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Measures to improve the dependability of automated power grid process control equipment

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Abstract. *Automated control equipment is being progressively integrated into the power grid. Automated process control in the electric power industry involves the ability to control the position of electrical switching devices, monitor their current status, as well as display numeric data on currents, voltages, etc. Disruptions in the automated operations control facilities (AOCF) cause defects in power systems and grid equipment. AOCF failures impair condition monitoring of power grids and operation of switching devices. Due to the impossibility of real-time remote management of power supply installations, the power provider is unable to guarantee continuous power supply. The article analyzes the AOCF equipment currently in operation as part of distributed systems at power substations, looks into the advantages and drawbacks of specific facilities, suggests methods to increase the dependability of equipment operation in the context of a 35-110 kV distributed power supply network. An AOCF equipment certification procedure is proposed. It is also suggested to provide process control documentation for power supply facilities that contain operator process control facilities (OPCF). The documentation is to be stored in maintenance areas as hard copies and at the IT portal as scans. The availability of the documentation at power supply facilities increases labor productivity of engineering personnel that perform operational checks and accident recovery activities. Apart from the mandatory set of substation documents (for the operational, maintenance and RPEA personnel), it is suggested to equip substations with OPCF equipment diagrams. This optimization minimizes time expenditures and errors made during maintenance and repair activities on automated supervisory and process equipment at power supply facilities. That enables remote management of systems operation recovery (power supply, resetting of sensors, controllers, data collection and communication devices, etc.). The efficiency of operational checks by engineering personnel is increased. The absence of emergencies ensures uninterrupted power supply to all categories of consumers and thus increases the overall investment potential of the power supply industry. Therefore, the fail-safe operation of equipment is an obvious factor of Russian technology development as well as complies with the Rosseti regulations regarding the common engineering policy in the integrated power grid.*

Keywords: *AOCF, remote control, electric reliability, distributed networks, integrated power grid.*

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Introduction. Purpose and scope of the research

Today's AOCF equipment is multilevel systems comprising process-specific hardware and customized software. As of now, the AOCF solutions are integrated into the railway, metal, nuclear and energy industries. AOCF systems enable real-time remote control and status monitoring of electrical installations. [1]

Personnel involved in the maintenance of electrical installations have to deal with frequent emergency failures of equipment due to sets of related reasons. That determines the aim of this research, i.e. provision of measures to enable normal AOCF equipment operation. In the context of the aim, the article describes the solutions for the following set of goals.

1. Analyzing AOCF facilities in operation in the 35-110 kV distributed power supply network, identifying the advantages and shortcomings of specific items.
2. Analyzing the primary causes of equipment failures.
3. Proposing the measures to improve the operational dependability of the above equipment.

1. AOCF facilities analysis, advantages and shortcomings

Currently in operation as part of the integrated power grid, there are several hardware and software AOCF solutions intended for collection of data on current position, as well as control of switches.

AOCF systems in operation

1.1. KOMPAS 1.1., supervised remote control station involved in the collection and processing of data. KOM-

PAS is a modular system consisting of a power supply unit, telemetry (TM), remote signalling (RS) reception and telecontrol commands (TC) units. It has a small number of remote signalling and current telemetry signals (8 to 64) and 32 telecontrol commands.

Make-up of the system:

- KTMS-M, modem and addressable module. It is used for interaction with data communication devices;
- KUKP-3, module intended for processing of received remote control data that is also equipped with a port for receiving TM signals;
- MVTS-M, module intended for processing of received telesignalling data that is also equipped with a port for receiving RS signals;
- MVTU, module intended for processing of TC commands that is also equipped with a port for receiving TC signals from direct-point repeater unit (BRP).

In 35-110 kV networks, the supervised station (SS) is connected with top-level devices by means of high-frequency aerial line communication. The significant shortcoming of the SS is the non-availability of synchronization with state-of-the-art communications channels (GPRS, 3G, 4G) which rules out remote connection and interaction with the SS device.

KOMPAS modules architecture is shown in Figure 1.

