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WAYS OF IMPROVING THE MANAGEMENT OF THE SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) AUTOMATED SYSTEM IN ELECTRIC POWER

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ABSTRACT

The purpose of the scientific paper is to analyze the issues of improving the management of the supervisory control and data acquisition (SCADA) automated system in electric power, which includes a comparative analysis of the development stages of the SCADA system, the use of cloud technologies, the introduction of modern digital applications that serve for real-time recording, control, monitoring of energy objects and others. It ensures significant development of the field of electric energy. Supervisory control and data acquisition (SCADA) automated system improvement methods in electric power within the framework of the research project, the issues of supervisory control and data acquisition (SCADA) automated system (SCADA) management improvement issues were analyzed and research questions were developed. 101 respondents were interviewed. The data was collected electronically, through an online survey of employees working in different structural units of the Georgian state electrosystem, who were users of the SCADA system. The survey will study the issues of improving the management of the supervisory control and data acquisition (SCADA) automated system in electric power, which ensures the reduction of the number of technological accidents, the sustainability of the sector, the improvement of the quality of management and the speed of work in electric power. If the recommendations obtained as a result of the research are implemented, the energy system will become more stable and efficient. The mentioned study will be useful for the electric power companies of different countries where SCADA system is introduced or implemented.The article was written within the framework of the Ivane Javakhishvili Tbilisi State University research project "Ways to improve the supervisory control and data acquisition (SCADA) automated system in electric power". A comparative analysis of the development stages of the SCADA system in terms of each component of the system is discussed in the scientific paper. The implementation of the research results will affect the development of the professionalism of SCADA users, as well as provide simplification, speed and high quality of the work of the management link of the personnel. Accordingly, this will contribute to the improvement of the field of electric energy.

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INTRODUCTION

Energy plays an important role in the economy, it largely determines the level of development of the country's economy as a whole. This is due to the fact that all production processes in various fields, such as agriculture, transport, all kinds of services for the country's population, and other types of entrepreneurial activities are connected with the ever-increasing scale of energy consumption. In recent years, the important role of electric energy is determined by the fact that the growth of economic activity leads to the increase of electricity consumption. As society is constantly striving to improve its standard of living, the demand for electricity will increase in the future. The rates and scales of energy development have a decisive influence on the final results of the country's economic development. The development of the field of electric energy, the construction/rehabilitation of new stations, substations and transmission lines created the need to introduce automated systems for the management of various energy processes in electric power enterprises. According to the authors of the scientific article, Oussama Laayati and others, "Electricity is and always will be important for all industrial sectors. The development of technology and the digital revolution have led to an increase in energy consumption. "In order to assess the stability and steadiness of the energy system, it has become necessary to implement various applications for real-time monitoring of energy objects", and scientists Ohirul Qayas and others stated that it is necessary to develop the technology of renewable energy sources, such as wind and solar power plants, as well as energy storage devices and their necessary integration into the energy network. According to some scientists, digital applications are software used to monitor, evaluate and manage the power grid. The mentioned systems help to control the operation of generation, consumption, electricity quality, transmission lines and energy devices. Also, their role in financial settlement between the end user, energy producer and distribution company is important (Mohamed A. Ali and others, 2021). One of the foreign scientific articles mentions that the data available in modern supervisory control and data acquisition (SCADA) automated system include the types of data that are used for centralized control of energy devices located at power facilities. This type of data helps to monitor the life cycle of devices, predict electricity production and consumption, analyze emergency situations (Pehardaa D. and others, 2017).

According to some scientists, the power distribution network and the data transmission networks used by SCADA systems have a great impact on daily life. Their proper functioning is necessary for modern society. The dependence between the two networks is especially visible when an emergency situation is created in the power system. At this time, a great role is assigned to the smooth operation of the communication network. The successful operation of the power system depends on the proper operation of the SCADA systems. To a large extent, the failure of the data transmission system can cause cascading defects in the infrastructure of the power system and create emergency situations (Damian K., and others, 2015). According to other scientists, power supply interruptions, production line shutdowns, nuclear reactor shutdowns, and other catastrophic events can be caused by SCADA system malfunctions. SCADA systems have become an important part of automated control and monitoring of critical infrastructure. Modern SCADA systems have evolved from stand-alone systems to sophisticated, complex systems that can be unidirectionally connected to the Internet. Nowadays, SCADA systems include open and closed protocols and have their own communication network. Both stand-alone servers and cloud technologies are used for data processing. Due to the criticality of its infrastructure, special cyber security standards have been developed for modern SCADA systems. (Yadav G., and others, 2021). In Georgia, the joint-stock company "Georgian State Electrosystem" is the only operator of the electricity transmission system. The company owns and operates 4357 km of power transmission lines and 93 substations throughout Georgia. The transmission network is managed by the National Dispatch Center, and its technical support is provided by four regional branches of the Operation Department (Eastern, Western, Southern and Kakheti regional networks). CSE also manages all power transmission lines connecting neighboring states.

