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USER INTERFACE FOR SCADA SYSTEMS

Master's thesis

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SCADA SÜSTEEMI KASUTAJALIIDES

Magistritöö

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Author’s declaration of originality

I hereby certify that I am the sole author of this thesis. All the used materials, references to the literature and the work of others have been referred to. This thesis has not been presented for examination anywhere else.

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Abstract

Over the last decade, there has been rising interest within the organizations, to build highly efficient and high-reliability systems for remote management and data collection. This is mainly related to computer capabilities, software, and telecommunication, which has significantly increased the possibilities of automated systems and the application area. In this regard, it is important to consider SCADA (Supervisory Control and Data Acquisition) system, which is a data collection and remote (operational) management system. SCADA is the most prospective method of automated management of distributed systems (processes). On the principle of remote management, large scale automated systems are being produced in various sectors like energy, transport, space, and military industry, also for various state structures. The study highlights the issues connected with the energy complex in Georgia and its structural locations, the importance of using the automated system of the remote management, which is incorporated in SCADA system, the structure of data collection and remote management of software-hardware complex, the systemic vision of its main components and characteristics. The study also shows structural analysis of the general management of the Georgian Energy System and outlines the role of SCADA system within the management framework. A special analysis is done on facilities that are incorporated in the energy system to use them more efficiently within the system. The study focuses on the use of “Zenon 7.1” software for a specific energy facility. All necessary functions that are needed to create a local area management system, which allows operators to see information on a display, monitor and manage is discussed. The study addresses the "blocking" functions and "user environment" mode that controls access to different operations. Zenon 7.1 is an object-oriented process management system developed by the COPA-DATA group, its software interface allows us to access the Zenon Editor and Zenon Runtime Program, Which plays an important role in solving automated tasks.

This thesis is written in English and is 51 pages long, including two chapters, 28 figures and 0 tables.

List of abbreviations and terms

ACS	Automated Control Systems
APC	Automated Production Complex
ASTP	Automation system of technological processes
BB	Busbar
CB	Circuit breaker
CS	Communication System
DAS	Design-Automation System
SRAS	Scientific Research Automation System
DB	Database
DCS	Distributed Control System
DMS	Database Management Systems
FMAS	Facility Management Automation System
FSK	Frequency Shift Keying
GSE	Georgian State Electrosystem
HMI	Human Machine Interface
HPP	Hydro Power plant
IED	Intelligent electronic device
IS	Information Systems
MS	Master Station
MTU	Master Terminal Unit
NCC	National Control Centre
OHL	Overhead line
PLC	Programmable logic controller
RTU	Remote terminal units
SCADA	Supervisory Control and Data Acquisition
SDH	Synchronous Digital Hierarchy
TUT	Tallinn University of Technology
WMT	Workflow Management Tools

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Introduction

Modern firms, companies with different profiles and organizations with various complexities, use greater scientific resources for technological processes, maintain large areas for distributed structures, employ and manage a large number of highly qualified personnel. In addition to each expansion and the additional complexities that it comes with, the management system is also becoming more difficult to manage for both common technological processes as well as for whole systems.

In many organizations, it is difficult to regularly manage human functions in the central area of management. This is particularly evident when the organization is a complex structure (with distributed objects) and control should be maintained continuously for the long-term period, especially when determining the causes of the accidents and providing solutions that require great attention and mobilization. Precisely because of this reason, each year human roles are assigned to automation. The automation and automatic systems of management can be found in large sectors like energy, oil industry as well as in smaller enterprises and firms.

The majority of automated systems are functioning with human assistance. Today, the most common software complex, which enables the implementation of the Human Interface is SCADA (Supervisory Control and Data Acquisition) Systems.

Today, the data collection and remote control of SCADA systems remain as one of the major. The most promising method of automated management of complex dynamic systems (processes) [1]. On the principle of remote management, large automated systems are being built in industries like energy, transport, space, and military, are also used for state structures, management of various types of research or applied processes. SCADA systems are used in most critical and vital areas because of their reliability and safety. SCADA is the real-time process of searching, processing, analysing information, in order to manage the object/process. It should also be noted that existing SCADA systems, alongside with their data collection and dispatch management functions, have many other different purposes, specifically [3]:

- Exchanging data with production controllers and input/output boards;
- Information processing in real-time;
- Displaying the information on the monitor in understandable for human;
- Data archiving;
- Emergency alarms and alert notifications, etc.

SCADA systems can be used to execute technological process management of automated systems with client-server or distributed architecture.

The aim of this study is to analyse the automated system's monitoring and management of distributed objects of the electrical power company based on SCADA system.

The solution of the following issues are imperative for realizing this goal [4]:

1. The importance of dispatch management in the organization and analysis of its fundamental characteristics.
2. Analysis of the purpose, characteristics and the use of SCADA system;
3. Structural analysis of the energy facilities management system;
4. Purpose and analysis of an automated system of automated facilities of energy facilities;
5. Ergonomics and efficiency analysis of the SCADA system.

The study consists of two chapters. The first chapter deals with the essence and purpose of the SCADA system in the formation of an automated system management process. By looking at the System structure, the functionalities of its components and characteristics will be analysed, alongside with the directions and features of the SCADA system usage.

The second chapter deals with the project that is to be implemented in the country's energy system, specifically is describes the project relevant changes in the automated management system and analysis of methods and means of using the SCADA system within this project. The study provides evidence that the application of the SCADA system into the existing electro system represents internal innovation for the organization. The study examines the electro-system, including full structural analysis of the organizational management system and the role of SCADA system within the management framework. Within the frames of the project, the study also explores the work carried out by the author in the **high voltage substation "Batumi 220",** specifically

about substation automation process including, technical and software services used and presents the analysis of the expected effects.

With the involvement of the author, digital, protection and management tools have been installed on the substation, the substation will be also be equipped with the modern local and remote control automated (semi - fully) system that has improved the quality of power delivery, It was made possible to fully control the data, monitor the existing devices on the substations and minimize the duration of liquidation of the discharges and the number of losses in the network.

Chapter 1. SCADA system

1.1 Essence, general structure, principles, concept and applications.

Automatic and automation management systems can be found in large systems, like in Energy, industry, oil processing sectors, also in relatively small private enterprises and firms. Automated management systems (When individuals do not participate in the regulation process) generally function within small and medium-sized facilities, While automated systems (where people perform certain functions) can be found everywhere and the reason is very often not because of the complexity of systems management, but the responsibility for management quality.

Any firm, enterprise, an organization of the complex structure that has several levels of an automated management system is known as Automated Production Complex (APC), which creates the union of Automated Control Systems (ACS), Design-Automation System (DAS) and the Scientific Research Automation System (SRAS). Depending on the profile of the organization APC's may be divided into the Automation system of technological processes. (ASTP), Facility Management Automation System (FMAS) and etc. (Fig. 1)

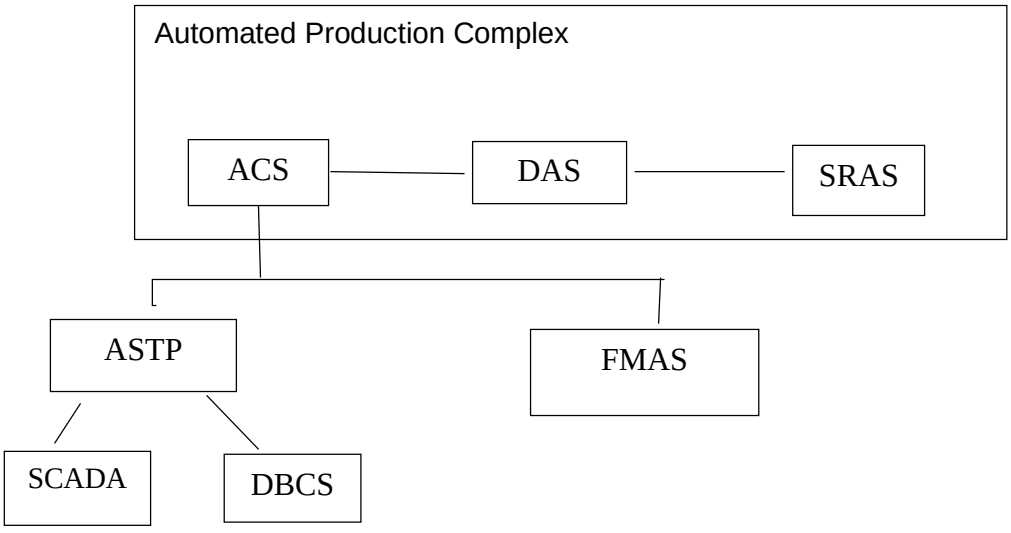

Figure 1. Classification of automated systems in the organization as part of the system

In case the problems that exist within the Facility Management Automation System (FMAS), falls to be solved by economists and managers, by all means, according to

automation system of technological processes the problem lies within Hardware/Software Automation Systems Processors and System Integrators (Support Staff).

SCADA is part of the Data Acquisition and Control Unit. In practice many experts of the field, under this term consider, the whole different packages of software, which not only monitor the workflow but also archive and interact with the database using Database Management Systems, including making the management decisions.

For the purposes of upper-level process management SCADA management and monitoring system is one of the best options [5].

The parameters of SCADA systems are flexible. They can be used during any process, ranging from small room monitoring and management to a nuclear power plant monitoring and management. The essence of this system is not derived from the size of the space or the distance it is installed; it's the main purpose lies in the objectives system is given.

The main function of SCADA is to enable the operators on duty to have the ability to manage the ongoing processes, in addition to having full access to the available information, which will make it easier for them to analyse the situation real-time, this will make process monitoring and procedural consistency possible. This will allow the operators in case of necessity to make a timely intervention to avoid possible negative consequences, including workflow interruptions or health hazards. SCADA is used in real-time to remotely process, analyse and control the facilities from distance [3].

Its main objectives are:

- Data exchange between the Facility controllers and input/output pads in real time;
- Information processing in real-time mode;
- Displaying the information on the monitor in the form that is understandable for the reader;
- Data archiving in real-time mode;
- Emergency alarm and management of alert messages;
- Preparing reports on the workflow process;
- Establish network interconnection with a personal computer;
- Connections with internal processes (database, electronic tables, etc.).

SCADA System is not a normal computer network, this is also known as the “Distributed Control System” (DCS). Generally, Computer Networks are divided into two categories [7]. These are Distributed Control Systems and Computer Networks (Fig. 2). The differences between Distributed Control Systems and Computer Networks are very important.

Distributed Control Systems is an industrial system, it is used in the manufacturing field and is integrated with intelligent electronic devices. This system is designed for companies with the ongoing workflow process, where programmable logic controllers and other intelligent devices are used.

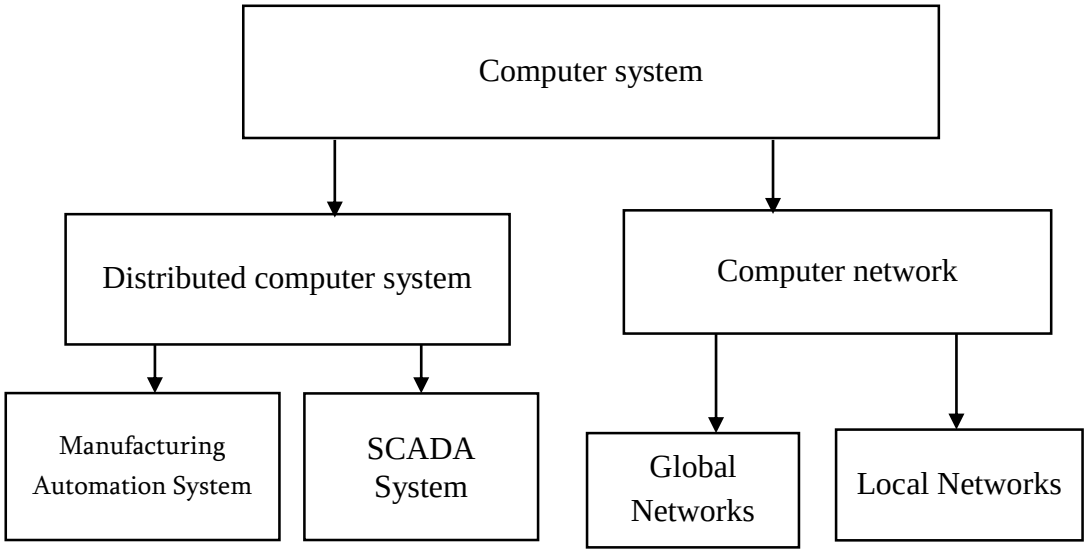

Figure 2. Classification of computer systems

The normal computer network is used to exchange information, which can be integrated into printers, scanners, servers.

1.2 Analysis of the evolutionary development of the SCADA system

Earlier managing decisions were done using so-called "telemetric" systems, it represented an attempt to organize remote monitoring of small number (one or two) of parameters. In the late 20th and early 21st century, it was impossible to imagine how the system managing operators could observe almost all events happening in faraway facilities. It should be noted that all necessary requirements that are necessary for a successful SCADA system, it has already existed in the telemetry systems of the 70s, but on the

"entry" level. The imitation wall (a mimics wall) was then used to present the existing state of the system, during which indicators and lights lit up mechanically, depending on what new data the operators were receiving at their distanced facilities [6].

SCADA type management systems have been developed to organize data gathering from remote locations (for debugging). In order to regulate critical indicators earlier SCADA like systems used one-two Alarm signals. The low number of parameters was caused because of the low development level of the existing remote management system. The remote monitoring of four or five indicators was considered to be a huge achievement for that time.

SCADA type management systems were introduced in such sectors where production capacities could not be integrated into one or more of the buildings in close proximity. General users of SCADA systems were always “spread out” companies and facilities.

