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ASPECTS REGARDING THE ASSESSMENT OF EQUIPMENT/INSTALLATIONS REGARDING COMPLIANCE WITH EXPLOSION PREVENTION REQUIREMENTS

MIHAELA PARAIAN[1], ADRIAN JURCA[2], MIRELA RADU[3], MIHAI POPA [4]

Abstract: According to the legislation regarding the minimum requirements for ensuring the safety and health of workers in the industry, the employer must take all measures to ensure the safety and health of workers, being obliged to be in possession of a risk assessment, in which an essential chapter is the risk generated by the equipment and installations used. If the installations are located in an area where an explosive atmosphere may be present, an explosion risk assessment must be made in order to establish adequate protective measures to prevent ignition sources that could initiate the explosive atmosphere. If for the equipment put on the market in accordance with the ATEx Directive, the evaluation methods with the essential dry and wet requirements are clear, for the installations carried out in situ by the user, there is no recognized method for evaluating the risk of explosions. The paper presents some aspects regarding the evaluation method of the installations used in environments with potentially explosive atmospheres in accordance with the requirements of the norms and standards regarding the prevention of explosions. Also, the work presents some aspects regarding the evaluation of the risk of explosion in the equipment already installed in specific conditions.

Key words: explosion risk, explosive atmosphere, risk assessment, ignition sources, methods.

1. INTRODUCTION

With the development of technical-scientific, new types of equipment / installations have appeared with increased reliability and safety, being available much improved components, electrical controls and extremely sophisticated safety devices as well as more resistant and durable materials. New technologies create new challenges

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in assessing the risks of explosion when they are installed in environments with a potentially explosive atmosphere [1].

The purpose of the explosion risk assessment is to set of appropriate measures to reduce it, in accordance with the requirements of the norms and standards. We can say that, through abiding by the norms, the presumption of providing an acceptable risk level is ensured.

2. APPLICABLE LEGISLATION

The placing on the market of equipment for explosive atmospheres is regulated by the ATEx Directive 2014/34/EU which establishes the manufacturer's obligations regarding the assessment of compliance with the essential health and safety requirements The evaluation of the equipment aims to prevent sources of ignition in normal or faulty operation, taking into account the intended use.

ATEx Directive 2014/34/EU, formerly known as ATEX 100a, is aimed at manufacturers. It applies to equipment and protective devices intended for use in potentially explosive atmospheres. Safety and controlling devices for use outside the hazardous area but essential for the safe operating of equipment inside it are also covered (fig.1). The directive applies to electrical as well as mechanical equipment and applies to gases, vapours and dust atmospheres.

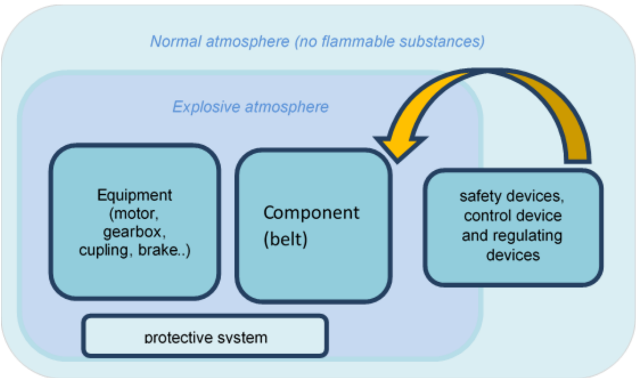

Fig.1. Scope of the directive ATEX 2014/34/EU

'Equipment' means machines, apparatus, fixed or mobile devices, control components and instrumentation thereof, and detection or prevention systems which, separately or jointly, are intended for the generation, transfer, storage, measurement, control and conversion of energy for the processing of material, and which are capable of causing an explosion through their own potential sources of ignition.

'Protective systems' means design units which are intended to halt incipient explosions immediately, and/or to limit the effective range of explosion flames and explosion pressures. Protective systems may be integrated into equipment or separately placed on the market for use as autonomous systems.

'Components' means any item essential to the safe functioning of equipment and protective systems but with no autonomous function.

'Safety devices, controlling devices and regulating devices' means devices intended for use outside potentially explosive atmospheres but required for or contributing to the safe functioning of equipment and protective systems with respect to the risks of explosion.