The full package of shares of GSE is owned by the National Agency of State Property, and the right to manage the organization has been transferred to the Ministry of Economy and Sustainable Development of Georgia. GSE provides electricity transmission and dispatching. Electricity is transmitted from hydro, thermal and wind power plants to electricity distribution companies and directly to consumers.

The main directions of the activity of GSE are:

- Planning and coordination of electricity generation and consumption;
- Provision of connection to the power grid;
- Development of power transmission network (construction of international and domestic power transmission lines and substations);
- Technical support of the power transmission network.

The activity of GSE is regulated by the National Energy and Water Supply Commission of Georgia. GSE has one subsidiary company - "Karchal Energy" (a company operating in Turkey). The function of GSE is to maintain system stability and reliability in both short and long term periods. The operating income of the organization consists of money received in exchange for electricity transmission and dispatching services for qualified enterprises.

Since 2009, "Georgian State Electrosystem" has been actively implementing the SCADA system and providing its further development. The main function of the SCADA system is to provide various types of information coming from the facility to dispatchers and operators.

The main features of the SCADA system are:

- Data collection - the RTU (Remote Terminal Unit)/Gateway located at the facility receives data from the transmitter/sensors in the real-time mode and sends them to the SCADA system servers and the HMI (Human Machine Interface) located in the substation/station;
- Remote control - a command is sent from the operator's workplace to the sensor located on any device to turn on and off this device;
- SCADA system communication network provides data transmission from the sensor to the dispatcher and vice versa;
- The data received on SCADA servers is reflected at the dispatchers through the appropriate user interface (User Interface) servers based on WEB-technologies;
- Along with real-time mode information, archive data is equally important for dispatchers, as it allows for comparison. For example, comparison of generation data of the previous and current day at a given hour, analysis of the period before and immediately after the accident, etc.
- Emergency signals inform dispatchers about disconnection, emergency situation, as well as violation of voltage, power or overflow limit;
- The Reporting System of equipment condition, generation, emergency situation, etc. is automatically or manually generated and sent to the person with the appropriate competence and responsibility.

The following questions were formulated based on the experience gained while working on the literature review and research project " supervisory control and data acquisition(SCADA) automated system improvement in electric power" and also based on the specifics of the research object (see Appendix 1).

METHODOLOGY

For the current survey, questionnaires were sent to 150 respondents, and finally 101 complete responses were processed for the research. Data was collected from employees working at Georgian State Electrosystem who were users of the SCADA system. Users of different levels of the SCADA system and also employees of different structural units were interviewed, an online survey link was sent and data was collected electronically through an online survey.

Comparative analysis of SCADA system development stages: Today, SCADA is an important and relevant system of the electric power industry, which provides real-time monitoring and control of power generation, transmission, and distribution. SCADA system includes hardware and software components. The equipment collects data from the transformers on the power plant and provides them to the field controllers, which in turn transmit the data to the first and second level systems, and in turn they process and display the information through the corresponding graphic interface on the video wall or at the operator's workplace. SCADA systems also record the status and corresponding changes of all processes occurring in the power system.

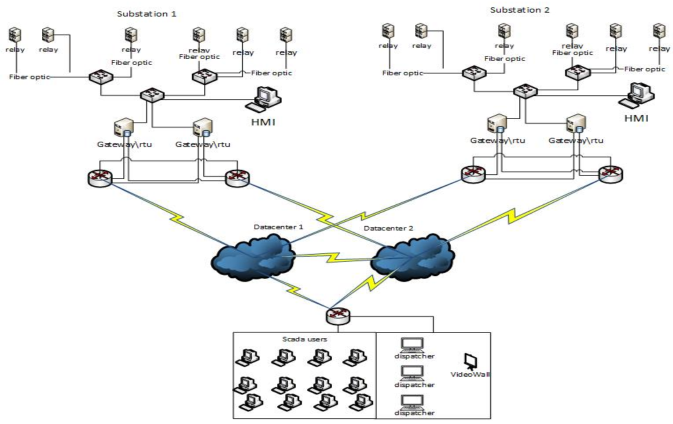
SCADA system plays an important role in power system management. It carries out:

- Remote management of substations and power plants;
- recording changes in data and measurements and reflecting the respective user's work environment on servers and workplaces;
- regulation of frequency and generation in the energy system;
- Recording data in databases and electronic archives, etc.