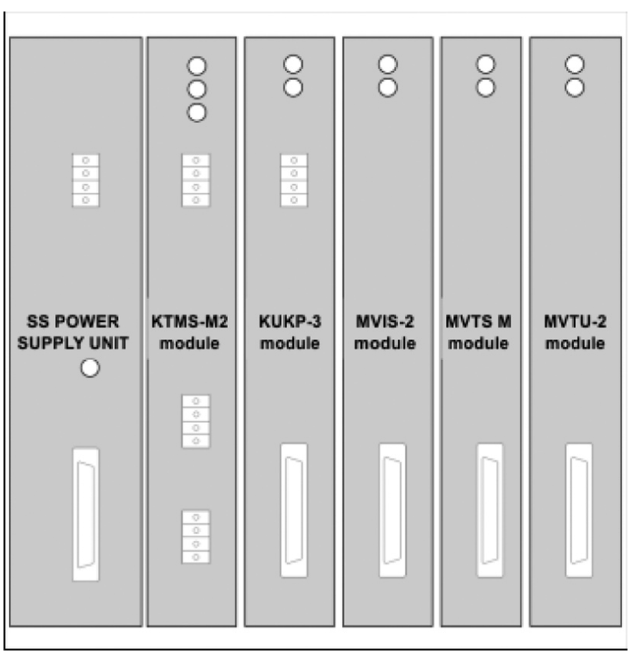

Figure 1. KOMPAS SS modules location diagram

It is not always required to deploy KOMPAS at electricity generation facilities, as in case of aerial line shutdown for maintenance, break or failure of high-frequency equipment channel, the KOMPAS equipment is unable to communicate data to the top level and switching devices monitoring and control is impossible. KOMPAS communications channels are not redundant (in tested conditions). In terms of configuration, technical specifications of electricity generation facilities, KOMPAS 1.1 is obsolete and is frequently replaced with new high-technology solutions.

1.2. MTK-30.KP is the most popular and dependable remote control solution for power distribution networks. The widespread deployment of MTK-30.KP is due to its universality, dependability, wide range of available peripherals and redundancy capability. The MTK-30.KP system is intended for operation as part of remote control solutions that ensure information collection in AOCF systems. The device has a distributed architecture, consists of a set of modules connected with RS 485, CAN and Ethernet buses, interfaces with several RS-232 communications channels by means of a specialized multichannel adaptor, Ethernet interfaces.

MTK-30.KP make-up

The make-up and number of modules is determined by the functionality and information capacity of the MTK-30.kp device. It includes the following primary modules:

- data collection and communication device;
- discrete signals input modules (RS);
- current telemetric input modules (TM);
- interface converter;
- telecontrol modules (TC);
- digital measurement converter (RS 485/232).

Figure 2 shows the layout of remote control modules. The make-up can be extended according to specifications.

1. Current telemetering module (TM) 2. Modem for interaction with data communication devices 3. Remote control cabinet 4. Interface converter 5. Remote signalling module (RS) 6. Main computer 7. Backup power supply module 8. Additional battery module 9. Power and data transmission cable channels

The advantage of the system is the redundancy capability of all components. If due to a combination of causes one of the modules or the main computer fail, the backup module can be activated. It can be observed that the software (SW) including the operational algorithms have been standardized. The software code used by solid-state equipment is adapted to specific operating environment. The monitoring management (SCADA) and personnel working modes undergo improvements, the probability of emergency failures is minimized. AOCF devices exchange data via fiber-optic and wireless channels.

There is also a number of AOCF hardware and software solutions (EKOM TM by OOO Prosoft Sistemy, Syndis SO-5 by OOO NPP Mikronika (Russia, Poland) in operation in the power generation industry. Most of them are comparable with MTK-30.KP in terms of performance, and their overview is unnecessary in the context of the considered tasks.