'Assembly' means a combination of two or more pieces of equipment, together with components if necessary, placed on the market and/or put into service as a single functional unit. Assemblies can be placed on the market in different ways.

Assemblies with a fully specified configuration of parts are put together and placed on the market as a single functional unit by the manufacturer of the assembly. The manufacturer assumes responsibility for compliance with the directive and must therefore provide clear instructions for assembly, installation, operation and maintenance, etc.

Assemblies forming a modular system. In this case, the assembly is not necessarily completed by the manufacturer of the product and placed on the market as a single functional unit. However, the user/installer selects and combines the parts from a manufacturer of origin for a given range, the manufacturer is still responsible for the compliance of the assembly with the directive.

'Installation' means a combination of two or more pieces of equipment which were already placed on the market independently by one or more manufacturers. Installing and combining the equipment on the user's premises is not considered manufacturing and therefore the resulting installation is outside the scope of ATEX Directive 2014/34/UE but will be subject to the legal requirements applicable such as Directive 1999/92/EC (ATEX 137) [4] or Directive 92/104/EEC [2].

In this case, the evaluation of the explosion risk is an obligation of the employer who must draw up a "explosion protection document" in accordance with HG 1058/2006 (Directive 1999/92/EC] if it is about industries other than mining, respectively draw up a "document of security and health", as regulated in GD 1049/2006 (Directive 92/104/CEE) in the case of mining aria [3].

The explosion risk assessment process focuses first on the formation of explosive atmospheres and then on the presence and activation of ignition sources. The principle of explosion protection is to reduce the probability of an ignition source occurring at the same time as an explosive atmosphere to a minimum acceptable level according to applicable norms and standards.

3. RISK REDUCTION. FUNDAMENTAL PRINCIPLES

The need for the simultaneous presence of an explosive atmosphere and the effective source of ignition and the foreseeable effects of an explosion lead directly to the three basic principles of explosion prevention as well as explosion protection:

a) Prevention

1) avoiding explosive atmospheres. This objective can be achieved, to a large extent, by changing either the concentration of the flammable substance to a value that is outside the explosion range, or the concentration of oxygen to a value below the limit oxygen concentration (LOC);

2) avoiding all possible sources of effective ignition. This is achieved through the appropriate design of the equipment, protection systems and components.

Note: In certain cases, especially in mining, an essential measure to prevent explosions is the de-energization of equipment containing ignition sources, when there is an explosive concentration.

b) Protection: limiting the effects of explosions to an acceptable level. This can be achieved, up to a certain limit, by protective constructive measures. Unlike the measures described previously, in this case, the occurrence of an incipient explosion is taken into account.

The elimination or minimization of the risk can be achieved by applying one or more of the principles of prevention or protection mentioned above. Avoiding an explosive atmosphere must always be the first option.

The greater the probability of the occurrence of an explosive atmosphere, the greater must be the extension of measures against actual ignition sources and vice versa. When flammable substances are involved that can generate an explosive atmosphere, we cannot speak of zero risk of explosions but only of a maximum accepted risk that is given in the legislation in force (ATEx Directives and applicable standards) in the form of minimum explosion requirements.

Explosion prevention measures at installations used in potentially explosive atmospheres to ensure a minimum risk are based on the principle that: the higher the probability or frequency of an explosive atmosphere, the higher the level protection provided by equipment / installations for the prevention of efficient ignition sources (minimum probability of arising the ignition source when an explosive atmosphere occurs) (fig.2).

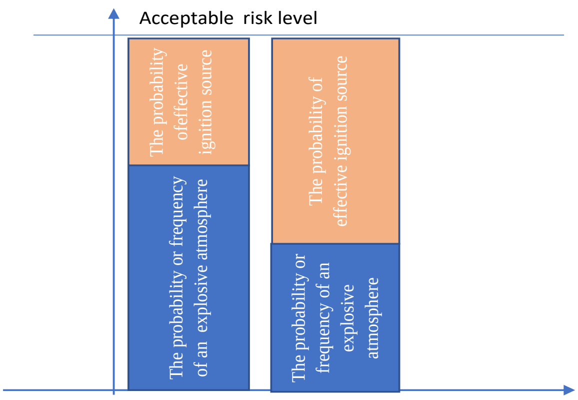

Fig.2. Maximum acceptable ignition risk

In order to enable the selection of appropriate measures, an explosion safety concept must be developed for each individual case.