- automatic generation of reports;
- forecasting electricity generation and consumption;
- control and regulation of voltage and active power;
- etc.

Based on the above, the introduction of the SCADA system in the power generation/distribution industry made it possible to automate the processes. It should be noted that this causedto a significant reduction of the human factor. Until 2009, in the control room of the "Georgian State Electrosystem" there was a control wall, the length of which exceeded 10 meters, and on it were placed the Mnemonic schemecircuits of the energy system of Georgia, relays, transmitters of information signals and various types of measuring devices. Each tool had an informational purpose only. The remote control of the power system was not carried out from the central control room. The chart included output and overflow data of key stations and high voltage transmission lines. Information was transmitted from the power plant to the central dispatcher via a high-frequency connection. To perform switching in the substation, the central dispatcher contacted the substation duty and gave the corresponding task, as a result of which the latter went to the open area of the power facility, where the corresponding devices were located, and manually switched them on according to the pre-agreed directive. The human factor was important in the operation of the system. Dispatchers or their assistants were responsible for mechanical recording of incoming events, making switches directly in the open areaof the energy facility, making orders and applications manually. Accordingly, the energy system of Georgia was completely dependent on the human factor, and each minor error in the energy sector could cause a major technological accident, which caused great damage to both the country's economy and the civil sector.

The development of technology played a big role in the improvement of energy management in the world, and in 2009, a new SCADA system was introduced and put into operation in Georgian State Electrosystem, which completely replaced the complex described above. At the first stage of SCADA system implementation, several stations and substations owned by GSE, were selected for testing. Appropriate hardware was installed at each selected energy facility. A remote control terminal RTU (Remote Terminal Unit) was placed at the facility, which collected information from the devices in the substations and stations and transferedit to the central dispatch, with the appropriate energy protocols, which fully complied with the European Union standards. At the central dispatching center, the old control panel schemes were replaced by a video wall, which was connected to the User Interface servers and displayed the current processes in the power system in real time. At the physical level, data was transfered through optical fiber channels, radio communication (Microwave) and high-frequency signal transmitting controller - PLC (Programmable Logic Controllers) systems. SCADA was a closed system that had no connection to the Internet. Despite automation of processes, it was impossible to make remote switching in substations without the help of personnel on site. When the new system was implemented, the control system in the sub-units was not changed, which promptedthe dispatcher to do switches on objects through the between the facilities a telephone connection. Since 2014, "Georgian State Electrosystem" has started rehabilitating the substation control system (mini SCADA) and working on updating the central SCADA system in parallel mode. As part of the renewal of the substation management system, digital sensors and relays were installed at all facilities, which sent data changes, equipment statuses and emergency signals through low-level energy protocols (DNP, MODBUS TCP/IP and 61850) to the data collection hardware complex (Gateway). The Gateway, in turn, processed and sent these data to both the substation management system (HMI - Human Machine Interface) and the central SCADA system servers, which after processing these data were displayed on the dispatchers' workplaces and on the control panel. The data from the sensor/relay to the HMI is transferred by a fiber optic network, which is installed locally in the substation (see diagram N1). HMI is a substation control system, where each unit and cell of the substation is schematically depicted, where each device and the signals that attached to them are described.



SchemeN1. internal substation management system,Source: Chart has been developed by authors

Since 2019, the implementation of the central SCADA system has been started in GSE. The project included a complete renewal of both the technical and software complex. Due to the criticality of the automated dispatch management and control system, three servers were organized according to world-recognized standards for insurance purposes. Instead of the old stand-alone servers, a virtual environment belonging to CSE was organized, the so-called Cloud (Cloud). 30-30 virtual machines were placed in each virtual environment. The cloud located in two locations works on the active-active principle, and the cloud located on the third location - in cold mode status (FailOver). Switching to it is carried out only if the first two are disconnected or there is a force majeure situation.