The main Stimulus of the development of SCADA systems and its popularity were two factors closely related to each other:

The first factor - the possibility to have full and high quality distributed control processes;

The second factor- The ability to reduce and regulate costs.

There are other factors as well, for example, Demographic changes, the rising costs of exploitation, the ineffectiveness of alternate methods.

The funding of mobile operators (for routine inspection purposes) from facility to facility was no longer bringing any profitable. Early SCADA systems used rented telephone connections, one pair on one signal. However, connecting the phone lines was very expensive and the rent prices were too high. Additionally, telephone companies did not show any desire to connect separate telephone lines to the communicator, therefore the operators sought other options.

In the 70s, many tried to transition to radio communication, but it had its own issues: in the 20th-century radio channel frequencies were very lower than in the early 21st century, also frequency licensing rules were so complex that SCADA system management on the basis of radio frequencies represented the far distant dream. The situation changed starting

80s, when everyone started moved away from analog telemetry, (which functioned on frequency manipulation principle - Frequency Shift Keying / FSK) to digital telemetry.

Simultaneous application of compression and coding technologies implemented by microprocessors and "NASA", allowed everyone to transmit multiple situation indicators at one radio frequency (or on one rented telephone line).

This allowed SCADA systems to transmit important information about the ongoing situation at the whole facility, in addition, it enabled full control of the facility from one centre. Despite the fact that early digital commands were not reliable, when connected via radio frequency or telephone line sometimes SCADA systems lost the connection, also some external factors sometimes interfered with the signals because the devices that transmitted these signals were unreliable. It could be said that early SCADA systems designed in a way that allowed more command functions at distant facilities. Thus began the work on remote terminal units (RTU). RTU's were able to store limited size information and in case of absence of connection with the central office, it had the ability to keep the remote facility operational. This was very unlike of first-generation SCADA systems, which were connected via "Mimic Wall" and for the service, they needed a permanent connection between a local administrator and remote operator [8].

1.3 The Basic Structure of SCADA system

Modern SCADA system consists of three basic structural components (Fig 3):

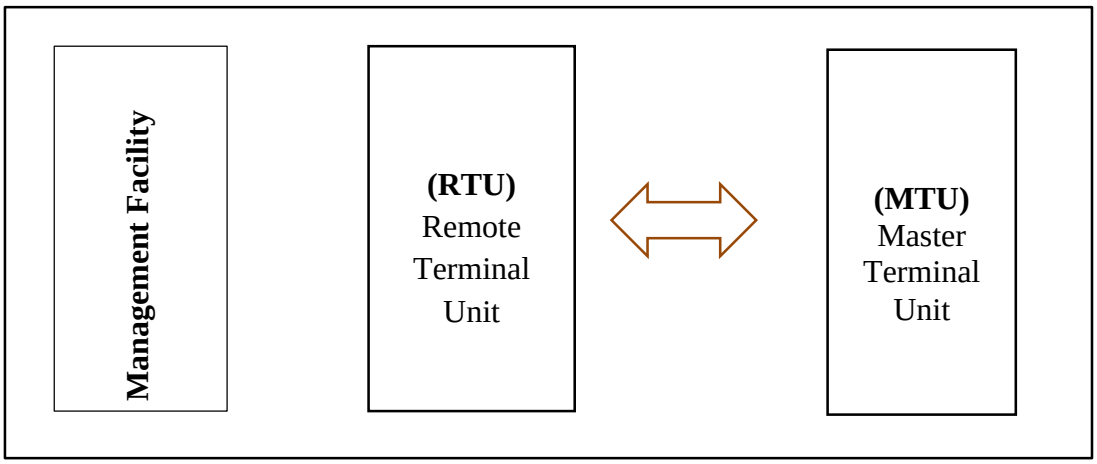

Figure 3. The basic structural components of the SCADA system

I) Remote Terminal Unit (RTU) - (Remote terminal) the specific iteration of RTU depends on the field it should be used. RTU can be specialized computers, including multi-proprietary systems, conventional microcomputers or personal computers. There are two competitive directions for industrial and transport systems: industrial personal computers and programmable logic controllers (PLC).

Production computers are typically compatible with personal computers, but are adapted to the strict conditions of operation and are installed in factories, production facilities, and etc.

Production Controllers (PLC) are specialized calculator devices, the purpose of which is to manage processes (facilities) in real time. Production controllers have the computational kernel and input-output modules. They receive information from transmitters, other devices and controllers, managing signals, drives, valves, switches, and other executable devices, and therefore run the process or the facility. The PLC's hardware is based on the principle of multiple reserves and allows the creation of the error proof system. Production PCs are mainly used in less critical areas (for example, automobile manufacturing), but there are also examples of their use in more critical areas.

II) Master Terminal Unit (MTU), Master Station (MS). This is a remote management point (main terminal), which manages the data at an upper-level, manages and monitors the work processes. One of its main functions is the interface between the human operator and the system. The main trend of MTU development is to switch to SCADA-Systems client-server architecture. This architecture consists of four functional components [9]:

1. User (Operator) Interface (User / Operator Interface). This component is very important in the SCADA system. It is characterized by:
    - User interface standardization around several platforms;
    - employing the user's standard graphical interface (GUI);
    - Use of object-oriented software technologies (DDE, OLE, Active X, OPC, DCOM);
    - Use commercial options for SCADA / HMI class software. In this case, the user interface objective oriented, as a result, it can display virtual objects created by other systems.

2. Data Management. This is a narrowly specialized process of transferring database files corporate standards like Microsoft SQL, Oracle.
3. Networking & Services. This is the transition process to standard networking technology and protocols. Scanning services for network management, protection, access, transaction monitoring, posting of mailboxes, accessible resources (processes) are performed independently from the target software code developed by another Vendor.
4. Real-time services. They operate the information exchange and SCADA processes with the RTU, manage the resource part of the database, notifies about the events, and operates the system management and delivery of information on the user via the user interface (the operator) to provide real-time functionality of the system to help reduce the risk of error.

III) Communication System (CS). The channels of modern dispatch systems are distinguished by great diversity. The choice should be made based on the distance between the system architecture, dispatch point, and RTU, the number of controlled points, the capacity of the bandwidth and the reliability of the channel.

Different channels of communication in SCADA systems can be involved in any such system, management facilities, implementing mechanisms, equipment for registration and processing of information, operators' jobs, database servers, etc.

Clearly, the SCADA system should provide a high-quality server network for effective functioning in such a diverse environment. It is desirable that it should work with standard communication protocols (TCP / IP Modbus, IEC 60870-5-101 or 104 and others) in standard network environments (IEC 61850, DNP3, Ethernet, etc.). The SCADA system should also support widespread production interfaces (PROFIBUS, CANBUS, EPICS, etc.).

These requirements are satisfied by virtually all modern SCADA systems; the only difference is network interfaces.

Based on many projects of automated control and management systems, it is possible to outline the overall plan for the realization of such systems (Fig. 4)

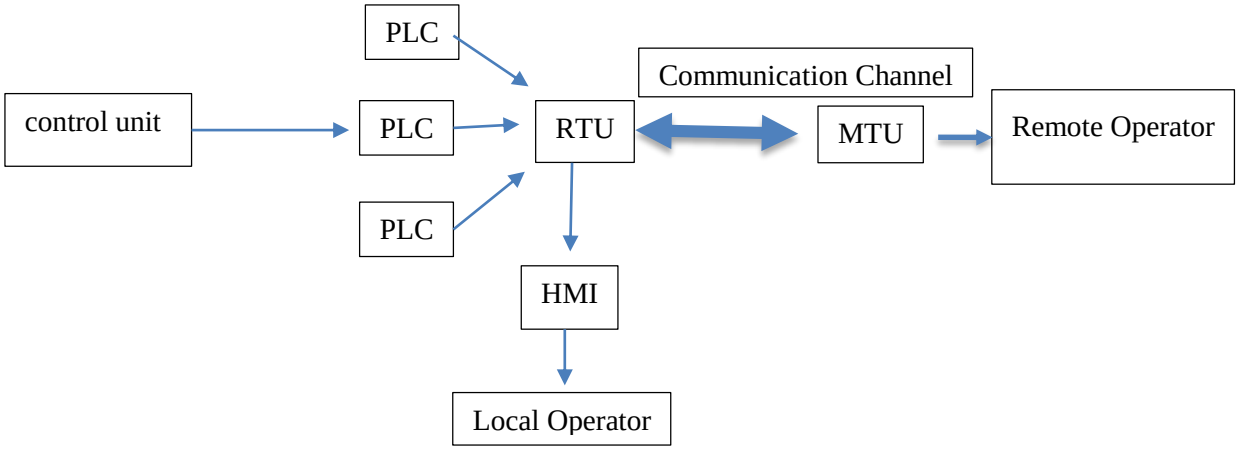

Figure 4. General SCADA Systems Realization Scheme

1.4 SCADA System Levels

SCADA systems, normally have two levels, where the workflow processes are managed. System specification depends on the software/hardware platform used on each level.

The System lower-level is the facility (controller) level. It includes various types of workflow checks for information gathering purposes; Electric drives and implementing mechanisms for regulatory and managerial impact. For intelligent electronic devices to perform calculation and defensive functions, sensors provide information on logic controllers (PLCs) to local programs that perform the following functions:

- Collects and processes the information on the technological process parameters;
- Manages the electric drives and other implementing mechanisms;
- Determines the automated logical management tasks, etc.

The controllers process the information in advance and sometimes use it for on location, therefore the requirements for the channel bandwidth significantly decreases. It is noteworthy that programmable logic controllers have to respond to the information received from the management facility in a strictly defined time for each event. Information from local controllers is accessed through upper-level controllers or directly encounters in the network of disputes. Upper-level controllers (switches, intelligent or communication controllers) perform various functions that includes:

- Collecting information from local controllers;
- Information processing and scaling;
- Maintaining uniform time in the system;

- synchronization of subsystems work etc.

The upper level of SCADA system - the remote point consists of one main and several local management stations. This is the automated working space for the dispatcher/operator. Also, there are database servers, specialists' workstations, etc. on this level. The purpose of the management stations is to monitor the process of workflow and operational management. The characteristics of the management process in modern remote systems, including SCADA systems are:

- SCADA process is used in systems where the human (operator, dispatch) is required;
- The SCADA process has been developed for systems where any incorrect action can lead to loss of control (loss), in some cases catastrophic consequences;
- Operator is responsible for the general management of the system. Generally, the system rarely requires a special set of parameters for optimal performance;

1.5. SCADA systems features

1.5.1 Functional capabilities.

Because of the requirements that SCADA systems have, their functional capabilities range are defined and implemented in all software packages. Listed are the basic features and specifications characterize all SCADA systems and differ only by the specific technicalities [6]:

- Automated processing, which gives the software the ability to execute commands without being programmed beforehand.
- Deciphering the preliminary data from low-level devices;
- Registering and management signals in the cases of emergency; Data storage tools for their re-processing opportunities;
- Preliminary data processing tools;
- Information visualization tools as graphs, histograms, and other objects;
- The ability to work with a set of parameters as unified, complete package.

It should be noted that the design technology of automated systems on different SCADA systems is similar and includes the following stages:

- Processing of the entire architecture of the automation system. At this stage, the functional purpose of each automation node is determined;
- Creating a consumer system for each management node. At this stage a specialist responsible for automated processes assigns the algorithms for each node. The combination of these algorithms leads to the resolution of the automation tasks;
- Setting system parameters in accordance to the lower-level data, received from outside the facility.

The possibilities of the SCADA system listed above, significantly determine the cost of software, also the duration, the creation and the time needed to recover the expenses.

1.5.2 Operational features.

The characteristics of the SCADA system's operational features are of great importance since they determine the speed of how fast the product is taken up and the development of the usage system. Finally, the exploitation characteristics are reflected in project execution and price.

Use convenience. It should be noted that the software package offered in SCADA systems is of the highest level. This is due to the basic requirements that exist for such systems. Almost all such systems have a "Windows" like user interface. This increases the usefulness of their use in both processing and execution process.

Automation Multi-Level System Integration. SCADA system is responsible to receive the information from the lower-level process. On Lower-Level [12] is there are various transmitters and programmable controllers, which provide information on the production process. After that, the low level of information will be provided to the SCADA system kernel. At the SCADA level, it is possible to manage the process more in a more mobile manner and based on received information it is possible to make tactical decisions. The information gathering process takes place from upper and lower levels. Information formed on the upper-level is responsible for the operation of the whole facility. The most important component in designing automated systems is a software product designed for system remote management. Software package created on specific programming languages gives us an opportunity to manage the workflow more efficiently.

1.6. SCADA Systems Concept

Under the SCADA terminology, it means either whole or complex centralized control or management system for remote systems. Formation of managing impacts is carried out automatically by RTU or PLC. Priority management functions are mostly limited to cancellation or control intervention. For example, the PLC may manage the flow of water cooling inside some specific parts of the workflow, while the SCADA system allows operators to change the flow rate and alarm conditions (such as setting the intensity of the flow or setting high temperatures). The management cycle is carried out through RTU and PLC feedback, when the SCADA system controls the entire cycle. Data collection starts at RTU or PLC level and includes data based on the indicators of measuring devices attached to SCADA. Later, the data is collected and summarized, so that the operator can make effective decisions through the consumer interface. Data can also be stored in the archives for the analysis work and figuring out general trends [15].

1.6.1 Modern SCADA-networks

Modern SCADA systems are almost entirely open source (since the beginning of the XXI century). Here all credit goes to open network protocols. The first such protocol was Modbus, followed by the IT-sector development in the corporate world, where they developed a network of "Client-Server" architectures.