For this, the norms and standards of ATEx have classified the equipment into categories depending on the level of protection it provides and the spaces where explosive atmospheres can occur have been classified into zones depending on the duration and probability of the persistence of the explosive mixture.

Thus, the ATEX directive classifies mining equipment (Group I) into 2 categories (M1, M2) and the others (Group II) into 3 categories (1,2,3).e

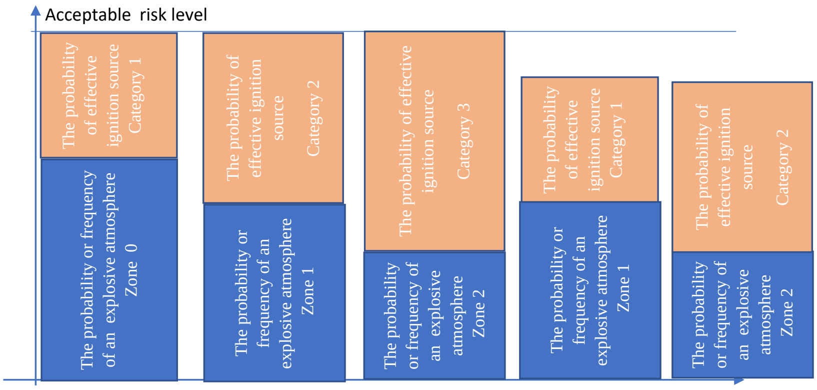

Fig.3. Risk of explosion of Group II equipment

Equipment category 1 comprises equipment designed to be capable of functioning in conformity with the operational parameters established by the manufacturer and ensuring a very high level of protection.

Equipment in this category is intended for use in areas in which explosive atmospheres caused by mixtures of air and gases, vapours or mists or by air/dust mixtures are present continuously, for long periods or frequently (zona 1 conform SR EN 60079-10-1 [5]).

Equipment in this category must ensure the requisite level of protection, even in the event of rare incidents relating to equipment, and is characterised by means of protection such that:

— either, in the event of failure of one means of protection, at least an independent second means provides the requisite level of protection,

— or the requisite level of protection is assured in the event of two faults occurring independently of each other.

Equipment category 2 comprises equipment designed to be capable of functioning in conformity with the operational parameters established by the manufacturer and of ensuring a high level of protection.

Equipment in this category is intended for use in areas in which explosive atmospheres caused by gases, vapours, mists or air/dust mixtures are likely to occur occasionally (zona 1 conform SR EN 60079-10-1).

The means of protection relating to equipment in this category ensure the requisite level of protection, even in the event of frequently occurring disturbances or equipment faults which normally have to be taken into account.

Equipment category 3 comprises equipment designed to be capable of functioning in conformity with the operating parameters established by the manufacturer and ensuring a normal level of protection.

Equipment in this category is intended for use in areas in which explosive atmospheres caused by gases, vapours, mists, or air/dust mixtures are unlikely to occur or, if they do occur, are likely to do so only infrequently and for a short period only (zona 2 conform SR EN 60079-10-1).

Equipment in this category ensures the requisite level of protection during normal operation.

Unlike surface industries, in grit mines electrical and non-electrical equipment and mining personnel are in permanent contact with gas and/or dust/air mixtures which, under unfavorable conditions, can form explosive atmospheres. That is why specific, stringent security requirements are regulated for explosion protection and evacuation possibilities in dangerous situations.

Traditionally, a safety factor has been introduced, which is a common practice of the member states of the European Union, to de-energize the equipment or make it safe and to withdraw the mining personnel from the workplaces, if the atmospheric conditions exceed a certain percentage of the lower explosion limit (LEL) of methane (grey) in air, as provided for in the relevant national legislation of the Member State.

NOTE – Current limit values for disconnection of equipment and withdrawal of personnel differ in each member state.