The communication network, through which information was transferedto the central dispatch, was divided into the following parts:

- energy facilities owned by GSE;
- energy facilities owned by GSE partner companies;
- Communication network connecting neighboring countries;
- Connecting network with other organizational services within the GSE;

Each network presents a closed channel where information is transmitted only through a strictly defined network protocol. In the new SCADA, the architecture of databases has also changed. If in the first SCADA we had only two databases, in the new SCADA there are eight static and one operational database. Information received from the facility, which has not yet been processed and sent to the archive, is recorded in the operational database.

Each hardware and software element of SCADA is a Spectrum power 7 module. Unlike the old system, the new system has a lot of tools to manage the energy system, such as:

- substation and power station data reception, processing, remote management;
- alarm management;
- Dispatcher log management;
- Switching sequence management;
- Disturbance data collection;
- etc.

The most important module - network status monitoring and evaluation based on incoming data includes SCADA analytical functions. These are expert systems, the main function of which is to calculate and monitor the dynamic indicators of the energy network, evaluate the incoming information and, if necessary, generate an alarm signal. Intellectual functions are divided according to groups of functions that contribute to the implementation of such processes as:

- ✓ Control of voltage and reactive power, which ensures the elimination of changes in voltage profiles, violation of voltage limits, and the minimization of losses in the process of power flow. The main task of the function is to determine the value of the voltage on the outgoing or incoming line from the high-voltage power plant. Control of the system voltage and reactive power is performed automatically based on the values and indications of the sensors in the substations and power plants.

- ✓ High voltage network management applications allow analysis of the state of the power grid, both in real time and through a training simulator. Real-time computing functions compare current and previous measurements to determine the current state of the network. The calculation result, if it matches the current state, can be used in power system management. These calculations, on the one hand, automatically check the security of the network in real time mode. On the other hand, they identify the violation of the threshold limits in the network and calculate the probability of disconnection in the current mode. In addition, it determines the share of electricity generated and transmitted by each power plant in the network and their losses in the Power transmission process. Real-time calculations also include dispatcher control before switching. This is not an automatic feature, although it can be enabled before making complex switches.
- ✓ The outage schedule feature includes a power system load distribution model for current and future planned outages. The shutdown schedule is stored on the server and starts to activate on the scheduled date. After that, according to the plan, the dispatcher carries out the planned switching or taking out of operation mode the devices located at different energy facilities.
- ✓ The functional group of energy demand, power and frequency control includes the function of controlling the electricity generated by power plants. The automatic generation control system (AGC) takes care of the active power control tasks. Active power control coincides with the electricity production of the regulated stations, which takes into account the electricity consumption in different periods of time. The automatic control of the generation should use the backup power plants of the secondary and tertiary system. AGC-controlled stations also provide secondary control of energy in a closed energy system, that is, in the case when we do not have an overflow with neighboring countries and only internal transmission is monitored;
- ✓ The function of determining the foult location is responsible for definingthe place of damage;
- ✓ Analytical functions are used to prepare reports, to study old data and to plan new generation and overflow based on them, as well as to carry out planned preventive works. Practically, by means of analytical functions, emergency situations are registered and their causes are subsequently investigated, various simulation scenarios are played out, equipment wear is analyzed, etc. These functions perform processing, store, analysis of large data volumes and presentation of its results to responsible persons.
- ✓ The main functions of a smart grid are data collection, analysis, transmission network design, complex control of load and production and further evaluation.

GSE's SCADA system provides a number of different types of data management, the main features of which are:

- Managing a large amount of data in a short period of time;
- Use of a unified methodology for different data types;
- Processing of different data types;
- Classification of information to ensure fast operation of applications according to databases.

SCADA system manages and stores a lot of data of different types and at different time intervals. Unlike basic data, transactional data is related to the time dimension or a change in the period of a certain operation, as a result of which it is reflected in the operator's workplace and then stored in the archive.

Archive data is divided into three parts:

- short period archive;
- The middle period archive;
- Long-term archive.

A short-term or operational archive stores data for one hour after an event, after which it is transferred to a middle-term archive. It is stored on the hard drive and is accessible for 2 weeks. Subsequently, this data is archived by means of a special script and transferred to a storage. In further need, it can be called through the appropriate module of the SCADA system. The control functions of the SCADA system provide remote monitoring and management of the power plant and substation by the dispatcher, sending the necessary parameters from the control panel to the devices and relays in the station, collects data and analyzes them to make management decisions. The first prerequisite for the smooth operation of the SCADA system is the control of hardware and software complex components, which are provided with automated, individually expandable monitoring and device control functions. these are:

- Monitoring processor resources;
- monitoring user program resources;
- capacity of the disk array, observation and monitoring of availability of other hardware components;
- Monitoring of the operating system, software components and databases;
- device management and testing;
- software testing, debugging, error analysis;
- Frequency of error occurrence monitoring.

