EXPERIENCE OF SMARTGRID IMPLEMENTATION IN ELECTRIC SYSTEM OF UFA CITY FOR OPTIMIZATION OF THE DISTRIBUTIVE ELECTRIC SYSTEM OPERATION EXPENSES

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ABSTRACT

This report focuses on the experience of metropolis power-supply system modernization through introduction of the SmartGrid international best practices. They solved systemic issues: low reliability, low controllability in case if standardization is not possible and there is no distance control, as well as a problem of high electric energy losses. While integrating SmartGrid into the Ufa city electric system the needs of electric distribution company in infrastructure development were taken into consideration. Based on the project experience key role in the SmartGrid implementation in large and complicated megalopolis distribution network is played by 100% observability of each grid node, detailed power metering in all key points and automated event analyses. The report describes the implementation process of the Smart Grid project, including the improvement of monitoring devices, and the achieved effects.

INTRODUCTION

Nowadays half of World's population is living the cities and according to forecasts urban population will reach 60% by the 2030[1]. Successful growth of city is highly depend on is energy system growth and improvement. Russian innovative energy company JSC BESK, who own transmitting and distribution power grids 0.4 to 500kV, during last 3 years implements complex renovation of the energy system based on SmartGrid principles.

Prior the project start Ufa city power distribution grid had a lot of system issues which prevent it's effective grown like usage of old and outdated equipment (at the most equipment production year was about 1970-1980), unsystematic building of the grid and significant load increase (up to 1/3 of total regional power capacity). City population and territory grown makes it harder to get operational access to the grid facilities while intensive construction inside existing areas cause demand to increase grid capacity without building of new power supply facilities as there is no space for them.

Based on results of the comparative analysis reliability index and power losses along with information about equipment wear in some large cities it was concluded that the following problems are most actual:
- low reliability;
- low control ability;
- high electrical energy losses;
- obsolescence and physical wear of equipment.

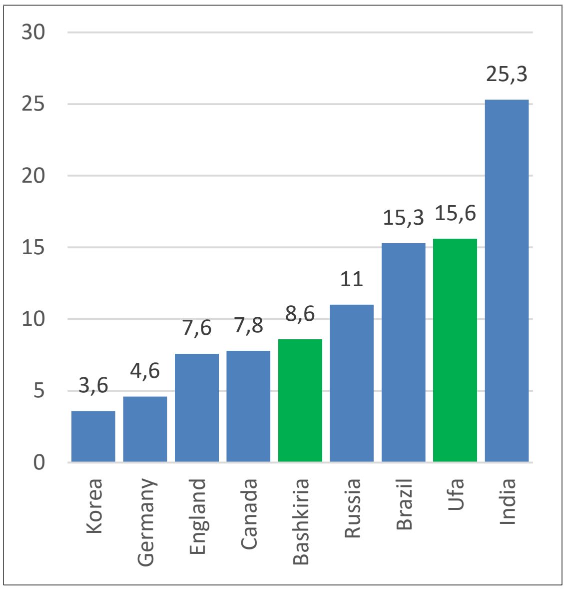

Fig.1. Power losses at the grid of different regions and Ufa city [2]

To select the set of required power grid control and monitoring base technologies that should be implemented (claimed as Smart Grid in total) it was taking in account specific characteristics of Ufa city power systems as well as forecast information regarding its future development.

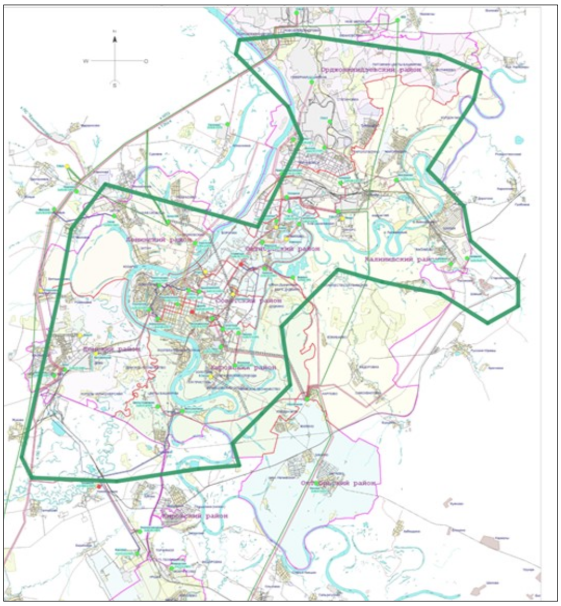

Fig. 2. Project area Smart Grid implementation of Ufa city

GOALS AND ROADMAP FOR SMARTGRID PROJECT

The first step of the power grid modernization was project feasibility study in 2013-2014. This study was done by JBS BESK in cooperation with Siemens Co, who have large experience of similar projects in another countries (India, Israel, Germany). During the pre-study work it was performed analyses of the global trends in control efficient of power grids and independent examination of grid system. As result the following main project goals was defined:

- Improve power supply quality and reliability;
- Reduce power grid fault rate;
- Reduce power grid operation costs;
- Improve power grid controllability;
- Significant reduce electrical energy losses;
- Increase transparency in consumption accounting for legal entities and individuals;
- Provide ability to enable distributed power generation.

