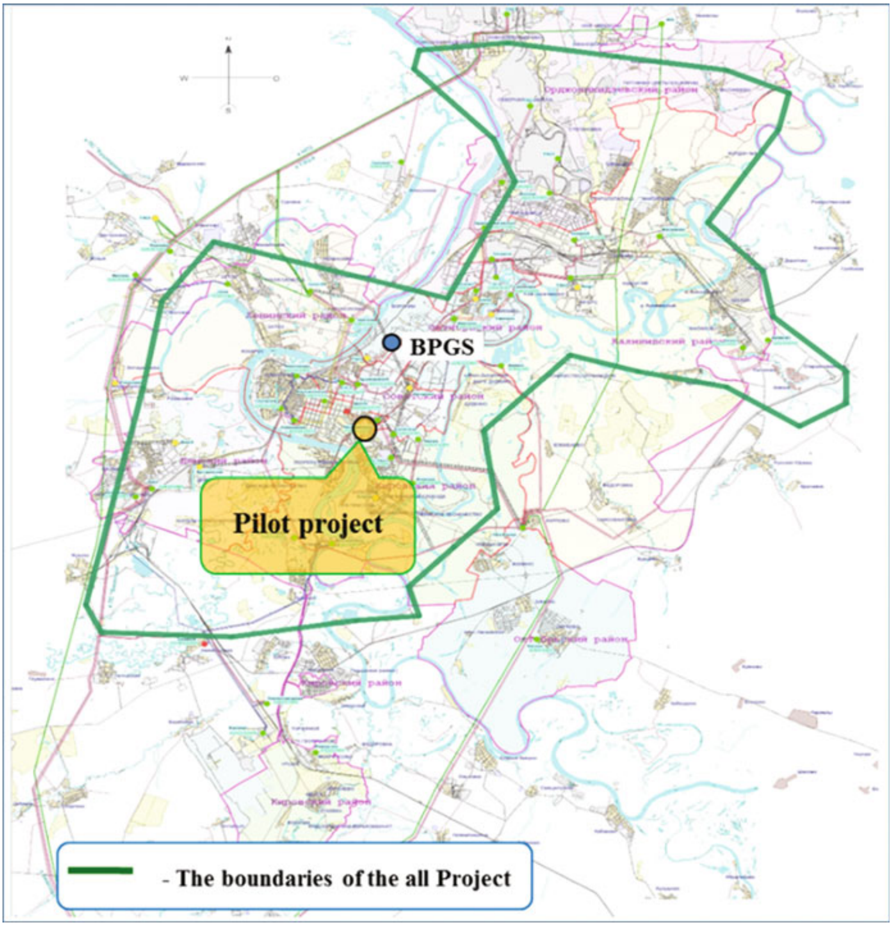

Fig. 4 The schematic map of Ufa electrical grid

Table 2 The analysis of price relation of various electrical switchgear producers

Technically identical electrical switchgear	Price relation, ea
European analogue	3.2
European equivalent	1.5
Domestic equivalent	1.3
Domestic equivalent	1.1
Gas insulated switchgear 8DJH Siemens 1250	**1.0**
Domestic equivalent	0.8

A pricing policy review showed that the gas insulated switchgear 8DJH by JSC "BPGC" and "Siemens" competes with the equipment of low-price segment regarding its price and with expensive devices one regarding its quality (Table 2).

Thanks to the usage of component parts by different producers, the balance between functional characteristics, price and quality of electrical switchgears relevant for power grid reconstruction projects was reached.

JSC "BPGC" will be able to reduce the volume of investments required for the project by setting up its own production. Besides, it will establish a centre of excellence in the Republic for further distribution of Smart Grid technologies in other regions of the Russian Federation.

JSC "BPGC" is the first power grid company in Russia implementing Smart Grid technologies. Best practices of JSC "BPGC" in implementation of power grid comprehensive modernization with Smart Grid technologies and production of modern electrical equipment necessary for it in the Republic of Bashkortostan are highly important and have great opportunities for power grid modernization in the cities of Russia and the CIS.

4 Conclusion

Based on the pilot project implemented in Bashkirenergo, the following are concluded:

1. Smart Grid implementation is impossible without a preliminary feasibility study.
2. Technologies providing observability and manageability are preferable for Russian power grids.
3. To ensure successful implementation of the technologies, it is reasonable to test them within a pilot project framework.
4. To provide sufficient speed and flexibility of the order execution, the company performing the comprehensive reconstruction must cooperate with the manufacturer of the equipment in use.
5. The company implementing Smart Grid must develop skills sets in the sphere of checkout of this equipment in order to be able to reconstruct it more flexible and independent from the contractor.

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