Depending on the criticality and importance of the SCADA system, each user is assigned appropriate authorization rights. For example, dispatchers have the ability to make switches in the power system, turn on and off, manage data, etc. Rights that users of the forecasting module do not have. Also, several users with the role of administrator are registered in the system, who can create, edit or delete other users, grant or revoke these or those rights.

Table 1. Technological development of the SCADA system by years

Name	Year			
	until 2009	2009-2014	2014-2019	Since 2019
Remote control from the dispatch point	No	No	partially	fully automated
Management of support processes	Manually	Manually	partially	fully automated
Control Panel	Mnemo scheme	projector	Video wall	Video wall
communication channels	PLC	PLC microwave	PLC microwave	Fiber optic PLC microwave 4G
Local system for the substation management	No	No	Partialy	fully automated
Receiving and processing data in real time	No	Partialy	Partialy	fully automated
Servers	No	Physical Servers	Physical Servers	virtual environment
Archive of energy events	Manually	partially	fully automated	fully automated
reporting system	Manually	partially	partially	fully automated
Connection with neighboring energy systems	by phone	by phone	Phone, data exchange	Phone, data exchange
Generation control module	No	partial control	partial control	Full control
Applications system	Manually	Partially automated	Partially automated	fully automated
Energy tasks module	No	No	partially	fully implemented
Forecast module	No	Support programs	Support programs	fully implemented

Source: Developed by the authors

Based on the above, if we arrange the development stages of the SCADA system with the corresponding modules according to the years, we will get Table 1. Table 1 shows technological development of the SCADA system by years. From 2014 to 2019, GSE has experienced considerable progress in the direction of technological development of the SCADA system, and from 2019 to the present, the implementation/updating of the SCADA system is ongoing.

RESULTS

There were processed 101 complete responses within the scope of the research. Data was collected from employees working at Georgian State Electrosystem who were users of the SCADA system. The demographic profile of the respondents is presented in Table N2. 81.2% of the participants in the research are male, and 18.8% are female. The majority of respondents are 21-35 years old (42.6%), while 40.6% belong to the age group of 36-50 years and 16.8% - 50 and above.

one", the answers were distributed as follows: the maximum number of respondents - 24.3% believe that the additional capability of the new SCADA system is "data analytics" (because based on it, it is possible to analyze the power system of the previous day condition assessment, as well as predicting the future condition), also 24.3% believe that it is a "user-oriented graphical interface" (which means easy access to SCADA system module dashboards), and 20.1% answer that it is a "forecasting module" (possible for consumption and generation forecast several years in advance). To the question (Q8) "How fast is the SCADA system working?" 50.5% answered that it was average speed (it was found that this was caused by the processing of a large amount of data and the average traffic of the network bandwidth), however, according to the user level, the responses were distributed as follows: 62.5% of administrators 100% of base administrators and 50% of dispatchers believe that the SCADA system is fast, and the speed is quite good. To the question (Q9) "What is the management quality of the SCADA system", the maximum number of respondents - 42.6%, answers that it is good, however, if we consider according user level, the answers are

Table 2. Demographic Information

Category		Frequency	Percentage (%)
Gender	Male	82	81.2
	Female	19	18.8
Age(years)	21 – 35	43	42.6
	36 - 50	41	40.6
	More than 50	17	16.8
user level	Dispatcher	30	29.7
	ordinary user	55	54.5
	administrator	8	7.9
	database administrator	2	2.0
	Training administrator	5	5.0
	Technical safety and inspection service	1	1.0