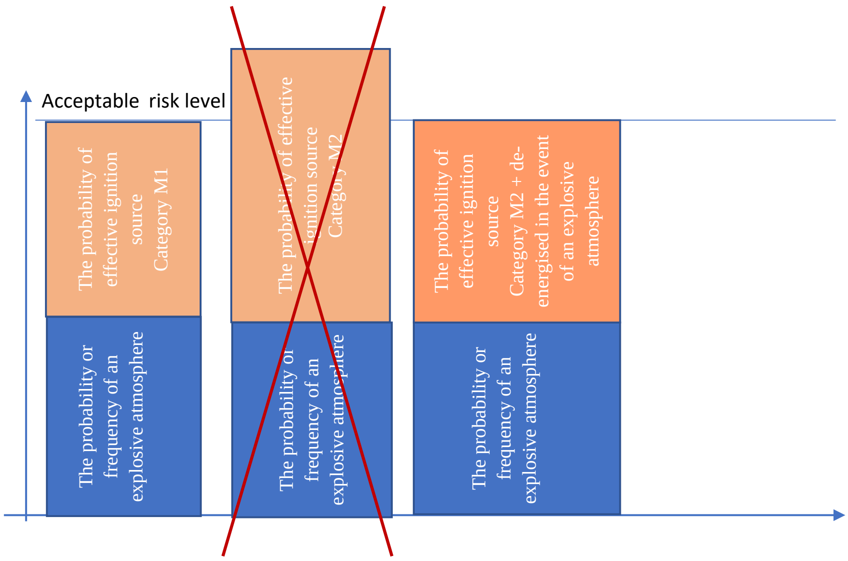

Fig.4. Risk of explosion of Group I equipment - mining

Equipment category M 1 comprises equipment designed and, where necessary, equipped with additional special means of protection to be capable of functioning in conformity with the operational parameters established by the manufacturer and ensuring a very high level of protection.

Equipment in this category is intended for use in underground parts of mines as well as those parts of surface installations of such mines endangered by firedamp and/or combustible dust.

Equipment in this category is required to remain functional, even in the event of rare incidents relating to equipment, with an explosive atmosphere present, and is characterised by means of protection such that:

— either, in the event of failure of one means of protection, at least an independent second means provides the requisite level of protection,

— or the requisite level of protection is assured in the event of two faults occurring independently of each other.

Equipment category M 2 comprises equipment designed to be capable of functioning in conformity with the operational parameters established by the manufacturer and ensuring a high level of protection.

Equipment in this category is intended for use in underground parts of mines as well as those parts of surface installations of such mines likely to be endangered by firedamp and/or combustible dust.

This equipment is intended to be de-energised in the event of an explosive atmosphere.

The means of protection relating to equipment in this category assure the requisite level of protection during normal operation and also in the case of more severe operating conditions, in particular those arising from rough handling and changing environmental conditions.

4. EXPLOSION RISK ASSESSMENT

There is no generally valid method for assessing the risk of explosions, but there are a number of norms / standards that give essential safety and health requirements, respective that specify requirements for the constructional features of equipment and components that may be an individual item or form an assembly, to enable them to be used in atmosphere potential explosive, such as the series of standards SR EN 60079 [11], SR EN 80079 [12] or standards with basic concepts and methodology for explosion prevention and protection - SR EN 1127-1[7] and SR EN 1127-2[8]. These standards have been developed to help designers, manufacturers, users of equipment and components that may be an individual item or form an assembly, and other interested bodies to interpret the essential security requirements in order to comply with European legislation and ATEx Directives respectively 2014/34/EU and 1999/92/EC. These standards are only the starting point for the minimum requirements.

If we refer to an installation, the risk analysis focuses on its design, construction, maintenance and supervision from a technical and organizational point of view. Even if a new installation has been evaluated during commissioning and complies with the explosion protection requirements, it is necessary, at all times, to apply adequate maintenance measures which are carried out according to a well-established schedule and with competent persons for these activities.

In the case of assessing the exploration risk of the installations already put into operation, several situations can be encountered:

- the installation has been placed on the market as an assembly by the manufacturer, with an evaluation document in accordance with the ATEx Directive and no further evaluation must be made by the user (employer);
- the installation was made by the user by assembling the components at his own responsibility and in this case he must make a risk assessment when commissioning.

Also, the employer must evaluate the installation regarding the risk of initiation whenever the installation is modified in order to upgrade it or if original spare parts that were considered at the initial assessment (commissioning) are not available on the market.

A common situation in old installations is when an initial evaluation is not available and then an evaluation of the installation must be made as if it were new.