The emergence of Ethernet technology enabled us to make a large number of data transmissions on long distances. In modern conditions, standardization has occurred between internal and external communications protocols, international corporation IEC has introduced standards that are strictly considered to be mandatory for all SCADA product manufacturers, according to which, internal address protocols have not been changed significantly using TCP / IP Modbus, IEC61850, DNP3 etc. IEC 60870-5-104 protocols are used for external references.

1.6.2 Analysis of the capabilities of the modern management system

The SCADA-style modern management systems possess the possibilities that previous versions could not dream of. SCADA packages in the 21st century provide the means for the facilities to store and process. Using these means a user can create their own graphical interfaces. Operators are equipped with everything necessary to make build SCADA

commands, on the basis of a commercial package, object-oriented configuration, including various instruments, templates, and instructions [14].

Using high-speed Ethernet and TCP / IP connections, operators can work with thousands of distant nodes and even get video outputs in case there is sufficient bandwidth of the channel. In many SCADA systems (oil and gas infrastructures), connection channels are organized by fibre optic cables that provide maximum possible bandwidth and speed of data transmission.

Nowadays, operators can see and analyse the data that are related to the services and optimization, including alarm and asset management, to the changes of the working characteristics of the management system without leaving the remote control chamber. The SCADA-style modern managerial solutions are open and allow the web client connection, which indicates some flexibility. In addition, modern SCADA systems should be protected from internal and external threats, for which there are special consumer security "firewalls".

SCADA's concept today is at the global level: Different users have a diverse type of management systems in different parts of the world, where operators speak in another language and system creators speak the other. The modern SCADA systems should present the data in a much easier way and make only small changes within various language packages.

Archiving the data in SCADA's modern management systems is not just a database (DB) function with structured references. The storage subsystem should be able to assist the operator, while it analyses the data the system has collected and displayed. The system enables high-quality graphical tools to work with data to help in preliminary analysis, in addition to comparing the processes and groups, visualizing and implementing its results. In addition to visual activities, SCADA systems should include integrated tools that allow staff to draw up detailed reports about what's happening at the work level.

Modern SCADA systems not only assist engineers and operators to create the reports, but also generate accounts and send them at the corporate level, even if it was requested by the Board of Directors. The modern SCADA class product enables you to create complete integrated systems that work with all the data that comes through input-output channels. Such systems should assist, to attach a global timestamp to all data it processes, it should

create data history and make their analysis. It also imports data from various databases and presents the stored images as if they were stored within a single database.

MES classrooms software products transform SCADA data in a more flexible form and later provides access to the people who have a professional obligation to learn the work principles of managing the SCADA system.

1.6.3 SCADA system application areas

It is very difficult to name the area where automated process management techniques are not used. Below are the main areas where SCADA systems are actively implemented and introduced:

- Management of electricity transmission and distribution;
- Industrial Facilities;
- Production of electricity;
- Water supply and water purification;
- Oil and gas extraction, transportation and distribution;
- Management of cosmic objects;
- Transportation management (all types of transport: air, metro, railroad, automobiles, water);
- Telecommunications;
- Military Field.

However, it is most important to use SCADA systems in the management process of the workflow. All existing modern enterprises are equipped with computer management tools. In developed countries, the introduction of new automated management systems in different fields of economy and modernization of existing systems is noticeable. In most cases, the above-mentioned systems are based on the principle of remote management and data collection. It is noteworthy that within the industrial field it has become so commonplace to upgrade existing facilities with a new generation of SCADA systems. Based on the type of facility the effect that annually comes with new remote system upgrades, may range from hundreds of thousands to millions of USDs.

Great attention is paid to the modernization of enterprises that create large ecological threats to the environment (e.g. chemical and nuclear enterprises). Also, there is a great

deal of attention paid to the modernization of vital business enterprises (e.g. water supply, sewerage and so on).

1.7 Features and basic tasks of SCADA system management process

The management process in modern remote systems has the following characteristics:

- The process SCADA is used in systems where human involvement is necessary;
- The process SCADA has been developed for the systems where any wrong action may result in the loss of a managed object or with other catastrophic events. The SCADA system minimizes the errors that may be caused by the negligence of the operator.
- Usually, the operator is responsible for system management. Under normal conditions, the system sometimes requires setting up the optimal performance;
- Operator intervention in management process occurs very rarely, e.g. when unforeseen consequences occur from critical events;
- The operator's actions in critical situations may be strictly limited by time (for several minutes or even seconds).

As we have already said, SCADA systems are central to the human operator and its tasks. That is why it is necessary that the user interface between human operators and systems meet all the ergonomic requirements. Information presented on the user interface should meet all conditional indications and should be presented in the form that is clear for the person reading. For instance, in the SCADA system that manages energy facility, the user interface should be built in a way that is acceptable within respective field. The same principle is true for other industries.

1.8 Basic requirements for remote management systems

The SCADA system of remote management follows the following basic requirements:

- Reliability (technological and functional);
- Management of security;
- The accuracy of data processing and presentation;
- The simplicity of system expansion;

Safety and reliability requirements include:

- Within the facilities, Singular errors found the device should not send out a false signal (command).
- A one-time error of the operator should not cause a false output of the signal (command) towards the command center;
- All Operations for Management Operator (Dispatch) should be intuitive and convenient.

With the general requirements listed above, the focus is on the following characteristics:

System Reliability (Technological and Functional). The functionality and the reputation of the entire system should not be impacted by rare errors of the operator nor by temporary hardware issues. As an example, we can bring Internet technologies. When one of the nodes goes down the functionalities are transferred and the alternative node is being used for the information delivery. In addition, all operations must be intuitively and convenient for the operator.

Management Security. It implies means personnel security. The SCADA system should be built in a way that is safe for an individual to use. Firewalls and other logical means should be utilized so that the operator will not have access to run the program in the wrong way.

The data processing and presentation accuracy. This demand was very important in the 60-80s of the last century when it was difficult to achieve high efficiency and accuracy. Today, technology has advanced significantly and meeting these requirements is not a big problem.

The simplicity of system expansion. The SCADA system must be an open system, its expansion should be easily accessible without sharp structural changes. The remote management systems for modern communication channels are well known for their large variety. Selecting a particular channel depends on the system architecture, the distance between the Master Terminal Units (MTU) and the Remote Terminal Units (RTU), the number of control points, the bandwidth, reliability, and the cost.

For physical communication channel purposes, cable, optical, radio networks are used. RS-232/485, Ethernet and other interfaces are used to build a communication channel.

In order to execute the data transmission through communication channels, special protocols such as MODBUS, PROFIBUS, TCP / IP, etc. must be used. In the modern industrial, energy and transport systems, the popularity of the channels connected to the computer industrial buses has gained much popularity. These channels effectively solve the reliability issues tied to the connectivity and the objective of sustainability on various levels of automation. From all over the world we are able to offer more popular and promising industrial options for Ethernet and PROFIBUS.

1.9 Threats of SCADA systems and their solution methods

SCADA systems are not 100% reliable for common reasons. There are several categories of threats that can cause the SCADA system out of order. In this subsection, we will consider the majority of these threats, and eventually, we will offer you practical ways in which to solve these problems.

A. The instrument is a malfunctioning issue.

As mentioned, the SCADA system consists of two parts - software and hardware. The SCADA system has many components and therefore the chance that any of these parts are damaged during operation is high. The electromagnetic field, weather, variable environment, humidity, and many others are factors that are negatively affected the operation of the equipment. Due to these factors, the equipment may be completely or partially damaged, which is a disruptive factor for the SCADA system. Big companies with experience in this field, recommend using specific containers to protect these devices.

Containers protect equipment from hazardous environmental conditions. These containers have a fire alarm system, temperature and humidity regulators, etc. This method improves the reliability of SCADA systems.

Figure 5. Digital device storage container

The second way to avoid system malfunction is to use the N-modular reliability system (Fig. 6). With the help of this method, it is possible to proceed with immediate and immediate replacement of the damaged part.

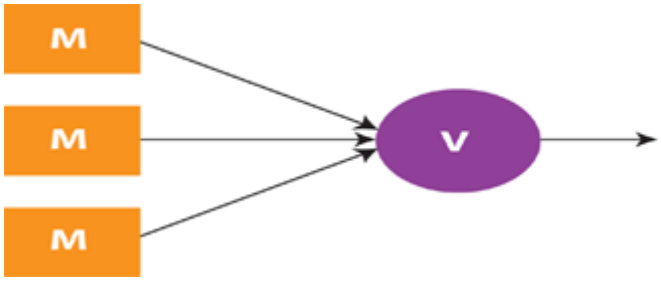

Figure 6. N-Modular Redundancy

B. Unchecked system

No one is insured from the shortcomings arising from software and hardware issues within the system during the installation process. There are specific devices that monitor and check the system performance in real time. Devices, such as the Omicron, Megger, and others serve this purpose. These devices are simulated and read by signals. For example: to send commands, check alert signals and more.

Figure 7. Simulation Device "Megger"

C. Human factors

SCADA system is not a fully automated system. People are still involved in these systems functioning process, which increases the risk of defects/errors. These errors may be caused by various factors such as: incompetent staff, stressful conditions, a rising number of alarms and more. The main options for solving this problem is to create a proper working environment and recruiting/training of competent staff. Also important is the information priorities and filtration of unnecessary flags and alarms. The most important method is interlocking. It significantly reduces the risk of human factors, limiting the operator to make certain odds according to appropriate situations.

D. Bad engineering solutions

Substation control automation systems have adopted international standards and protocols. The most commonly used protocol in SCADA is IEC-60870, DNP3, IEC-104, and IEC-61850. The communication protocol represents the standard rules for displaying information and transmitting information through the communication link. This allows devices to exchange information with each other. If the devices use different protocols they will not be physically able to do the job together. This is a problem of SCADA systems when devices from various manufacturers use different protocols.

Large power systems are made up of many devices, and often these devices are from different manufacturers, so SCADA systems for such a situation need to be able to communicate while using different protocols.

E. Cybersecurity

SCADA uses TCP / IP protocol for communicating and accessing the Internet [15]. This creates threats, and if the SCADA network is connected to business networks it will increase the threats. The SCADA systems cyber threats can be grouped as follows:

1. Malware - As in IT systems, SCADA systems are also threatened with different viruses, worms, Trojans, and more. These viruses may cause damage to SCADA systems, ranging from damaging data, harmful additional communications (caused by worms), installing back-door or password spam programs.
2. Spy programs- is a program that may be installed by an individual working with the SCADA environment that can cause great damage to the whole integrity of the system. It can physically damage many parts of the SCADA system. It is also possible that fatigued operators may allow many problems by neglecting to take greater care.
3. Hackers - Such individuals may be interested in finding the information within the SCADA system, they may also resort to obstruction or control of the system, which may be caused by simple interest to cause damage. For instance, in a case from 23.12.2007 in Ukraine, when hackers cut off the entire electrical grid working based on the SCADA system, it caused the power outage in the whole Ivano-Frankivsk region [16].
4. Terrorist - The purpose of such individuals can be either to damage the system or provide bad service that could result in the digital delivery of incorrect information on the operator.

The main methods are to protect against cyber-attacks:

- Maximum use of local networks, as it is almost impossible to attack such networks from external networks.
- To sort and store all actions and activities and sending them to the headquarters.
- Limit the scale of some actions within the system.
- Introduction to safety measures to the staff, so they are aware of cybersecurity issues and that they are actively observing for potential threats.
- Using the “Gate protect Network Protector 5.2” firewall, created in 2015 for implementation within energy specific SCADA systems, it allows storing network information that can be used to find the source of the problem.

Chapter 2: User interface for SCADA systems

2.1 Organizational systems of management, distinguishing features and characteristics.

One of the distinguishing features of modern organizations is the high level of specialization. Therefore, it is considered that the management of established (functional) organizations based on specialization is related to certain peculiarities. These links are quite complex and multifaceted and require some regulation. The organization is a multilevel system, therefore the main task of management theory is to help decision-makers to realize the objectives of the organization, to improve the functioning of the organization [14].

Any organization that is either technology, economy, or non-economic oriented represents a system, with the appropriate structure and functionality. We mean the system where the management functions are realized. It employs two subsystems: the subject and the object, in other words, a controller unit and the controlled unit. The controller Unit does all management functions, and the controlled unit executes all commands received from it. In case the actions of the control unit are straightforward, it is identified with the subject of management. The functions of the controller also include the responsibility to define management goals. It is necessary for the controller and controlled units to have management and information channels. “Figure 8” shows the management system modelled after "Subject-Object", the possible impact of the environment in addition to direct and feedback channels.

The management system receives information through the feedback channel about the state of the managed system [8]. More accurately - the feedback channel is transmitted, the current variables of the main variables of the object of management. And direct communication channels will be transmitted from the management system to the control system, or as it is called management influence. It seems that both parts interact with each other and this process is uninterrupted. Necessary communication links are also in the environment.

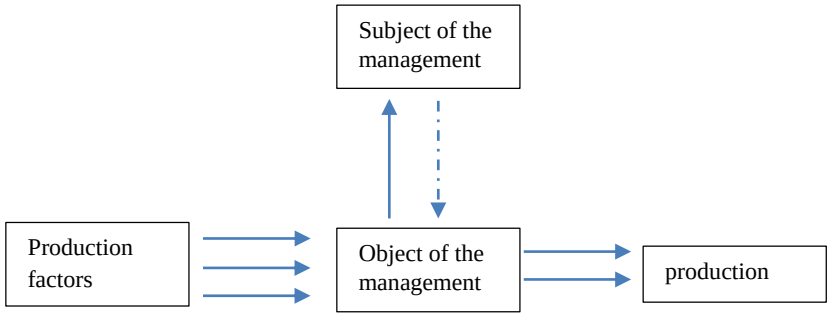

Figure 8. System performance as "subject-object"

2.1.1 Management contour, analysis of constituent blocks

During the twentieth century, the theory of management experienced a significant evolution. Management is already identified with management functions (planning, organization, motivation, control, coordination, etc.) in sequence with the execution process. This understanding of the management allows us to introduce the concept of management contour and discuss the subject on figure 8 in the following manner as on figure 9, we will not be able to analyse all the components of the controlling contour, we will only focus on the information security and automation part. It should be noted that information in the modern world is considered one of the most important resources, Information Systems (IS) and information sources are necessary tools for managing practical activities in every field. The diversity of tasks that will be solved with the help of IS has led to many different types of systems [6].