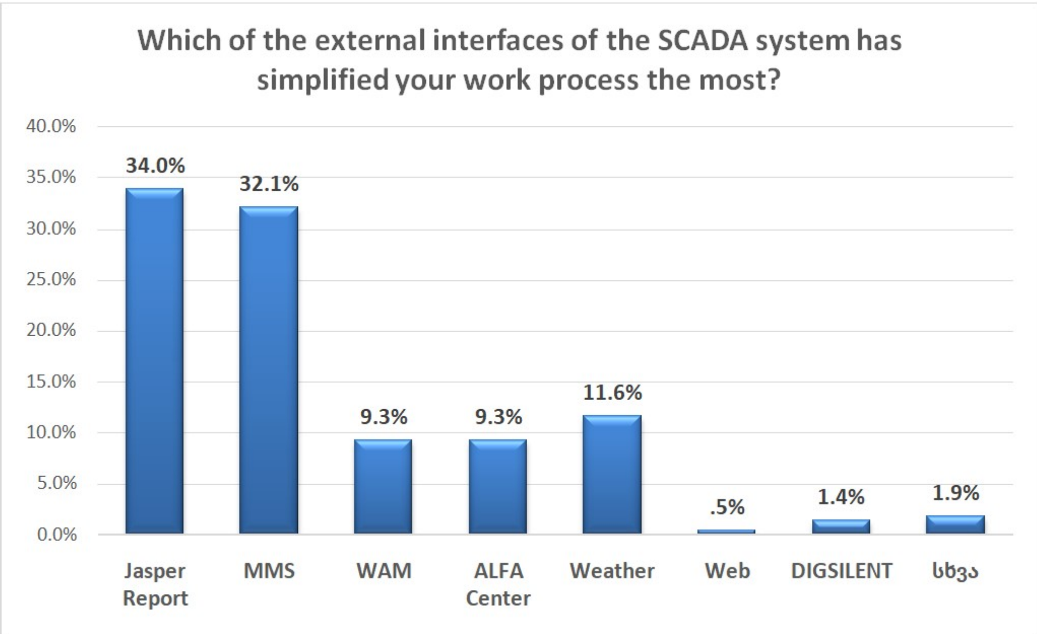


Diagram 1. Which of the external interfaces of the SCADA system has simplified your work process the most?

After processing and analyzing the data received from the respondents, let's review the main results of the research: To the question (Q6) "How easily did you migratefrom the old SCADA system to the new system", the maximum number of respondents - 48.5% answer that they did not work in the old system (because it turned out that they were hiredafter the introduction of the new SCADA system), 46.5% answer that it was easy to migrate, 4% answer that they prefer the old system and 1% answer that it was difficult to adapt to the working environment of the new system. And if we consider and According to user level, it was found that 100% of data base administrators, 75% of administrators and 53.3% of dispatchers easily migrated from the old SCADA system to the new system. In the multiple-choice question (Q7) about "what additional capabilities does the new SCADA system have compared to the old

distributed as follows: 37.5% of administrators believe that the management quality is very good. It is interesting to discuss the results of the research question (Q10) "Which of the external interfaces of the SCADA system simplified the work process", which is detailed in the diagram N1. In order which of the external interfaces simplify the work process, 34.0%, the maximum of the respondents choosed Jasper Report, since it is an automatic reporting system that automatically generates reports from the recorded data archive and the results are instantly sent to the higher responsible persons. The results of the question (Q11) "Which advanced technology has been implemented to improve performance management of SCADA systems" are detailed in Figure 2. A maximum of 47.2% of the respondents answered that it is appropriate to use cloud technologies to improve the management of SCADA systems, becausethe servers of SCADA systems are located in a virtual environment, which allows for more optimal use of server resources, which increases the speed of data processing and consequently increases the quality of power system management.

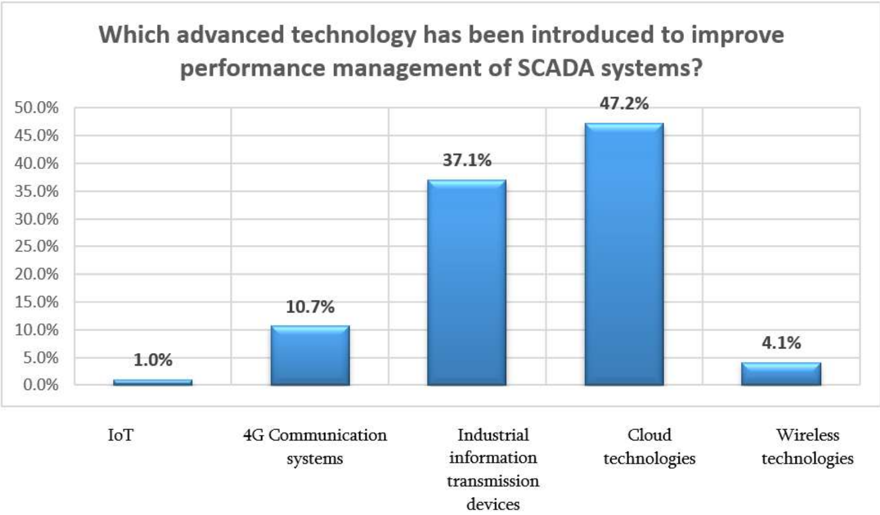


Diagram 2. Which advanced technology has been introduced to improve performance management of SCADA systems?

