Experience of Smart Grid Implementation for Operation Costs Optimisation of Distribution Power System

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Nowadays half of World's population is living in the cities. According to the forecasts urban population will reach 60% by the 2030. Successful city growth is highly depend on its energy system growth and improvement. Russian innovative energy company BESK, who owns transmission and distribution power grids 0.4 to 500 kV implements complex renovation of the energy system based on Smart Grid principles during last 3 years.

Prior the project start Ufa city power distribution grid had a lot of system issues prevented it's effective growth like: usage of old and outdated equipment (the equipment was mainly mounted in 1970-1980), unsystematic building of the grid and significant load increase (up to 1/3 of total regional power capacity). City population and territory growth makes it harder to get operational access to the grid facilities while intensive construction inside existing areas causes demand to increase grid capacity without building of new power supply facilities as there is no space for them. To select the required set of power grid control and monitoring base technologies which should be implemented (claimed as Smart Grid in total) it was taking in account specific characteristics of Ufa city power system as well as forecast information regarding its future development.

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 no more than 25% of substations. That's why it was important to range overall grid facilities such as substations and cable power lines by renovation priorities. First of all, criteria for providing substations with remote control and remote monitoring was defined. The criteria was required for SmartGrid model. Then equipment renovation order priorities were set.

Priorities for substation remote control:

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

Priorities for substation remote monitoring:

1. All distribution points and transformer substations provided with remote control.
2. All new substations and substations which will be renovated or rebuilt.
3. Other transformer substations where observability is significant (typically it should be one observable for each two-three no observable).

Priorities of equipment renovation order:

1. Meeting the requirements from the System operator about the amount of power involved in the temporary shutdown schedule.
2. Elimination of the network overload, reliable communication channels organization.
3. Reliable power supply for consumers from the first power supply reliability category (health facilities, child care facilities, control centres etc.).

This chronological priority order of equipment renovation allows energy company to provide high power system reliability during the project execution and after its completion.

FINE-TUNING TECHNOLOGIES IN PILOT PROJECT

The test of selected approach under conditions of target system and the creation of the basic foundations of pilot project modernization were initiated in May 2014. The scope of the pilot project included:

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

PCI Control automated dispatch control system became the core of Network management centre of the BESK. Reconstruction of distribution points and transformer substations included replacement of the old and worn-out switching units to new ones, replacement of measuring current and voltage transformers with advanced devices and also transferring the data to electricity generation facilities in normal or emergency modes to Network management centre.

Significant contribution to electric system reliability improvement and minimization of emergencies during the pilot project was made by network optimization during connection of new clients. Previously observed

Comparison of feeder monitors from different manufacturer

Indicator	Sicame FCM, Siemens		IKI-50, Kries-Energietechnik		A-signal, Antraks	
	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

network overload had disappeared and replacing overhead power line sections with cable ones allowed to improve the insulation.

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

As a result of this, Smart Grid pilot project level of commercial power losses was decreased by 96.3%: from 27.3% to 1% (about 500,000 rubles). According to the results of the successful pilot project, the estimations obtained on the stage of feasibility study were 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 of devices from three different manufacturers (Germany and Russia) have shown that devices identification 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. According to this, 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 A, new-generation device which can precisely determine very short-term network processes was developed. Network consisting of such devices can collect the data of residual fault current and transfer it into the cloud system which performs correlation analysis and precisely detects emergency area. Versatile distributed network of developed feeder monitors with intellectual cloud computing might help not only to detect the emergency area but also, in some cases, to predict this process and needs 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 engineers 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.

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.

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. P