Which are different from the principles of building on top of each other and the processing of information. For the purposes of correct operation, the management system, on the one hand, should have the access to the data coming from the outside of the complex and on the other hand, should have detailed information on the structure and condition of the system itself. More the information provided to the governing system about the status of the control subsystem is close to reality, the decisions made by the management system will be much more optimal.

During the automation, the information processing quality of the IS is divided into [7]:

1. Manual handling;
2. Automated;
3. Automatic;

Manually handled systems do not use technological means of information processing and any processing is done by an individual person.

Within the Automatic systems, all the processing is done automatically, without involving any human participation in any form.

Within the automated systems, technological means and individuals are involved in the process of processing the information. In this process, time-consuming and routine tasks are completed by using technological means, and people are responsible for overseeing the methodology of information processing and ongoing algorithmic processes. As we mentioned, humans have a significant role in making sure that automation systems are running smoothly, e.g.: data collecting, processing, transmitting and functioning. A human operator acts as an important figure in the management contour, making sure that providing information on security, monitoring and effective management of the system are handled properly.

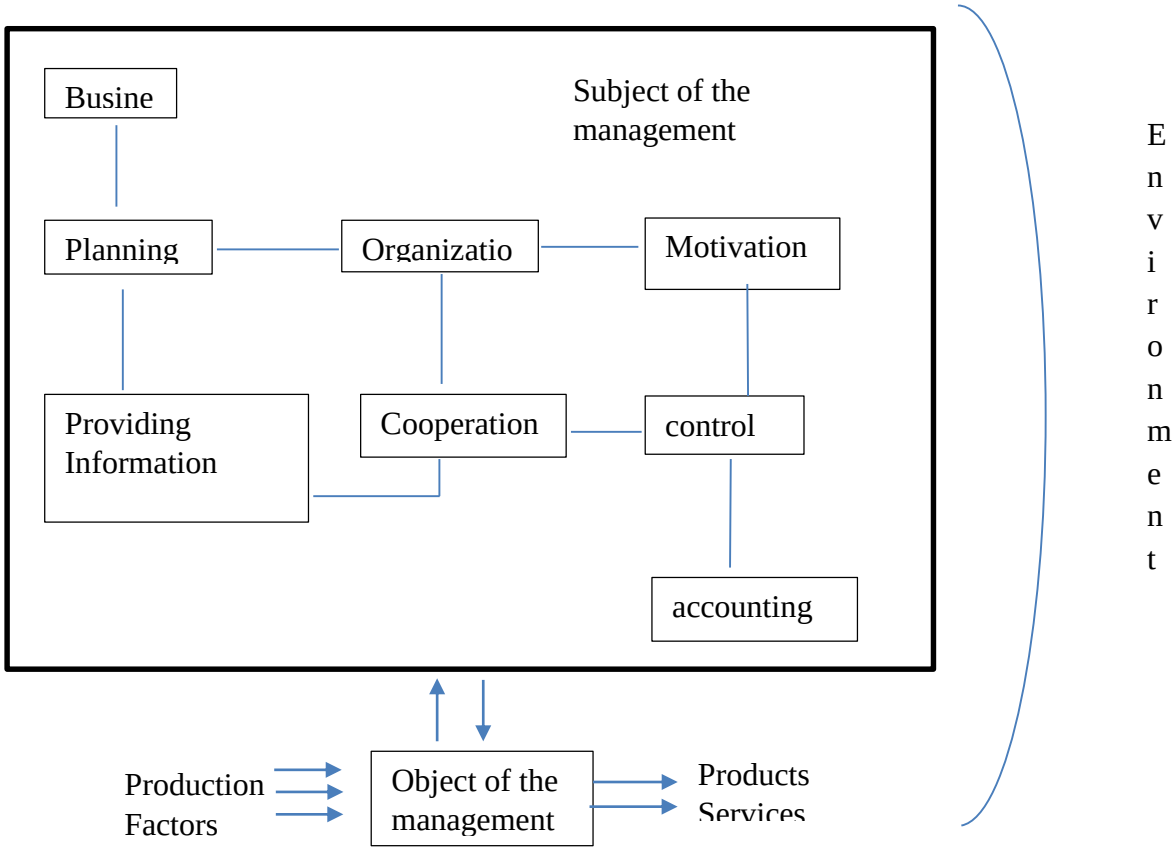

Figure 9. Organization's management contour and system components

According to the material presented above (Fig. 9), it is clearly visible that as a result of

Decomposition of subject of management, the goal block, general management functions, and corresponding blocks, also other supporting functions provide an opportunity to realize and establish a connection with outside information channels. Their existence largely determines the process of openness of any system.

2.1.2 Structural analysis of the Georgian State Electro system (GSE) and its facilities

It is important, that in case it is necessary, the decomposition process of the object of management, which is very often a determining factor to conduct specific studies and necessary to make relevant decisions. An example of the possible decomposition of the objects in the power system is shown in Figure 10.

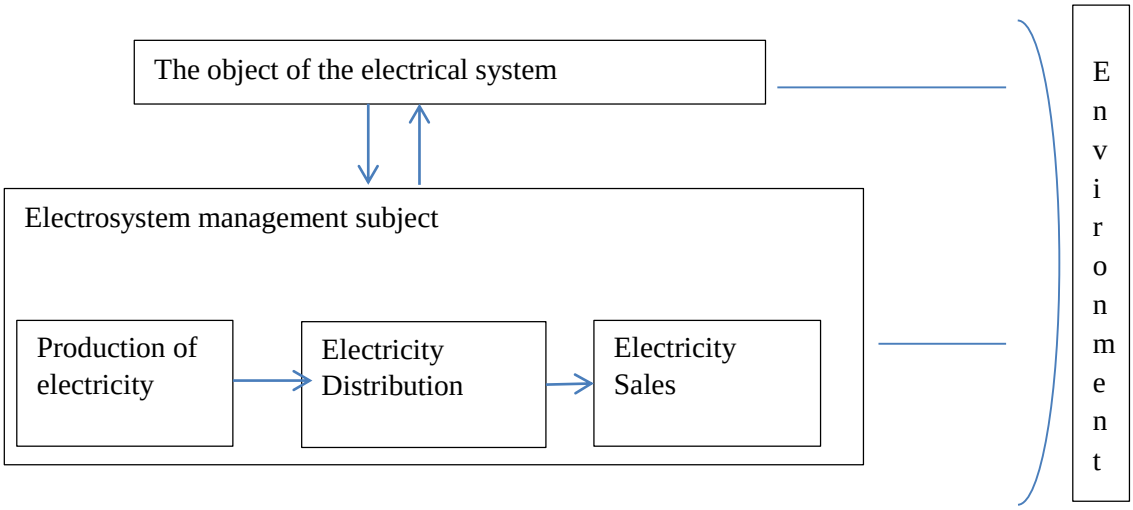

Figure 10. Possible option for the decomposition of the object of management in the power system

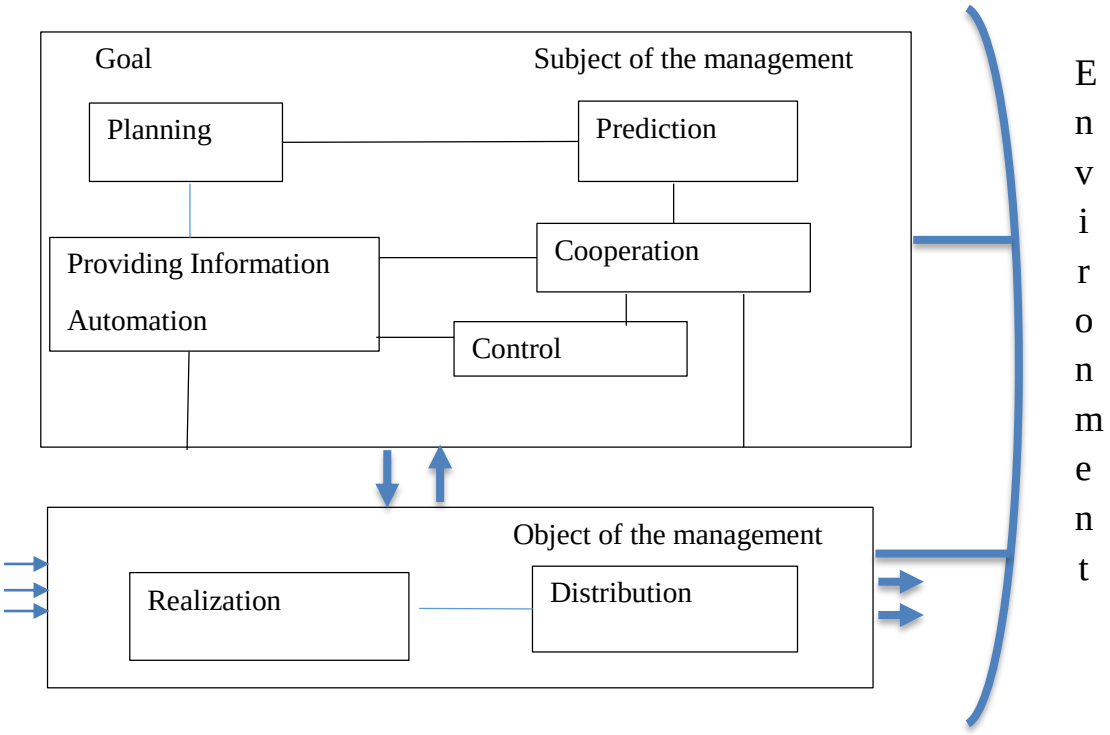

Figure 11. A system of autonomous constituent management of the electrosystem

In this case, the ongoing process is considered as the process of electricity generation, distribution and sales. For the purposes of the study, it is possible to conduct further decomposition of the stages of process. It is also important to have information channels with the environment. It is possible to simultaneously decompose both the subject of the management and the object of the management. One possible option is presented on Figure 11.

Such a system can describe the process of functioning the autonomous subsystem of the electric system (egg, a city or region key company).

Here are the management functions and information block that can be used to organize data monitoring and remote management process using SCADA system. It is possible and probably necessary to manage the data within the management contour, between the functional blocks of the management, management functions, and process stages, in direct and feedback connections, and by providing connections with the environment [18].

2.2.1 Description of the specific object management in the GSE system and analysis of the characteristics of the SCADA system.

JSC "Georgian State Electro system" is the operator of the electricity transmission system [18]. According to this status, it is responsible for the overall coordination of the

electricity delivery system of the country and balancing the demand and supply of electricity. The company also manages the exchange of electricity with neighbouring states and actively cooperates with other systems operators who transmit electricity.

GSE is the only responsible for dispatching and for providing real-time electricity, demand-delivery balancing and ensuring that electricity is maintained in the country.

To conduct planned maintenance works, the GSE shall periodically power down important electric transmission lines and some parts of the substations and, if necessary, will temporarily restrict electricity supply. It is also responsible to prepare realistic emergency protection plans and analyse networks in case of accidents.

The GSE's National Dispatch Centre in order to use energy resources in an optimal way, coordinates the activities of the electricity market participants. It also manages the electricity transmission network in both normal and emergency situations.

SCADA system made it possible to carry out full monitoring of 500/200 kV network, including substantial parts of 110 kV loop stations and major parts of generation stations, as well as to ensure, automatic generation control, which allowed the company to better regulate system frequencies and with creating common schedules with neighbouring countries [18].

The SCADA system was implemented on the basis of the technological means and programs that are generally accepted and easy to manage and finance. It is an open source, expansive and provides an opportunity for interfacing to make an autonomous program planning.

A high-quality renewable map and three jobs for operators were arranged in the hall belonging to the control centre. The centre is also provided with a sound recording system.

The work processes are actively underway for all electrical power stations owned by the Georgian State Electro system. The paper presents the example of substation “Batumi 220”, where during the project, upgrades (or repair) of existing primary (power) devices were made, including the installation of digital, protection and management relays, the substation was equipped with modern local and automated (semi - fully) remote control system that improved the quality of power supply, making it possible to fully control the

data, Substation Monitoring of the equipment was achieved and reduction of the duration of liquidation of the outages and the number of losses in the network were also cut short.

2.2.2 National Control Center (NCC)

"Georgian State Electro system" is the only dispatch licensee. It is responsible for operational management of the Georgian energy system, 500-220-110-35 kV of operation of the transmission facilities and the sustainability of the energy system. The central dispatcher ensures that the power system works as a single unit, in both normal and emergency situations, the National Control Centre (NCC) aims to monitor about 1,000 information nodes. Specifically, the following electric values are monitored [18]:

- Condition of the main circuit of 500/220 kV circuit
- An active power output of main 500/220 kV and 220 kV / 110 kV transformer cores and the voltage of 500/220 kV busbar.
- Control the condition and the capacity of HPP generators.
- The condition of the 330-kV line with the neighboring country.

SOLARIS operating system, ORACLE database, and SIEMENS software are used for functioning of the Dispatch Centre and WINDOWS OS is used for users.