To the question (Q12) "Which modules do you use when working in the SCADA system?", the maximum number of respondents - 22.6% prefer the TNA module (because the TNA power tasks module flexibly performs various mathematical calculations in the power system, evaluates the stability of the power system in one or another moment, participates in the training simulator, also provides data to the anti emergency system, etc.), 19.5% - Archive and 18.4% - AGC modules. On the question (Q13) "Which advanced visualization tools are used for electricity monitoring and control", the maximum number of respondents - 40.6% choose one-line diagrams (since the layout of each substation's equipment is clearly visible), and 31.8% use consumption and overflow graphs. To the question (Q15) "To what extent does the subsystem of data analytics and forecasting implemented in the SCADA system contribute to power system management in real time", the maximum number of respondents - 41.6% answered that it is good, and 31.7% - very well. To the question (Q16) "Which of the following do you consider more important in terms of improving the SCADA system management", the maximum number of respondents - 33.0% answered that the inclusion of several stations working in parallel mode in the AGC, 27.5% - the establishment of a third new dispatch center, 21.0% - small hydropower plants Receiving and transmitting information wirelessly through IoT and 18.5% - connecting energy facilities at a fast 10G speed.

To the question (Q17) "Which of the following, in your opinion, will improve the management of the SCADA system", the maximum number of respondents - 39.9% answer that the integration of complete information of high voltage lines (humidity, temperature, wear, etc.) into the SCADA system, 38.3% - digitization of substations, 20.7% - implementation of modern SCADA systems in partner organizations and 1.0% - nothing to change. As a result of the cross-tabulation between question Q4 (Which user level is yours in SCADA system implemented in GSE?) and question Q10 (Which of the external interfaces of the SCADA system has simplified your work process more) it was found that dispatchers, ordinary users and administrators answered that the JASPER REPORT interface ((Automated Reporting System) and MMS (Marketing Management System) interfaces have simplified the work the most. As a result of the crosstabulation between question Q4 (Which user level is yours in SCADA system implemented in GSE?) and question Q11 (Which advanced technology has been implemented to improve the performance management of SCADA systems) it was found that the maximum number of dispatchers 48.3%, ordinary users 46.8% and administrators 38.5% Cloud technologies are believed to have improved SCADA system management. As a result of cross-tabulation, between question Q4 (which user level is your in SCADA system implemented in GSE?) and question Q16 (which of the following do you consider more important in terms of improving SCADA system management, please state your opinion regarding this) it was found that the maximum number of dispatchers - 40.0%

The maximum number of ordinary users - 28.4% believe that it is necessary to include several stations working in parallel mode in AGC, at the same time 40% of administrators believe that it is necessary to establish a third dispatch center. As a result of cross-tabulation between question Q4 (Which user level is your in SCADA system implemented in GSE?) and question Q17 (which of the following do you think would improve the SCADA system management the most, please state your opinion regarding this) was distributed as follows: the maximum number of dispatchers - 43.1% and The maximum number of ordinary users - 42.5% believe that it is necessary to integrate the complete information of high voltage lines (humidity, temperature, wear, etc.) into the SCADA system, at the same time the maximum number of administrators - 46.7% believe that it is necessary to digitize all existing substations. Correlation analysis was performed between question Q8 (speed of SCADA system) and question Q14 (how fast are SCADA system servers located in the virtual environment) and as a result we got 0.622 (accordingly it was found that question Q8 correlates on average with question Q14. i.e. speed of SCADA system average depends on the speed of the SCADA system servers located in the virtual environment).