Next step in the SmartGrid implementation project was to collect overall power grid information and develop the existing grid model. Using this model it's become possible to evaluate different network modernization approaches. Three major variants were introduced and new power grid models were developed for each of them. Afterwards this models were compared against each others and preferred one was chosen as generic target system.

According to current initial state and selected target system the detailed system transition plan for next five years was developed. Total project cost was estimated as 4 billions of rubles (approximately $65 millions). It is about 4000 rubles per person when converted to cost per power system subscriber. The discounted payback period after the project completion expected to be 10 years.

DEFINITION OF MODERNIZATION CRITERIA

According to the project feasibility study one of the most important concepts was to provide full network observability and manageability by renovate not more than 25% of substations. That why it was important to range overall grid objects such as substations and cable power lines by renovation priorities. First of all it was defined criteria for providing substations remote control and remote monitoring that is technically required for SmartGrid model. Then there were set priorities for equipment renovation order.

Priorities for substations remote control:
1. All distribution substations;
2. Transformer substations, where a network division points are located (normal breaks);
3. Transformer substations, from which there are to two or more branches to other transformer substations;
4. Transformer substations that significantly affect the power supply of particularly important consumers;
5. The most important for operational and technical management transformer substations located in the transmission networks.

Priorities for substations remote monitoring:
1. All distribution points and transformer substations provided by remote control;
2. All transformer substations which will be renovated or rebuild, all new substations;
3. Other transformer substations where observable is significant (typically it should be one observable for each two-three no observable).

Priorities for equipment renovation order:
1. Meeting the requirements of the System operator on the amount of power involved in the temporary shutdown schedule;
2. Elimination of the network overload, organization of reliable communication channels;
3. Reliable power supply to first reliability category consumers (health facilities, child care facilities, management centres etc.).

This chronological order priories of equipment renovation allows to provide high power system reliability during the project execution and after its finish.

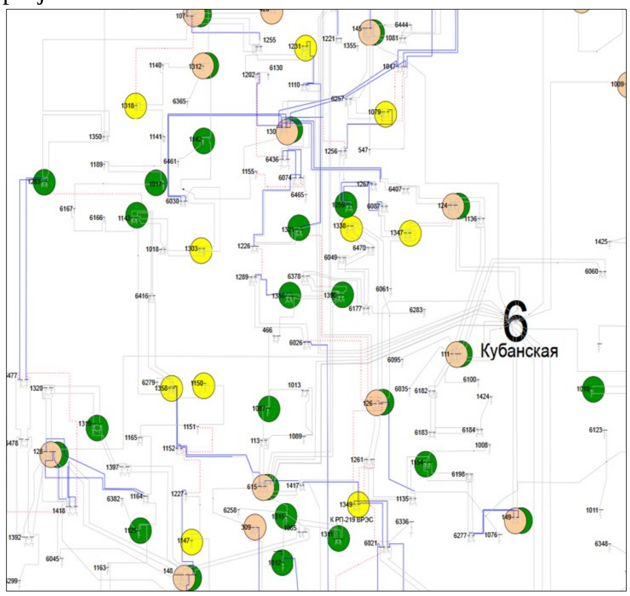

Fig 3. Modelled target system: Green - transformer substations with remote control, Yellow - transformer substations with remote monitoring.

FINE-TUNING TECHNOLOGIES IN PILOT PROJECT

To test selected approach in conditions of target system and the creation of the basic foundations of modernization the pilot project was initiated in May 2014. There was in the scope of the pilot project:
- Renovation and automation of power grid section consist

of two distribution substation and five transformer substations (according to full project it should be renovated about 500 substations in total);
- To build power grid control centre in Ufa city;
- Creation intelligent commercial power metering system in pilot region.

PCI Control automated dispatch control system had become the core of Network management centre of the "BESK" JSC. Reconstruction of distributing point and transformer substation included replacement of the old and worn-out switching units to new ones, replacement of measuring current transformers and measuring voltage transformers with devices with better characteristics and also organizing of transferring of the data on electricity generation facilities in normal and emergency modes into Network management centre.

Old substation equipment New substation equipment

Fig 4. Power grid renovation in pilot region.

Significant contribution to electric system reliability improvement and minimization of emergencies during the pilot project was made by network optimization and connection of new clients. Previously observed network overload had disappeared and replacement of the overhead power line parts to cable lines cable allowed to improve the insulation.