Figure 12. Dispatch Center

Figure 12 displays the Georgian State Electro System Dispatch Centre and where Barco's VIDEO WALL with its controllers and screens are used. Also for consumers (for

dispatch), four monitors, enhanced data sets for managing and monitoring substations were installed.

Data changes on VIDEO WALL are reflected in real time, it is updated every second. Remote control and switching of substations, also balance control and monitoring, automatic regulation of power stations, system frequency control, and regulation are accomplished from the Dispatch Centre.

Unlike the old system, a new one is radically different, as it’s moved from analog to digital system. Increase a capacity of information, processing speed and speed of information transfer, and lead to better accident detection capabilities. Energy sustainability has also improved.

Digital relays, industrial switches, converters, optical fibre systems, substation info collectors, convertible and transmitting devices (GATEWAY), L3 level switches, SDH equipment, microprocessor devices and radio systems, GPS and GPRS devices, time synchronization devices and frequencies, servers, personal computers, management board (VIDEO WALL). This is a list of devices that provide a reliable and real-time exchange of information between substations and central dispatchers.

2.3 The Description of the work carried out in Batumi "220" substation

During the project, the existing primary (power) equipment upgrade (or repair) was completed, the staff installed the digital protection and control relays, substation was equipped with the advanced local and remote management and automated (half - full) system, on-duty operators were trained, these actions noticeably improved the power delivery quality and It was made possible to fully control the data, monitor the existing devices on the substations and minimize the duration of liquidation of the outages and the number of losses in the network.

Due to its location, the "Batumi 220" substation is an important part of Georgia's energy sector, it is also the main substation in western Georgia, which is responsible for transiting electricity between Georgia and Turkey [18].

The purpose of transit substations is to generate generated electrical energy and correctly redirect the corresponding electric transmission line, this is a general description of the work performed by the substation, however technologically it's not as easy as it sounds. In order not to take into account the unexpected cases, do not lose electrical energy and be a safe environment for work, for this purpose, the proper functioning of many basic or supporting equipment is necessary and it is necessary to observe all the processes.

In order to correctly understand the process, we are talking about, we shall discuss the overhead line "Paliastomi1" in Figure 13. On what main components are used in its proper functioning.

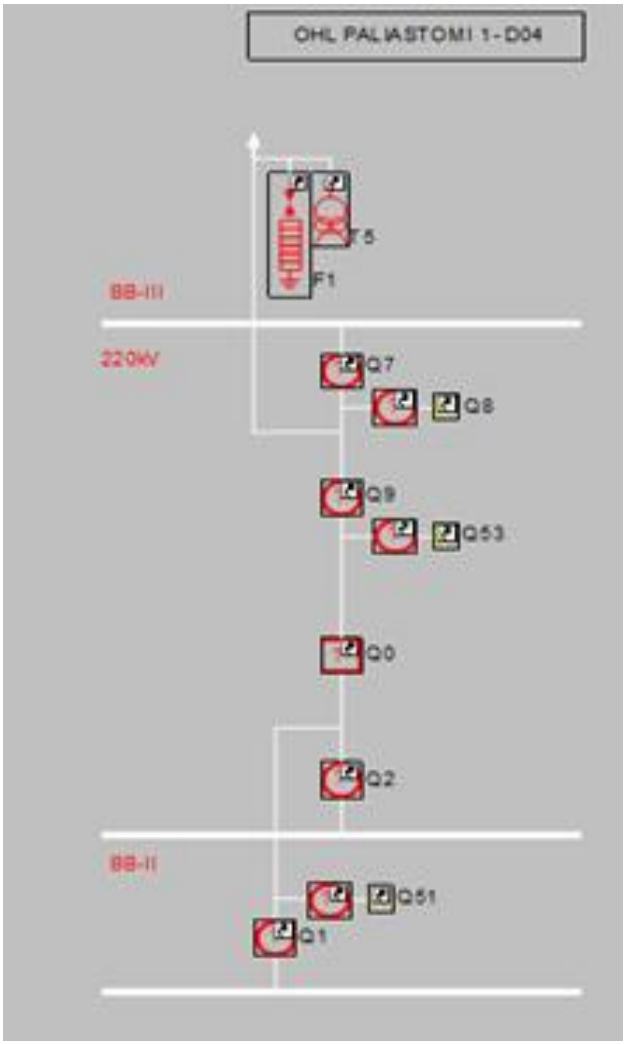

Figure 13. OHL "Paliastomi 1" primary components

Batumi 220 Substation consists of two busbar systems (BB-I, BB-II), bypass busbar system (BB-III), the picture shows the overhead line "Paliastomi 1", which is compatible with the BB-I with the First Busbar System (Q1) switch. Accordingly, BB-II is

compatible with the second busbar system (Q2) switch, the Bypass busbar system (BB-III) through the passage of the bypass system switch (Q7). The picture also shows Q51 - I and II busbar switches are grounded. Additionally, Q9 - circuit breaker, and the Q8 transmitter "Paliastomi 1" are also grounded. Q0 is a line breaker whose function is to turn the line on-off when it is under load. Also connected to the line is the voltage capacity transformer, which measures the voltage in the line and supplies relay protection devices.

For example, when the line is on at the first busbar system, at this time, the first busbar switcher is Q1 is closed off situation and Circuit breaker Q9 and Q0 are on, during which “Paliastomi 1” is supplied with power through first busbar system through the devices mentioned above.

Together with other power devices, each power supply line has its own programmable logical controllers responsible for safety and management. Those controllers are therefore responsible for their proper and safe functioning and enable them to monitor all the existing processes, which are in the middle between the power line and dispatch.

We discussed the example of one power supply line, during which the main components are utilized while considering that in “Batumi 220” we have [18]:

- 220 kV power supply line 9 units
- 110 kV power supply line 11 units
- 35 - 10 kV feeder with 19 units

Therefore, the number of the above-mentioned devices is proportional to the number of power supply lines.

2.3.1. Digital Protection and control relays

Protection and control relays are the main means of automation, monitoring their current processes and management of the equipment, these relays are managed by special algorithms and by using those safety measures are implemented.

Each power supply line has logical controllers for its management and safety, which are responsible for power line security. The relays produced by the company SEL are used for the management and safety in "Batumi 220" substation:

- SEL 311C is used for remote protection and direct electric protection, it measures and the power and voltage within the power line. Using the corresponding formula, it reports active and reactive power use.
- SEL 487E - The Auto Transformer and Transformer safety relay, which receives information from Power Transformers, compares and analyses them. Taking into account the results obtained from the shift from the Short circuiting.
- SEL 451 - Protection, Management, and Monitoring relay, which is responsible for the management and safety and monitoring of the cells.
- SEL 421 - Remote protection relay of the transmission line, it is installed at the top of the power supply line, which receives the information from line power transformers and provides the basis for the remote control of the line.
- SEL 411L - Differential Protection relay of the power transmission Line, which is installed at both ends of the power line and is connected to each other with a fiber optic cable, the information for this relay is forwarded from power line transformers, it compares information received from both power transformers and compares them, in order to analyses the process.
- SEL 487B - Busbar Protection Relay, which receives information from all existing relays from all busbars, as well as from busbar the voltage transformers, it examines and analyses them. Taking into account the results it gets, it protects the busbars and every connector from short-circuiting.

2.3.2 SCADA System Architecture implemented in "Batumi 220" substation.

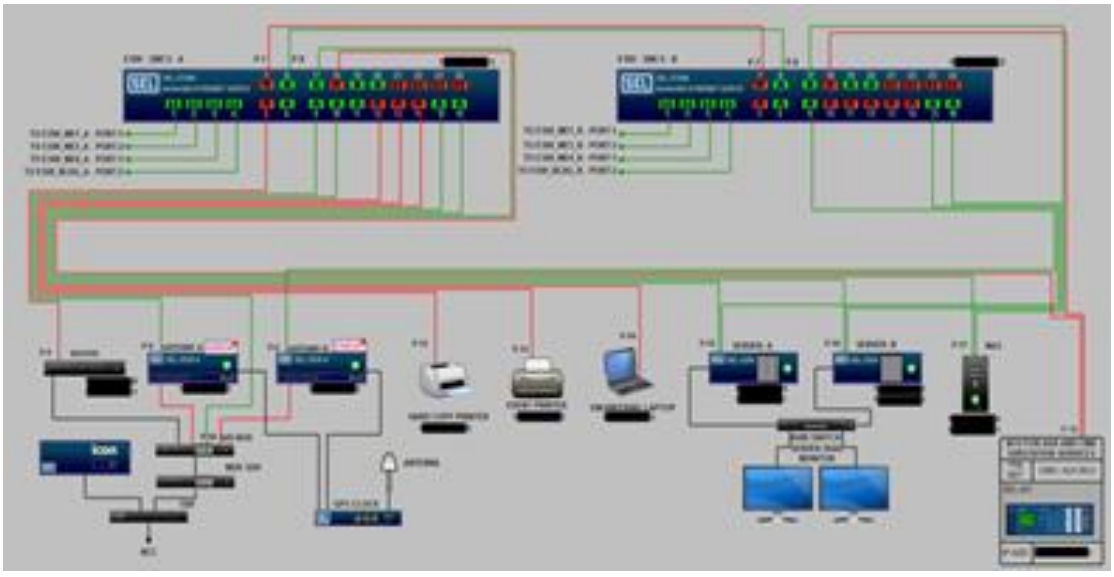

Figure 14. Topology of the main devices

In the Figure 14 are the basic equipment needed to exchange information used on the "Batumi 220" substation, specifically:

- Layer 3 Managed Ethernet Switch - SEL 270 M
- Human Machine Interface - SEL 3354
- Gateway - SEL 3530-4
- GPS Clock
- Data archiving equipment

As well as the existing network topology (IP addresses are removed due to security stands).

It is also evident what path the signal undertakes after gathering the information on the central switch of the substation, On the one hand, with the help of GATEWAY 1 and GATEWAY 2 the signal is transferred to the main dispatcher and the second path (human machine interface) SERVER A and SERVER B is allocated for the local management system. For the purpose of data protection and reliable communication, the Georgian state system has chosen N-Modular Redundancy type security, which means that two independent channels, one of which has a priority and in case of emergency or damage the system will automatically switch to the second channel, For example, if we imagine the model of the local management system, If SERVER A will not function properly due to any external factor or software error, the system will automatically activate SERVER B and the operator will inform you about the first server damage, this is the main reason why of two GATEWAY and HMI exist.

The existing visual interface allows you to detect the problem without knowing the information details about the damage, for that purpose the colour system is used, for example, in case of damaged communication the colour of the corresponding line changes to red and when everything correctly it takes green colour.

There are also additional devices such as full colour or black and white printer devices, an engineer's laptop that is used in case of a compromised computer, there is also an information storage device, its existence is very important because in the case of the unforeseen occurrence of the problem both servers (SER.A, SER.B) the operator will have this device and will be able to see the logs of each action. After the problem is solved

it is easy to restore the lost information, it can be said that it has a "black box" function, a device that can provide us with information about the existence or irregularities.

Also the picture features GPS Clock, which is the time synchronization device that is connected to the satellite and is able to get the exact time in order to set it in the network, its existence is quite important because the servers and the equipment in the main dispatch are all connected to the substation of the NCC, have the exact same time to avoid the inaccuracies and the subsequent unwanted situations that can lead to improper measuring of the signals.

2.4. Creating a local management system using Zenon Editor 7.1.

Together with the physical components SCADA is one of the most important components of the software, as, with the development of the above-mentioned technologies, the number of manufacturers who were trying to create their own software support for their equipment has grown considerably.

Zenon is an object-oriented software that helps to create a process management system based on the COPA-DATA group, its software interface allows us to access the Zenon Editor and Zenon Runtime Program, which plays an important role in solving automation tasks. All necessary features built into it are required to create a local management system to enable operators to monitor information on the screens for further monitoring and management. Zenon's automation engineer has two software:

1. Editor is used to create a project
2. Runtime - is used to display the project on the screen

The master's work is presented is based on the Project of GSE and the results achieved with the help of Zenon Editor 7.1. The study seeks to explore the prerequisites that are required to create a set of SCADA systems for monitoring and management.

The software aspects of the substation were determined based on how the technical side of the substation was organized, initially, only single one-sided plan was unveiled which comprised of, the number of switches, busbars, breakers, transformers, and autotransformers for the power supply line, and their deployment in the open distribution territory of the substation.

After drawing up the relevant open distributor diagram, arrangement for the primary and secondary circuits was made, this involves the installation of the programmable logic controllers and compilation of relevant algorithms. After completion of the above works using Zenon 7.1. It was decided to use the local management system software interface. Below, I will review the main functions used to create a local management system software interface.

2.4.1. Zenon Editor 7.1 functionality

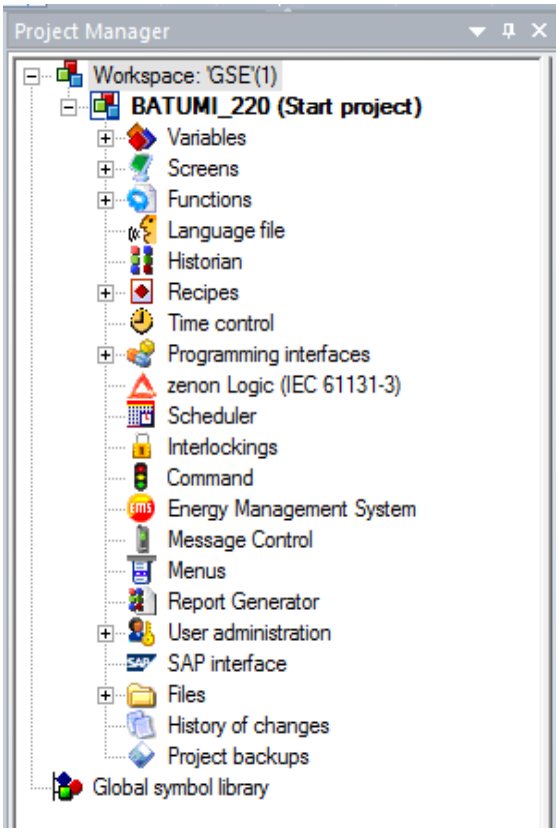

Figure 15. Zenon Editor 7.1 features

The Figure 15 features Zenon Editor 7.1 functionality that allows software solutions to create a runtime file that allows operators to fully monitor and monitor current processes. This program is intended only for creating a local management system and it is necessary to have a connection with the internal network and HMI to detect, process, correct logic, and send them to the appropriate recipient.