2. Analysis of the primary causes of equipment failures

Deployment of new technology involves the improvement of maintenance and diagnostics practices. The requirements for the personnel involved in the adjustment

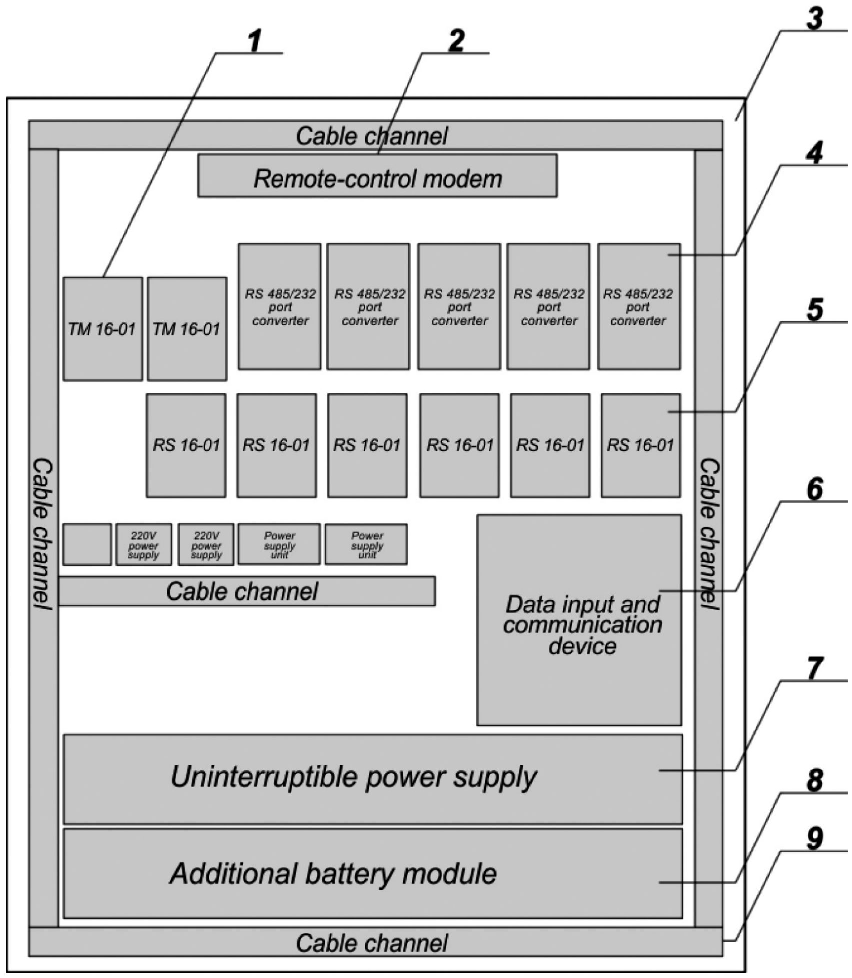

Figure 2. Modules location diagram of MTK-30 supervised station

of complex automated systems also increase. [2] Before commissioning, equipment undergoes numerous simulation tests . Given the commitment to power efficiency and non-interference of personnel in the business process, the probability of emergency failures still remains high. Given below (Figure 3) is a block diagram that indicates the types of process violations, their causes and possible methods of elimination.

3. Measures to improve the operational dependability of the above equipment

3.1 Managerial and engineering activities

3.1.1. Provision of additional redundancy

The review of the systems above leads to the conclusion regarding AOCF devices redundancy. [3] Providing redundancy not only in power supply, but for the switching devices, transformers, data collection and communication devices (DCCD) as well. Each unit in the equipment channel is structured and if one part of the system fails, communication with all remote control and remote signalling facilities is lost. If two devices operate in parallel, the probability of failure is lower, and in case of one or several modules failure the power generation facility remains under dispatcher supervision and control.

3.1.2. Application of stable voltage sources

A stable voltage source enables required power quality in the network and dependable and stable operation of AOCF power supply units. Modern power substations that supply AOCF devices use the Shtyl PS220-14/48-40 uninterruptible power supply (PSU) units that include a considerable number of batteries and a stable voltage source, which prevents abnormal operating modes and failure of AOCF power supply units. Voltage is applied in accordance with the equipment's nameplate data.

3.1.3. Routine inspection and supervision of equipment. Quality installation and setup in accordance with the manufacturer's requirements.