Replication of pilot project proven solutions is currently performed in the entire Ufa city electric system. The plan for transition from current situation to SmartGrid target model is designed for 5 years and includes the following: reconstruction and automation of 513 distributing points and transformer substations ensuring their controllability and observability, network structure optimization (installation of 100 km of cable lines) and also installation of more than 80,000 of metering devices.

As result of this Smart Grid pilot project level of commercial power loses was decreased by 96.3%: from 27.3% to 1% (about 500 thousand rubles). Results of the successful pilot project confirm that estimations that was made in feasibility study was correct.

ENSURING SYSTEM OBSERVABILITY

Implementation of the functions specified in feasibility study has required substantial increase the amount of normal mode data as well as emergency mode data.

Normal mode data included the traditional set:
- switch positions (circuit-breakers, draw-out elements, earthing blades, jumpers);
- current mode parameters for each connection (current, power, quantity of electric energy) and parameters common for all sections (voltage, frequency etc.).

According to the results of the pilot project, difficulties of the transformer substations observability were understood. Practical tests on devices from three different manufacturers (France, Germany and Russia) have shown that devices identification of the direction of phase-to-ground short circuit direction as well as of double- and triple-phase short circuits and double and triple line-to-ground short circuits plays critical role. Accordingly, feeder monitoring devices performance was improved.

On the basis of more sensitive device manufactured in Russia by A-signal which determines the direction of emergency processes with current of more than 0.5 Ampere, new-generation device which can precisely determine very short-term network processes was developed. Network consisting of such devices can collect the data on residual fault current and transfer it into the cloud system which performs correlation analysis and precisely detect emergency area. Versatile distributed network of developed feeder monitors with intellectual cloud computing might help not only to detect the emergency area but in some cases to predict this process and need in network equipment maintenance. Cost of each measuring point was reduced during the development stage.

Application of the specialized feeder monitor "A-signal" devices ensured the increased amount of emergency data on each feeder - short-circuit current, damage type (PTP, PTG), failed phase, fail direction. Such data content allows to significantly reduce duration of emergency areas detection and respectively to substantially improve key SAIDI and SAIFI indicators.

Practical test of "A-Signal" devices capabilities included:
- double- and three-phase short circuits between phases;
- phase-to-ground short-circuits;
- phase-to-ground short circuits in different feeders.

Type Short Circuit	France		Germany		A-signal, Russia	
	En. CL	Non en. CL	En. CL	Non en. CL	En. CL	Non en. CL
Insulated neutral						
Double- and three-phase short circuits identificat.	Yes	Yes	Yes	Yes	Yes	Yes
Double- and three-phase short circuits direction identificat.	No	Yes	Yes	Yes	Yes	Yes
Double- and three-phase ground return short circuits identificat.	Yes	No	Yes	No	Yes	Yes
Double- and three-phase line-to-ground short circuits direction identificat.	No	No	Yes	No	Yes	Yes
Single line-to-ground short circuits identificat.	No	No	Yes	No	Yes	Yes
Single phase-to-ground short circuits direction detection	No	No	Yes	No	Yes	Yes
Compensated neutral						
Double- and three-phase short circuits identificat.	No	Yes	Yes	Yes	Yes	Yes
Double- and three-phase short circuits direction identificat.	No	Yes	Yes	Yes	Yes	Yes
Double- and three-phase ground return short circuits identificat.	No	No	Yes	No	Yes	Yes
Double- and three-phase line-to-ground short circuits direction identificat.	No	No	Yes	No	Yes	Yes
Single line-to-ground short circuits identificat.	No	No	Yes	No	Yes	Yes
Single phase-to-ground short circuits direction detection	No	No	Yes	No	Yes	Yes

Fig. 4. Results of feeder monitoring devices tests: En. CL - Energized cable line, Non en. CL - Non-energized cable line.

Now, distribution and transformer substations are being equipped with modified feeder monitors, which has already resulted in up to 70% saving of time required for switching.

Total amount of signals over distributing substation and transformer substations in PSI during project implementation 513 facilities might be more than 100 thousands.