The main components of Zenon Editor 7.1 are:

- Variables
- Drivers

- Screens
- Commands
- language bar
- Report Generator
- Interlocking

2.4.1.1 Variables:

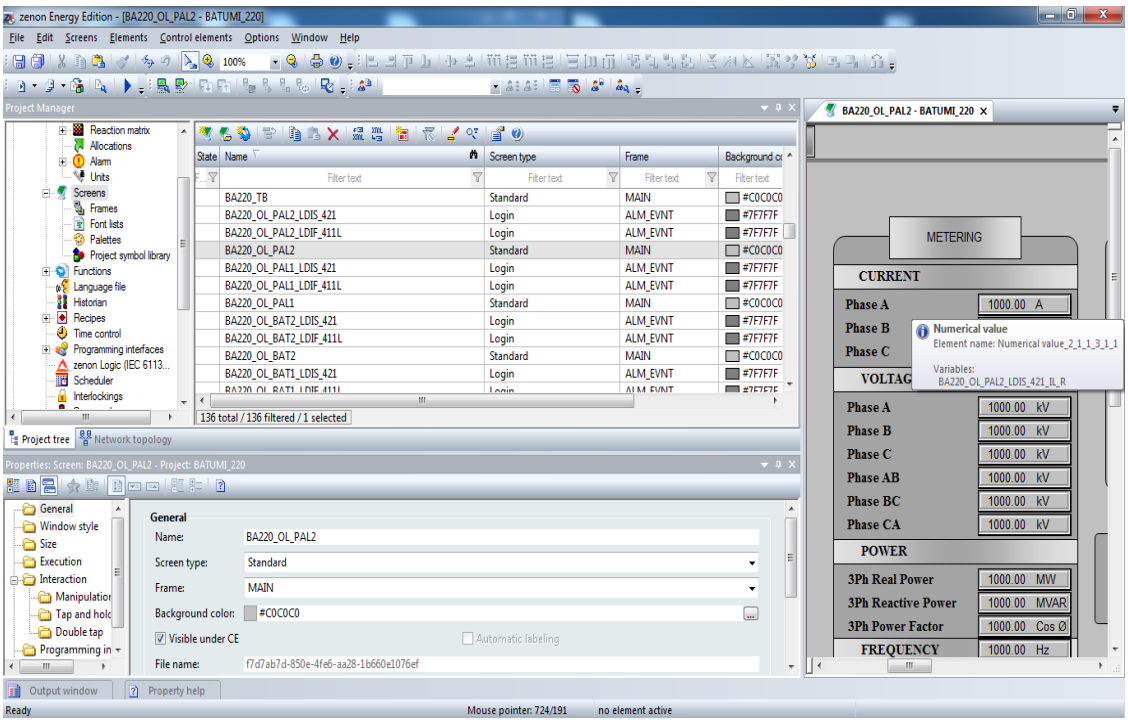

Figure 16. Description of the variables

In automation engineering, signals and memory signals, memory bits, all measurements or statuses that take part in the work process, are considered as variables. Depending on the specifics of the work we may have several hundred or thousand variables, so their resolution needs to have a unique name, Identification, Driver, and the type of signal that can be used to determine what it is. This is where the variable window of Zenon Editor 7.1 comes in. Here the description of all the existing signals is done, it also gives them the correct username and IP address, with the help of all the signals in one environment that makes the process more flexible. Variables are downloaded directly from each play via a real-time driver. The program is connected to the DATASET in the relay, where the program is generated in one DATASET, which will then be required for local and remote control systems. Relays exchange specific variables between the so-called GOOSE

messages. There are also varieties that are created in the program directly (Internal or Math Variables).

Internal Variables are used to perform functions that are generated in the program and will not use other external tools, such as granting different colours for busbars or power lines that makes it visible to the operator whether or not the line or slot are either on or off. Or whether or not the grounding is done and etc. We use Math Variables if we need to generate or use any formula for different variables, such as multiplication of measurements, change of mark, etc.

The matrix block is used to give different values for characters. For example, Figure 17 displays the four-letter of the caller's symbol, based on the status (turned on, off, uncertain and missing).

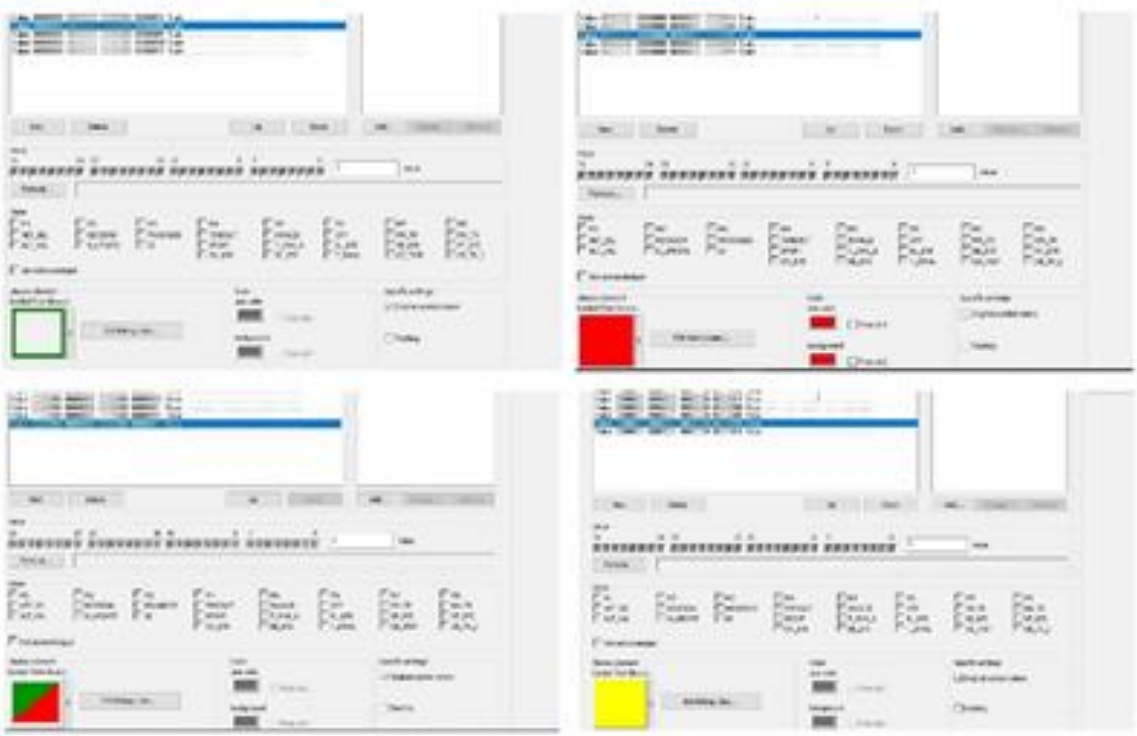

Figure 17. is the symbol of the breaker in 4 different conditions

2.4.1.2 Drivers

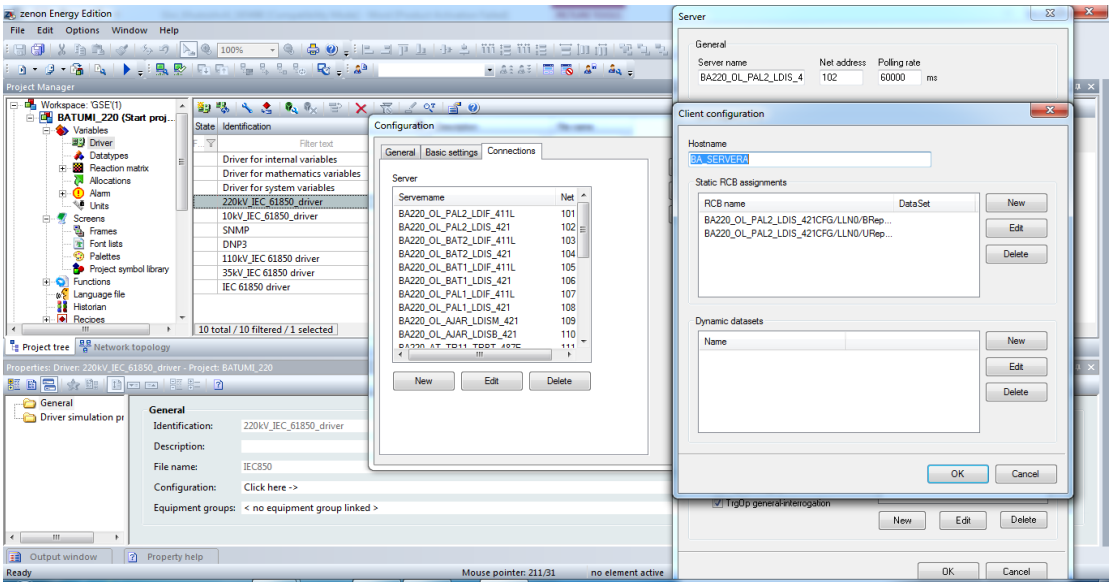

Figure 18. Drivers

The role of drivers is to establish the communication between HMI and IED (Intelligent electronic devices), whereby the IP addresses indicate paths, buffer sizes, priorities assigned to existing servers, and the IEC addressing names that are necessary when describing the appropriate variable to be sure. Drivers help us to activate various communication protocols and configure the task accordingly. Drivers are divided into several groups: Internal Driver, Mathematical Driver, SNMP Driver, Driver for System variables, DNP3 Driver, IEC_61850 Driver.

Internal Drivers are used to create variables that are generated in the program and will not use other external supporting tools.

Mathematical Driver is used to generate a variable, if you need to generate or use any formula for different variables such as multiplication of measurement, change of mark, etc.

The SNMP Driver is used to communicate with switches or other communications tools to generate their variables such as health status of the device or the engagement of the ports, etc.

DNP3 Driver is used to communicate directly with GATEWAY and generate its variables such as GATEWAY ports engagement-switching status, etc.

Driver for system variables is used to generate system variables.

The IEC_61850 drivers are used to communicate with relays and generate variables. In our case, for more visibility and convenience, IEC_61850 Driver is divided by voltage levels at the substation, 220 kV, 110 kV, 35 kV, 10 kV. Each driver assembles only specific voltage level relays. The driver will be able to write the exact name and IP address of the drive and to download the specific DATASET from which the variables should be downloaded. If any of these components have been violated, the communication between the program and the physical device will not be possible.

2.4.1.3 Screens

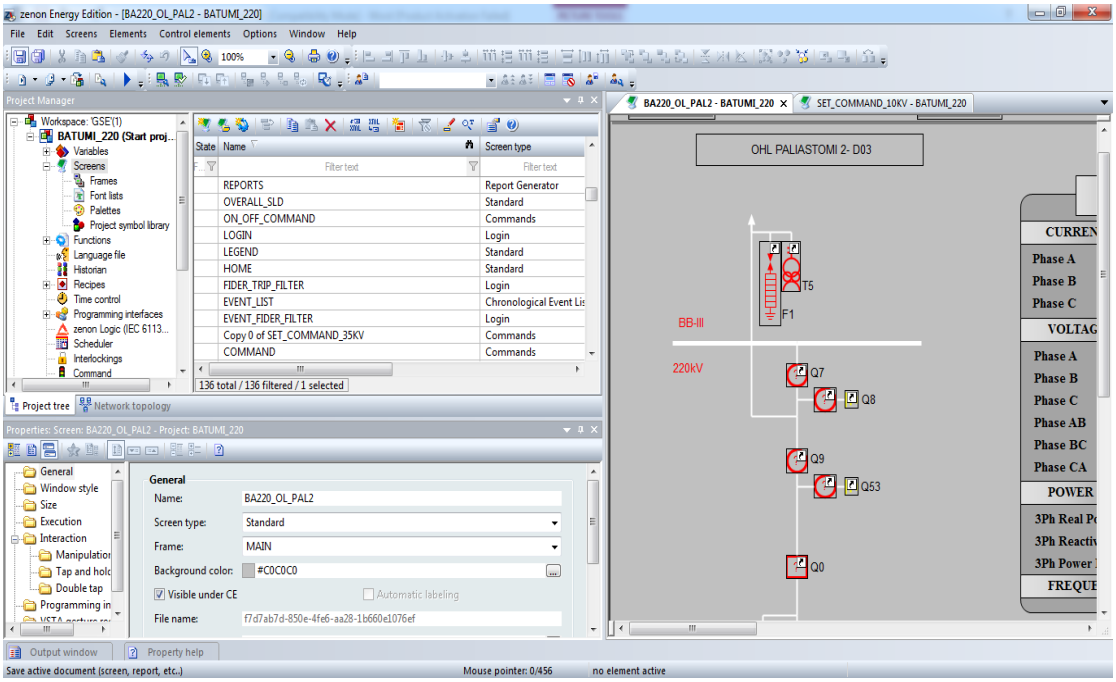

Figure 19. Screens

The screens are used to work on a graphical interface, an environment that is designed to create a Zenon Runtime Program graphical environment. With its help we are able to visualize the logic of the figures and symbols, it is quite flexible and easy to use, allows us to add and allocate all the items in our preferred places, which are visible to the operator in the screen environment, here you can create all kinds of visuals, such as the main screen, where you can visualize the architecture of the substation, the miniature circuits, the reports, and the various accessories, and so on.