Activities shall comply with the schedule. Provision of equipment supervision for the purpose of identifying

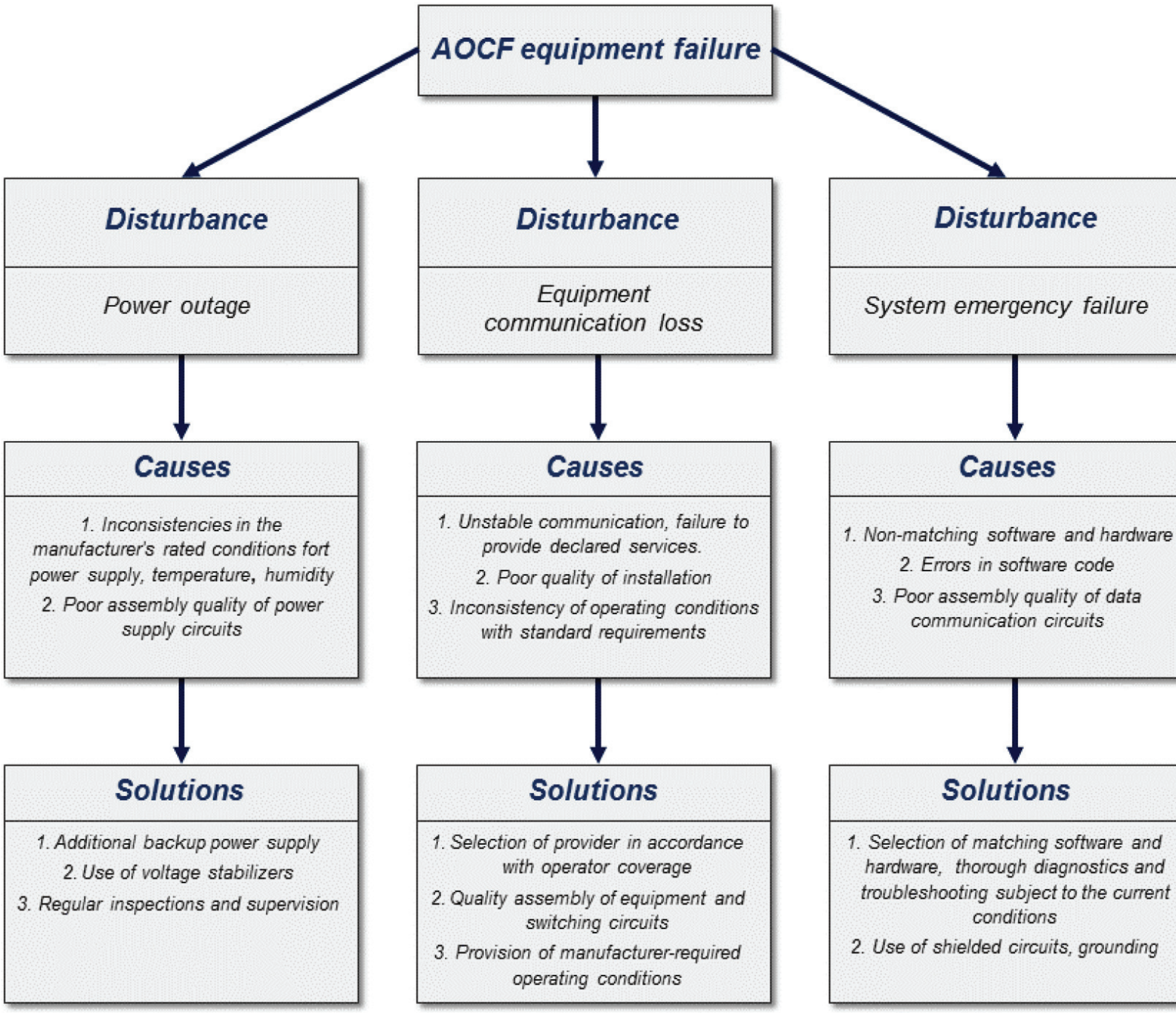

Figure 3. Block diagram of process violations, causes and solutions of AOCF equipment failures

possible defects. Provision of the temperature and humidity in accordance with the manufacturer's requirements. Increased vigilance for the safety of automated equipment, password policy and access to the hardware and software system at power generating facility to prevent accidents and terrorist attacks. While performing inspections, due attention must be given to obsolete equipment that is especially sensitive to the changes of ambient temperature, atmospheric pressure, humidity. The external part of the high-frequency communication channel (high-frequency choke, coupling capacitor, terminal blocks) are prone to contact defects, therefore scheduled inspection of secondary circuits is required. Assembly and setup must be entrusted to well-known companies that specialize in assembly activities and can provide letters of recommendation from Russian and foreign customers. The personnel involved in the assembly, setup, maintenance and operation of AOCF should have certificates issued by the manufacturers (Cisco, ProSoft, etc.) and allowing for the performance of maintenance operations on the given type of equipment.

