The Functionality of Monitoring Systems under Transforming Power Grid of Active Consumers

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The current transformation of power system towards a decentralized model brings some features in the changing power supply from the practice of complex distribution networks. The presence of prosumers in the grid and the need to integrate renewable energy sources require a dynamic change in the transmission and distribution of electricity. The key features of new generation networks are power lines operation with alternating feed from different directions and smart control of power system facilities, which require not ordinary maintenance, but a quick response to the state of power equipment.

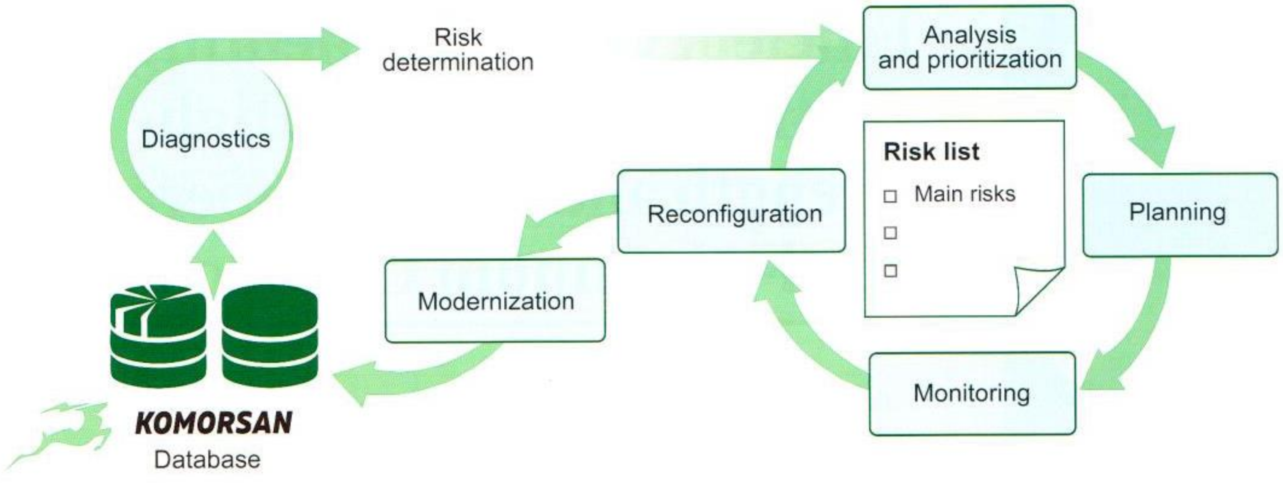
For simple configuration and reconfiguration of the upgraded power grid, automation level increase in the field of observability and controllability of all power system components in real time is needed. The calculation of network automation points, support of self-restorability functions, dynamic voltage regulation and load reduction require continuous monitoring of power lines and equipment, as well as self-diagnostics of monitoring and control devices. As of today, existing modern software and hardware systems process information from various data sources simultaneously, compare the received information with accumulated database of network performance and use a probabilistic model and artificial intelligence mechanisms for cutting off false data and assessing risks and management decisions respectively. These software and hardware systems increase the depth of diagnostic information analysis significantly.

The use of geographic information systems, including information about the location and properties of three-dimensional objects in the coordinate-time system, provide maximum visibility and usability of upgraded networks monitoring. Using the geographic information system it is possible to form a multi-level information network and monitoring and control systems for overhead and cable lines based on the data from various diagnostic devices: current sensors, voltage sensors, power line temperature sensors, icing sensors, three-dimensional position sensors of the conductor, topographic and remote devices for determining power line damage location. These data will not only provide immediate response to events in the power system, but also create the conditions for implementing predictive damage diagnosis mechanism, assessing the probability of individual network nodes failure and moving on to active adaptive configuration of distribution networks.

The basic functionality of the monitoring system is the correct identification of all power lines damages (single-phase-to-ground faults and phase-to-phase faults), when taking place any direction of power flow or zero power flow (line under guard voltage), wire breakage, automatic reclosing or damages, occurring in normal operation, and when connecting consumers to distribution network. Determination of damage location with visualization of the current network state and the accident place, power lines automatic sectioning during an emergency process and accounting for unserved electricity are ensured by the implementation of a geographic information system for monitoring and controlling power transmission.

The monitoring and automation system of the distribution network, offered by ANTRAKS, is based on the use of intelligent sensors of its own design and production (short-circuit indicators for overhead lines, A-signal electrical network monitors, smart digital disconnectors). The system allows engineers to identify any accidents on 6-110 kV overhead and cable lines, as well as promptly sectionalize damaged areas. In addition, the system predicts some emergencies in advance based on the analysis of overhead lines equipment. When scaling up the analytical part, the system allows engineers to manage information and business analytics based on digital technologies for processing large data arrays using artificial intelligence systems and machine learning.

The central part of the system is the KOMORSAN data acquisition and processing server. Data from smart sensors is sent to the server via different communication channels, depending on the



types of devices included in the system. Instrument packages equipped with a GSM module establish TCP/IP connection for data exchange. Indicators, using a data relay channel based on Mesh network, transmit information to the server via an intermediate data acquisition controller, which is the network coordinator and interface converter. Information transfer to the KOMORSAN system takes place in real time. The flexibility of KOMORSAN system data model allows engineers to manage a set of roles and privileges as well as login level of users in the KOMORSAN Web client. The system has built-in cyber security mechanisms and stores information about user actions.

The system is optimal for monitoring 6-110 kV overhead and cable lines due to the high sensitivity of devices. Registration of emergency currents from 0.5 A and implementation of several emergency detection algorithms guarantee the absence of false alarms at low emergency currents and reliable determination of all emergencies (single-phase-to-ground faults and phase-to-phase faults). Determining the direction of short circuit current makes it possible to locate damaged overhead line section and exact distance to the fault.

The monitoring system does not require the installation of additional equipment at substations (it reduces the overall cost of the system), complex erecting work at substations and creation of artificial modes with current surges, reducing the service life of network equipment. Synchronous voltage and currents measurements in each phase with real-time stamp and construction of oscillograms and vector diagrams for each phase make it possible to verify the correct power line phasing and to monitor the processes in real time for transiting to risk-oriented network management.

ANTRAKS smart sensors are made in plug-and-play technology and do not require user customization. The use of controlled devices for power system sectioning increases power equipment lifetime, as opposed to vacuum circuit breakers (reclosers), generating high-frequency (50-200 kHz) overvoltage in electrical networks and leading to premature failure of transformers.

The system offered by ANTRAKS is cross functional. It is integrated with existing infrastructure of distribution networks, including SCADA systems. Also it provides the possibility to control power districts when connecting sectionalizing devices. The system is easily customizable: it is possible to switch on mimic diagrams, to add allocation of damaged area, to point out additional user roles and to collect analytics in a convenient form. Monitoring provides an opportunity to increase power line transmission capacity.

The system allows engineers to control peak loads. It is especially important when integrating renewable energy sources and active consumers. The system is capable to make independent decisions, including the control of power flow. The use of probabilistic algorithms and machine learning algorithms ensures fault tolerance of the system as well as its self-diagnosis and self-learning. The phased implementation of an integrated system is very convenient economically, the system is easily scaled "in width" (geographically) and "in depth" (connection of new devices).

An integrated approach to electrical network monitoring provides a simple solution for the problem of upgrading and improving power system reliability. Using the achievements of modern electronics, communication systems and machine learning technologies makes it possible to cost-effectively solve the problem of quick power restoration without installing primary equipment and changing the network topology. P

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