Conclusion and Recommendation: The development of technologies in the world has played a big role in the improvement of energy management. The level of development of electric energy has a great influence on the dynamics and arrangement of the country's productive forces, creating a necessary prerequisite for raising the standard of the population living and improving working conditions. Within the scope of the scientific research, the importance of SCADA system installation in electric power industry and the analysis of its development stages in Georgia were highlighted. The introduction of the SCADA system contributed to the development of dispatch management and control, which reduced the number of technological accidents and made the electric energy sector stable in Georgia. The results of the conducted research revealed that most of the users easily switched to the new system, the quality of management and the speed of work improved, and the speed of the SCADA system servers located in the virtual environment increased. The research also confirmed that the automated reporting system simplified the workflow of the users, and the data analytics and forecasting subsystem of the SCADA system helped to improve the management of the power system in real time.

As a result of work on the research project "Supervisory control and data acquisition (SCADA) automated system improvement methods in electric energy" and on the basis of the above-mentioned scientific research, the following recommendations were developed:

- For the stable operation of the dispatch management and control system, it is recommended to integrate the complete information of high voltage lines (humidity, temperature, wear, etc.) into the SCADA system, which will increase the quality of data analytics work, contribute to the production of more accurate calculations in the energy tasks module, and make electric power more sustainable;
- In the automatic generation control module of the SCADA system, it is recommended to integrate several regulatory power plants, which ensures the stability of the power system, increases overflow control and reduces possible losses ofthe electricity overflow;
- Digitization of all existing substations is recommended, which will increase the efficiency of SCADA system management and monitoring, reduce technological errors and emergency situations caused by the human factor.

If the recommendations obtained as a result of the research are implemented, the energy system will become more stable and efficient. The mentioned researchwill be useful for the electric power companies of different countries where SCADA system is introduced or implemented.

Limitation: The following type of restrictions were implemented in the research: the surveyed respondents were only direct users of the SCADA system and the lower age limit started from 21 years.

Annex 1

Q1. indicate your gender (male, female);
Q2. indicate your age (21-35, 36-50, 51+);
Q3. Which structural unit do you belong to in the organization? (SCADA and Information Technology Department, Electricity Balancing and Auxiliary Services Market Management Department, National Dispatch Center, Strategic Planning and Analysis Department, Electric Power System and Balances Department, Information Security Department, Commerce and Electricity Accounting Department, Relay Protection and Automation Service, technical safety and inspection service);
Q4. Which user level is yours inSCADA system implemented in GSE? (dispatcher, regular user, administrator, base administrator, training administrator, technical security and inspection service);
Q5. How familiar are you with the SCADA system you use for work? (I don't know, more or less, average, well, very well);
Q6. How easily did you migrate from the old SCADA system to the new system? (simply, it was difficult for me to adapt to the working environment of the new system, I prefer the old system, I have not worked in the old system);
Q7. What additional capabilities does the new SCADA system have compared to the old one? (User-oriented graphical interface, simplified form of authorization, new power system control modules, forecasts module, simplified training simulator, data analytics, I don't see any difference between the new and old system, the old system is better, I have not had contact with SCADA systems);
Q8. Rate the performance of the new SCADA system on a scale? (very low, low, average, good, very good);
Q9. How would you rate the management quality of the new SCADA system? (very low, low, average, good, very good);
Q10. Which of the external interfaces of the SCADA system has simplified your work process the most? (Jasper Report, MMS, WAM, ALFA Center, Weather, Web, DIGSILENT);
Q11. Which advanced technology has been implementedto improve performance management of SCADA systems? (IoT, 4G communication systems, industrial information transmission devices, cloud technologies, wireless technologies);
Q12. Which modules do you use when working in a SCADA system? (Jros, Siguard, AGC, NA, OTS, OMS, Archive, TNA, DB);
Q13. Do you use advanced visualization tools to monitor and control power grids? (Google Maps, 3-D graphics, one-line diagrams, consumption and overflow graphs, video recording of current events);
Q14. Evaluate how fast the SCADA system servers located in the virtual environment work? (does not work, more or less, average, well, very well);
Q15. How well does the data analytics and forecasting subsystem implemented in your SCADA system contribute to real-time power system management? (does not work, more or less, average, well, very well);
Q16. Which of the following do you consider more important in terms of improvingSCADA system management? (inclusion of several stations working in parallel mode in AGC, establishof the third new dispatch center, connection of energy facilities with fast 10G speed, receiving and transmitting information of small hydropower plants via wireless connection through IoT);
Q17. Which of the following do you think would improve SCADA system management the most? (Digitalization of substations, introduction of modern SCADA systems in partner organizations, integration of complete information of high voltage lines (humidity, temperature, wear, etc.) into the SCADA system, nothing will change).

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