Of course, it is not enough just to create elements and select an appropriate design for them, all the existing features in Zenon Editor 7.1 are directed to sorting these elements

and giving them the correct functionality, for example, all elements correspond to the variable with which we can use it and we take the value of this variable to the screen, Measurements come in numeric form, digital signals according to their status (enabled - disabled, active - are not active).

2.4.1.4 Commands

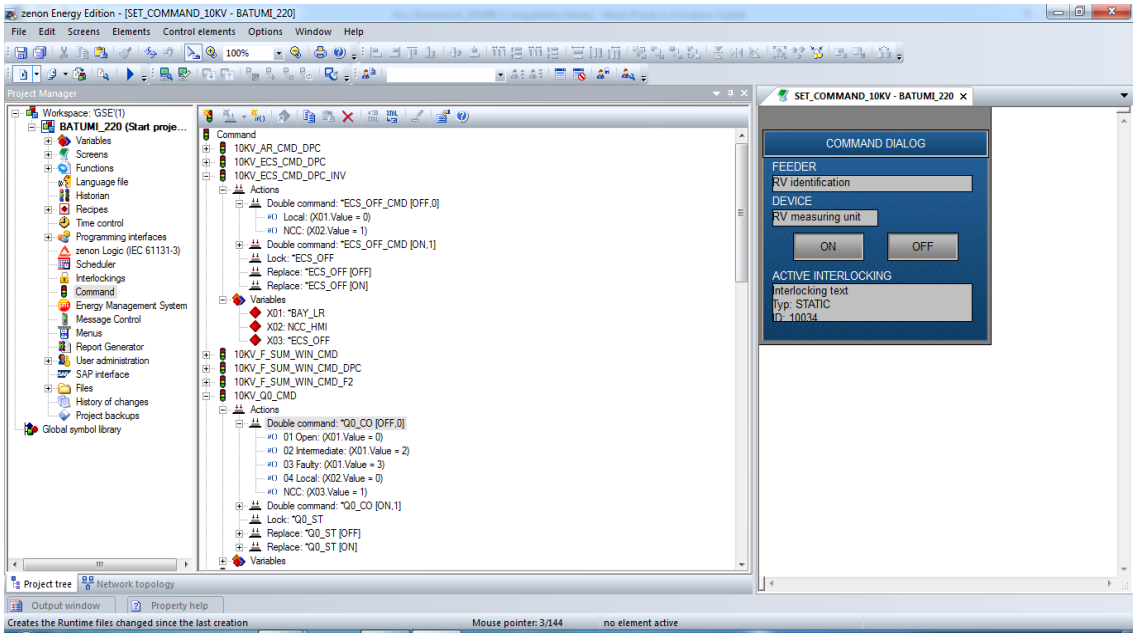

Figure 20. Commands

The environment of the commands incorporates single and double orders, “Single command” is defined when only one variable is involved and the result depends on its value, for instance when logic 1's corresponds to the “on” command and logic 0’s translates into the command “off”, such as blocking order, winter and summer regiments, etc.

In the case of the double command, several variables are involved, this is a command that depends on several signals, for example, turning the breaker and switches on and off, the interactions with grounding elements, etc.

The purpose of this environment is to create management elements that are one of the main priorities of the SCADA system, so it can manage remote facilities in different areas.

2.4.1.5 Languages

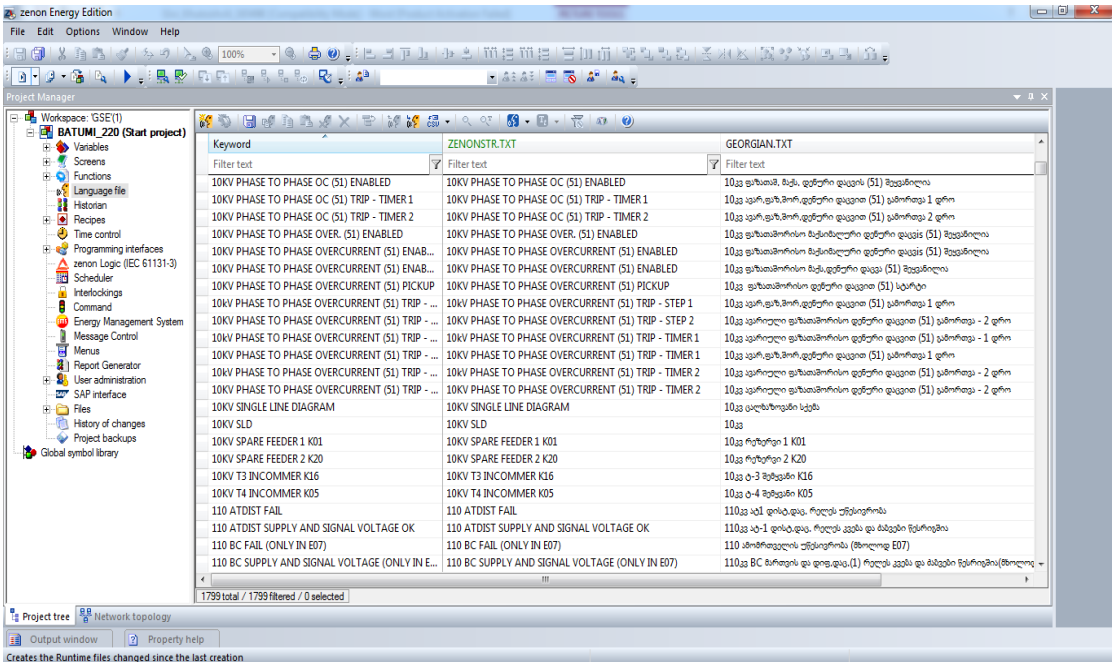

Figure 21. language bar

The language bar environment allows you to create a customized runtime project for users of all nationalities, such as, for example in Georgia, many operators do not know the English language. If the Zenon Editor did not have the opportunity to create a suitable environment for Georgian operators, then it would be unthinkable to have timely and safe production of substations, because as the duty of the operators would have to study the English language, it would also be difficult to find the staff who would have enough English language skills to work on a similar position.

2.4.1.6 Reports:

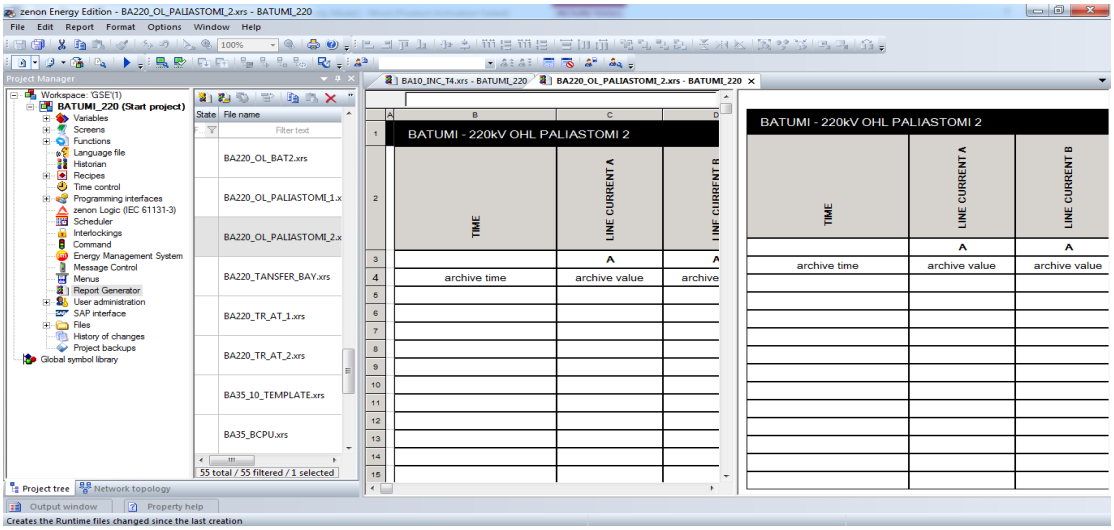

Figure 22. Reports

Substation monitoring and security controls are required to record current measurements, for instance, prior to the installation of the local SCADA system, operators measured the transformers, busbar sections, voltages, and current manually. Therefore, the risk of its error was high, but the Report Generator excludes the possibility of error completely because the data are automatically presented for all relevant elements. Report Generator allows you to specify any measurement you need at any time interval. In this case, we use hourly reports.

2.4.1.7 Functions

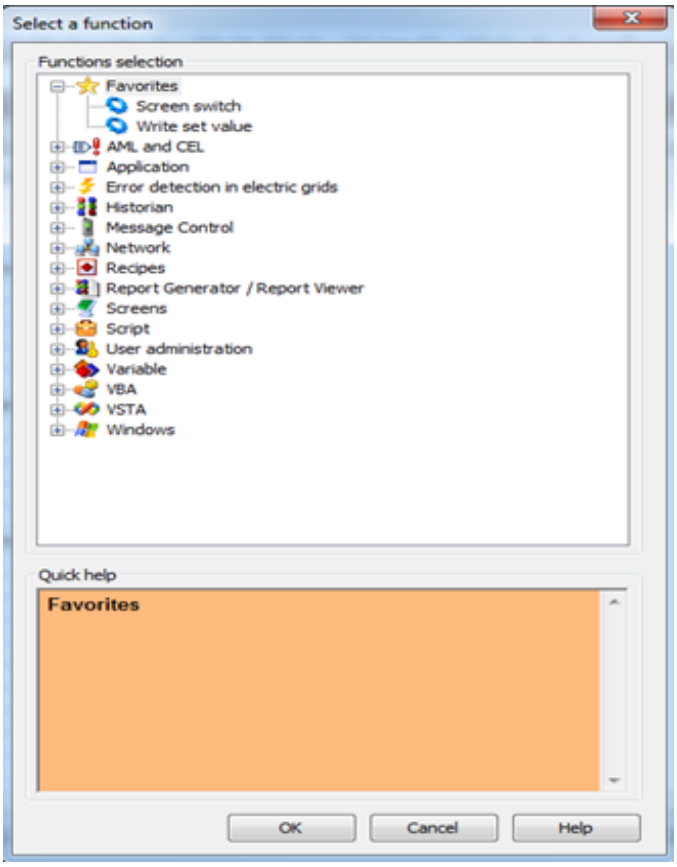

Figure 23. Function graph

Figure 23 features a list of all the functions available in the program. The local managing system is one of the most important places in creating this block, all the functions are generated here. By using the functions, it is possible to install time filter in the report graph, also selecting colours for the diagrams and attaching the measurements. The functions block also includes scripts that combine several functions. Mainly we use the "screen switch" function. We use the “screen switch” function to open the screen and call the window. Also, we use the “write set value” function to give a value to the variable.

For simulation, we have “write set value” functions to value to variable measuring variables. For the Deputy operators program, there are functions like special options for any type of editing, such as user authorization, printing event logs, closing the windows, switching main devices on and off, changing language, exiting the software and shutting it down

2.4.2. Results:

Figure 24. shows the control panel of “Batumi 220” substation, this is the basic scheme on which the operators work, it is referred to as MCS - Main Control Scheme, it is also known on the name of the MIMIC diagram, it represents a way to display Digital and analog signals on the screen.

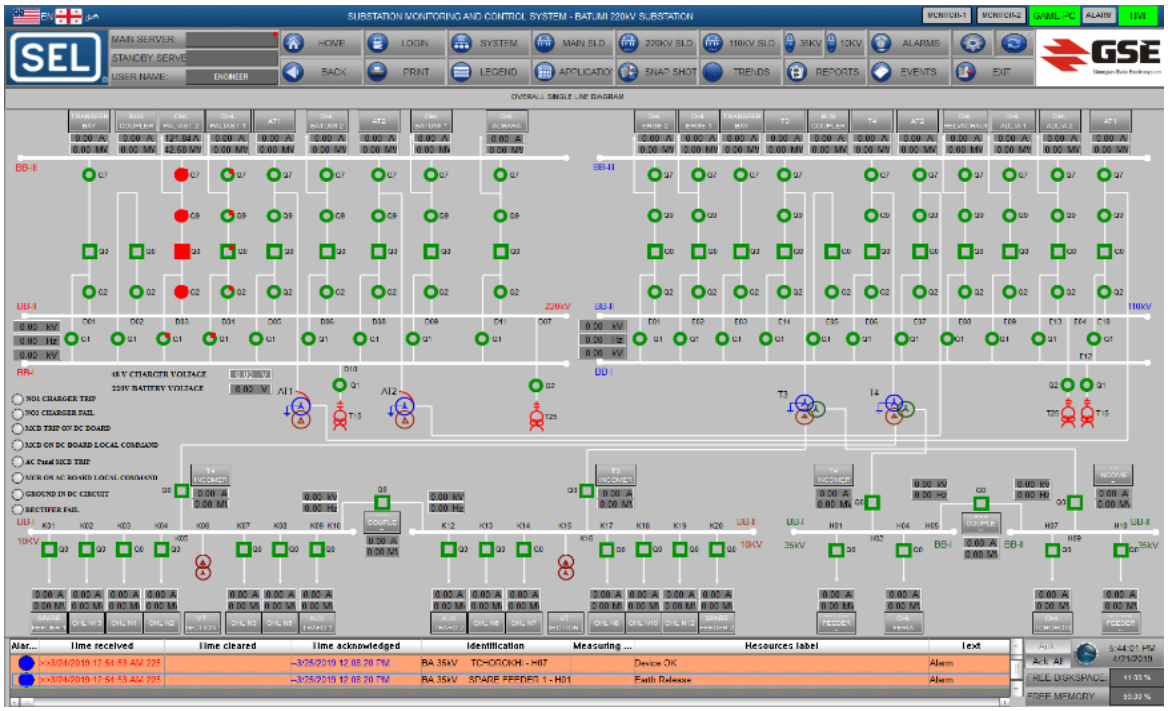

Figure 24. MCS Main Control Scheme

2.4.2.1 MCS Main Control Scheme:

The Zenon runtime software gives you the ability to visualize a scheme like this, which helps operators to monitor and process processes in real time, It is reflected in the conditions of autotransformers and transformers, measurements of connections and buses, conditions of breaker and switches, real-time situation of all high and low voltage power lines, etc. , On the Figure 24, it is visible that once you select any connection Under the buttons, it will show detailed information on that unit. For example, the "Paliastomi 2" button will then open the corresponding window (see Figure 25).