3.1.4 Selection of provider in accordance with operator coverage

Wireless data communication services (GPRS, 2G, 3G, 4G) in most cases are provided by the mobile telecommunication services provider. The channels may be primary for a number of categories of equipment where deploying broadband wired channels is complicated or unnecessary. E.g. ASKUE equipment, remote-controlled reclosers exchange data with the server via the above channels. [4] [5] Wireless channels (GPRS, 2G, 3G, 4G) are typically used for integration into an existing AOCF solution that supports synchronization with the given communication and its use the redundant feature that runs in parallel with the primary one. Using wireless communication channels is associated with the problem of contracting for data communication services for equipment situated in scarcely-populated areas where there is no mast structures with telecommunication operators' transmit-receive modules. Therefore, in order to optimize the task, while concluding the contract it is required to provide the geographical coordinates of the facility that will use the specific type of communication. In case of fringe reception in the area where equipment operates another data communication provider may be chosen. [4] [5]

3.2. OPCF facilities certification

It is suggested to provide process control documentation for power supply facilities that contain operator process control facilities (OPCF). The documentation is to be stored in maintenance areas as hard copies and at the IT portal as scans. The availability of the documentation at power supply facilities increases labor productivity of engineering personnel that perform operational checks and accident recovery activities. Apart from the mandatory set of substation documents (for the operational, maintenance and RPEA personnel), it is suggested to equip substations with OPCF equipment diagrams.

It is proposed to classify the lists of documentation per each facility as follows

1. General information on the equipment A set of high-quality photographs of OPCF equipment, general OPCF equipment layout, list of operated equipment with serial/part numbers, battery replacement dates, uninterruptible power supplies (UPS) calibration, etc.

2. AOCF documents. One-line connection diagram of equipment power supply (per each AOCF cabinet), equipment location diagram with branding (per each AOCF cabinet), signal circuit of telemetry information of the facility, functional chart of AOCF facilities with IP addresses. This section should also include copies of documents on the inclusion of new remote signalling and telecontrol facilities, operational check records.

3. Telecommunications equipment documents (TCom). One-line connection diagram of equipment power supply (per each TCom cabinet), equipment location diagram with branding (per each TCom cabinet), functional charts of data communications channels. It is also proposed to complement this section with copies of communication channels redundancy check records.

4. Automated system for fiscal power metering (ASKUE) documents. One-line connection diagram of equipment power supply (per each ASKUE cabinet), equipment location diagram with branding (per each ASKUE cabinet). Metering devices connection diagram at inputs, outgoing lines and received data (real and reactive power).

5. Security and engineering video surveillance documents (SEVS). One-line connection diagram of equipment power supply (per each SEVS cabinet), equipment location diagram with branding (per each SEVS cabinet). Location and power supply diagram of video surveillance cameras.

6. OPCF power supply and grounding documents. It is proposed to include in this section documentation regarding OPCF equipment power supply in the facility, records of earthing bars tests in the facility.

This optimization minimizes the time expenditure and errors made during maintenance and repair activities on automated supervisory and process equipment at power supply facilities. That enables remote management of systems operation recovery (power supply, resetting of sensors, controllers, data collection and communication devices, etc.). The efficiency of operational checks by engineering personnel is increased.

Conclusions. The article reviews the advantages and shortcomings of AOCF equipment operated at 35-110 kV voltage class substations. The authors have analyzed process violations, causes of failures and recovery methods. Efficient AOCF equipment operation methods are suggested. The absence of emergencies ensures uninterrupted power supply to all categories of consumers and thus increases the overall investment potential of the power supply industry. Therefore the fail-safe operation of equipment is an obvious factor of Russian technology development as well as complies with the Rosseti regulations regarding the common engineering policy in the integrated power grid.

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