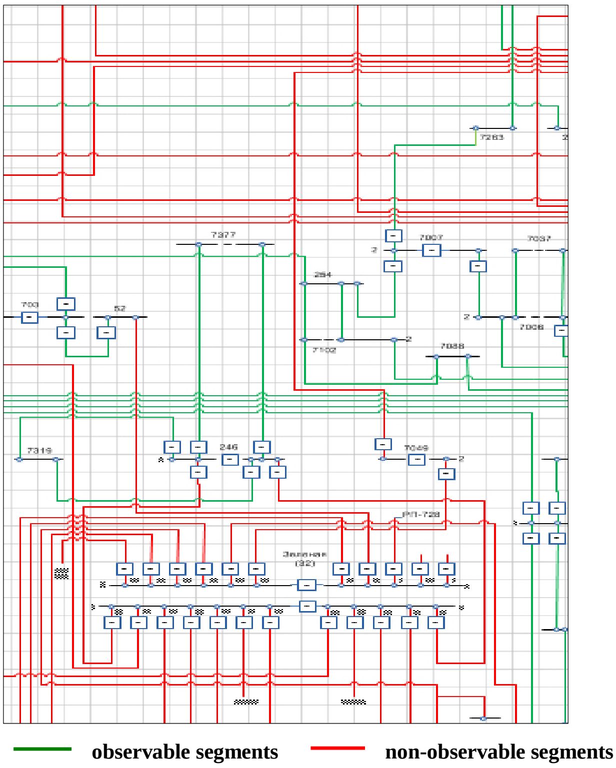

Fig. 5. Fragment of 6-10 kV network diagram without possibility of defect identification between substation and distributing point.

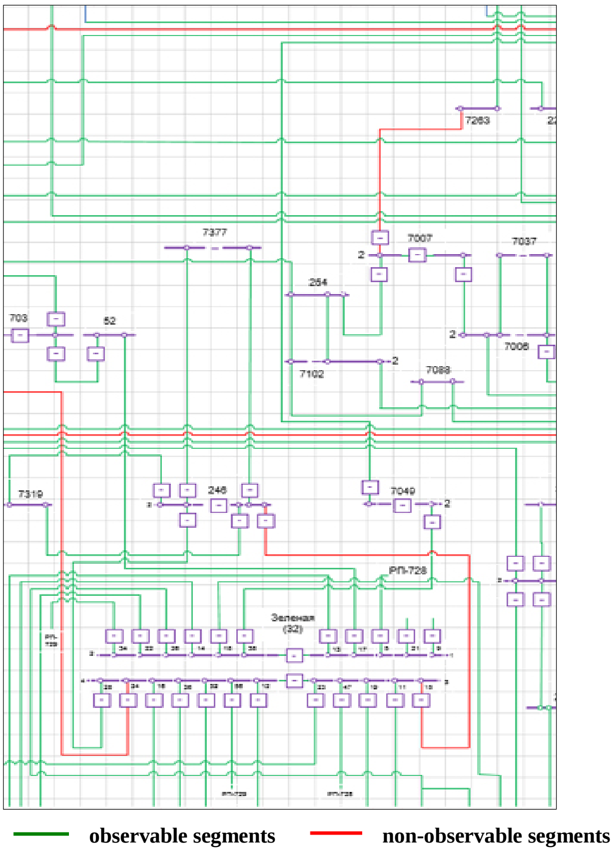

Fig. 6. Fragment of 6-10 kV network real diagram when integrating feeder monitor.

At the present time during Smart Grid project implementation on the reconstructed distributing points and transformer substations integration of supervisory system with upgraded feeder monitoring devices is being performed. Full capability of equipment remote control and observability of fails on the directions foregoing from distributing points and transformer substations. Now there is a capability of network overload rapid identification, changing of network diagram, performing of scheduled and post-emergency switchings. Operating costs on reconstructed facilities were reduced due to installation of plug and play equipment.

CONCLUSION

The expected effect of Smart Grid project implementation in the Ufa city will be the reduction of failure rate and operational costs due to what reduction of charges amounts for consumers are expected. Substantial improvement of electric system main reliability indexes was achieved during the project implementation:

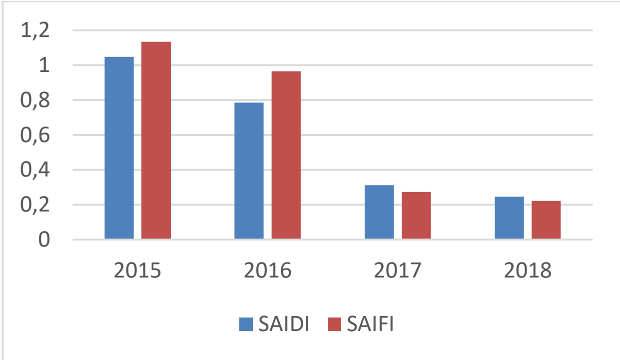

Fig.7. Improvement of SAIDI and SAIFI reliability indexes in 2015-2018

Practical experience of introduction had shown that while introducing of SmartGrid in conditions of large metropolis distribution network the detailed observability of each segment and corresponding electric energy accounting aimed at 100% with subsequent analysis of current events play critical role.

During implementation of the project, apart from application, feeder monitoring devices which allowed to identify all possible emergencies in network with insulated and compensated neutral were improved. This allowed to significantly reduce duration of emergency areas detection and respectively to improve reliability of metropolis power supply system.

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