2.4.2.2. The built-in environment on the example of "Paliastomi 2"

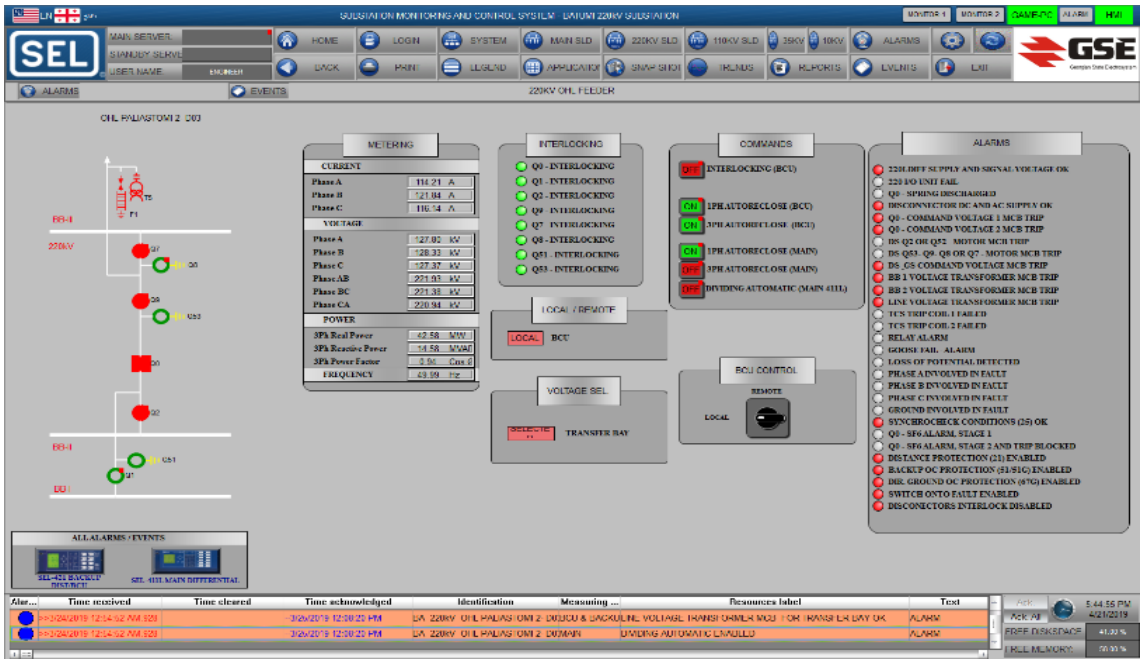

Figure 25. Detailed scheme of the "Paliastomi 2" connection

The picture depicts the detailed scheme of "Paliastomi 2", this active interface gives the operator the ability to control the complete monitoring of the specific connection, from here it is possible to either turn on/off the breakers and switches, set the desired modes and edit them, also to observe existing voltage at any stage of operation, perceive Its active and reactive power frequency, monitor and evaluate the expected risks and threats.

The program uses interlocking functions, which reduces the risk of human error to almost zero. As the picture shows only Q0 (circuit breaker) is green, this tells the operator that other components (Switch, Grounding) that are red, cannot be interacted (Switched on/off) upon because of the ongoing process at the connection. The program utilizes the User Interface (User Environment) that controls the access to various operations, such as it restricts the operators access the part of the program that is the only engineer's prerogative, this means that not everyone can make software changes in the existing runtime and so on.

2.4.2.3. Event list

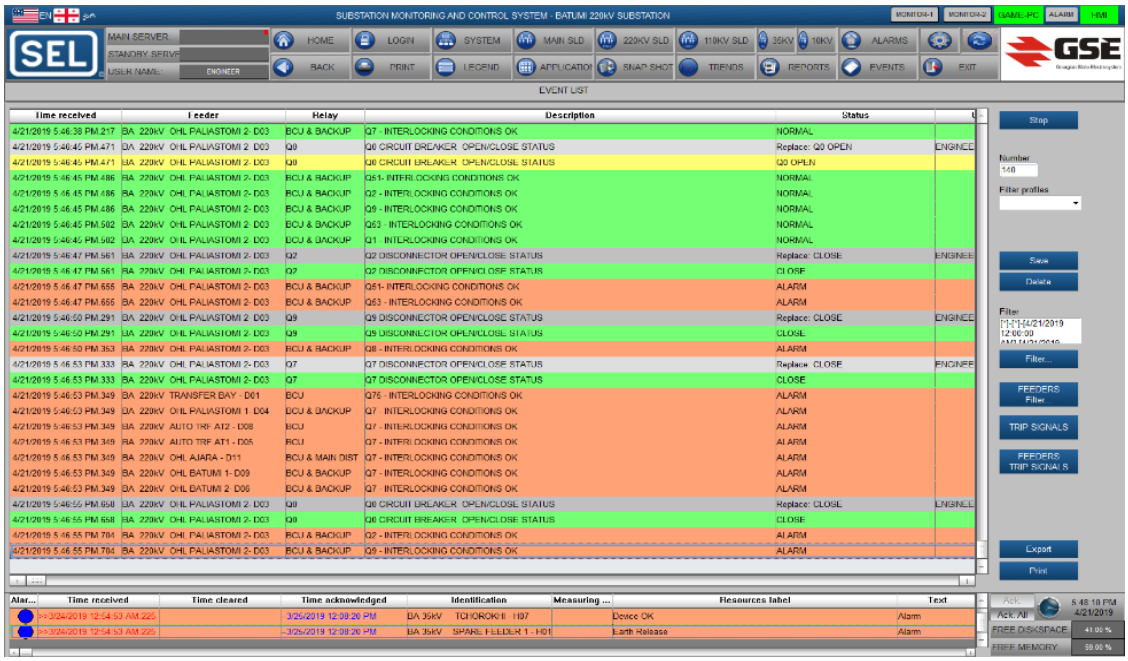

Figure 26. Event List

Figure 26 shows the list of events where the screen is displayed instantly as a result of all processes or messages. The existing signals are sorted by the time and depending on its purpose, the colour is different, for example, the green colour means that the command has properly been executed, the yellow colour is displayed when the status of the breaker is open, the purpose of the warning is to ensure that the operator is more attentive in order to avoid unforeseen incidents. With the red colour, the alarm signal will be displayed, similar signals are delivered to the local shield, and the operator will also receive a text and sound notification. The event list also allows the operator to find a specific time period to find any event in the substation.

2.4.2.4 Trends

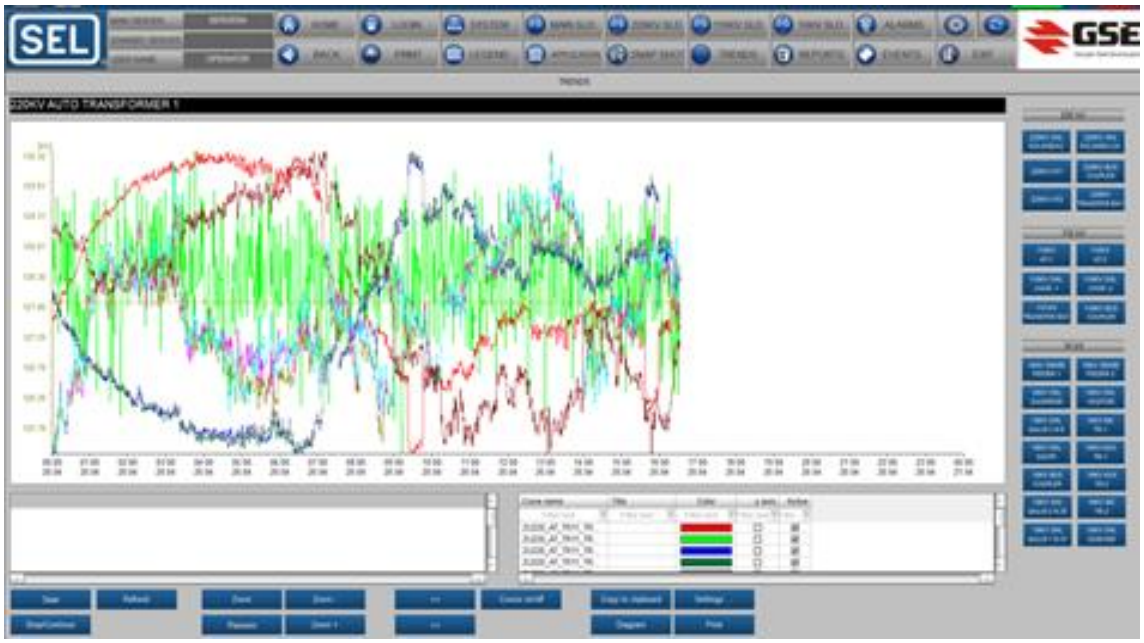

Figure 27. "Batumi 220" is a graphic indicator of AT's measurements

Figure 27 shows the "Batumi 220" substations “Auto Transformer 1” measurement graphic indicator in specific of time frame, all colours have its corresponding name, making it easier for the operator to monitor the process and make the reporting easier. It also gives you an opportunity to predict critical situations in a short time notice.

2.4.2.5 Used symbols

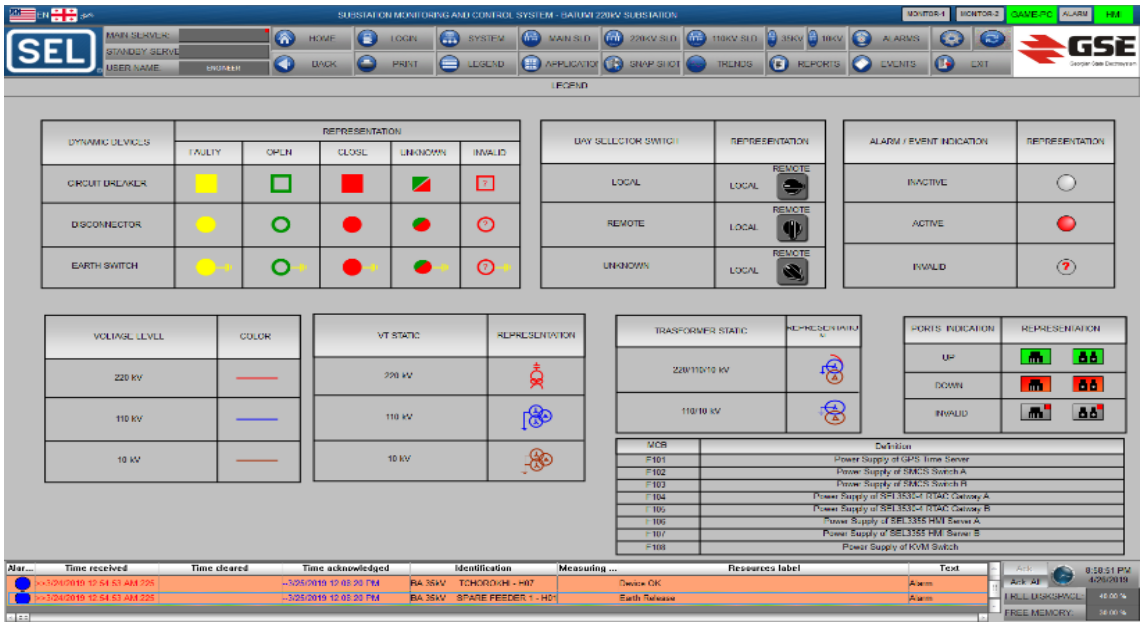

Figure 28. Used symbols

The values used during the project work. It was very important to ensure that these characters were selected correctly to enable the operators to perceive them and understand them much easier, especially in the beginning stages of the project in order to make sure that the work process was safely conducted. That's why we added them to this environmental program.

Summary

At the moment, SCADA system is the major and most promising methods, for the automated management process of complex dynamic systems. The capabilities of the human-machine interface that exists within the system, the complete and clear nature of the information displayed on the screen, access to management “tools”, easy to use reference system and instructions menu - Enhances the efficiency of interacting by the dispatcher (operator) with the system and minimizes errors in the management process.

The SCADA system in a way is an innovation for Georgia and especially for energy companies. The 65-70% of electrical substations existing within the country were installed during the Soviet Union period, therefore not viable for automation. The complexity and discretionary nature of the system is mainly due to lack of information about the functionalities and features of various SCADA systems.

Functionalities and solutions provided in the current master's thesis represent the basic tools that automation engineer needs to create a suitable environment for the manufacturing process. Such an environment can facilitate efficient monitoring and management of all events.

The introduction of SCADA system in high voltage substation "Batumi 220" has increased capacity of that specific substation, Reduced network outages and disruption numbers, the work environment has become more safe and it is possible to conduct the observation, monitoring and timely analysis of all processes from one location. Sharing experience and awareness of SCADA systems by other energy companies will significantly enhance their efficiency and ensure stability of the country's energy system.

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