5. EXPLOSION RISK ASSESSMENT OF INSTALLATION

According to the legislation in force, employers are responsible for the safety and health of workers and in this regard they must take appropriate measures to prevent explosions or, as appropriate, to limit the effects of possible explosions. For this they have to make an explosion risk assessment which will be an important chapter in DPEX that the employer has to prepare, according to art. 10 of GD 1058/2006 (Directive 1999/92 / EC).

Whenever possible, the employer should prevent explosive atmospheres. It follows that the first step in assessing the risk of explosion is to determine whether an explosive atmosphere may occur under the given circumstances and then, in step 2, it must be determined whether it can be ignited or not (fig 5).

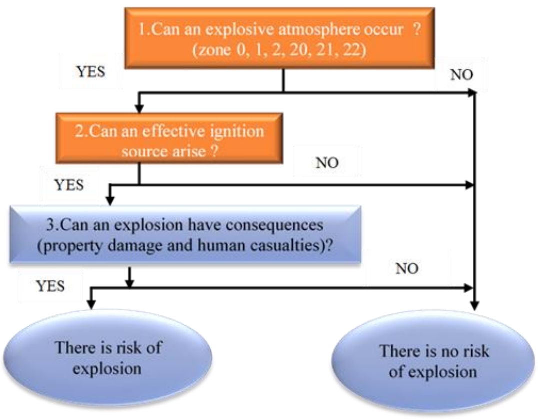

Fig.5. Assessement of explosin risk

Steps 1 and 2 represent ignition risk assessment. The process of assessing the risk of initiation cannot be generalized, it is specific to each case. The specific considerations are the probability and duration of the occurrence of the dangerous explosive atmosphere, the probability that the ignition sources will be present and become efficient and active by analyzing the installations, the substances used, the processes and their interactions.

If we refer only to installations, we must think of the ignition sources that it can generate in normal operation, of foreseeable failures or rare failures. Ignition sources are well defined in SR EN 1127-1 and SR EN 1127-2. Thirteen types of ignition sources are distinguished: hot surfaces, hot flames and gases, mechanically generated sparks, stray electric cleaners, cathodic corrosion protection, static electricity, lightning, electromagnetic fields in the frequency range between 9 kHz and 300 GHz, electromagnetic radiation frequency range between 300 GHz and 3□106 GHz or wavelengths from 1000 µm to 0.1 µm (optical spectrum), ionizing radiation Ultrasound, adiabatic compression, shock waves, gas leaks, chemical reactions.

The evaluation procedure of an installation, new or existing, must be based on the following functional statutes:

– normal operation, including maintenance
– commissioning and decommissioning
– malfunctions, foreseeable fault conditions
– misuse that can be rationally predicted.

The method of assessing ignition risk installations must be systemic, performed in a structured manner, on an objective and logical basis. An analysis is made of existing sources of hazardous explosive atmospheres and of efficient sources of ignition that may occur at the same time.

The principles and guidelines for risk management defined in the ISO SR 31000:2010 together with methodology from SR EN 15198:2008 [9] can be applied to ignition risk assessment.

The minimum level of risk accepted by the rules corresponds to the minimum probability that the ignition source will appear in the same place and at the same time as the explosive atmosphere. The application of this principle is based on the classification of the hazardous area into zones according to the frequency and duration of the explosive atmosphere and the classification of the equipment into categories according to the level of protection provided, and the acceptance criterion is given in the table 1.

Table 1. ***Level of protection required, in function of the explosive atmosphere***

	Category of equipment	***Atmosphere***	***Level of protection***	***Performance of protection***	***Condition of operation***
EQUIPMENT GROUP I (MINES)	M 1	Methane, dust	Very high	2 independent protection methods, or safe with 2 faults	Equipment remains energised and functioning
	M 2	Methane, dust	High	Suitable for normal operation and severe operating conditions	Equipment is de-energised

EQUIPMENT GROUP II (SURFACE)	1	Gas, vapour, mist dust	Very high	2 independent protection methods or safe with 2 faults	Equipment remain energised and functioning in zone 0, 1, 2 (G) and/or 20, 21, 22 (D)
	2	Gas, vapour, mist dust	High	Suitable for normal operation and frequently occuring disturbances, or safe with 1 fault	Equipment remain energised and functioning in zone 1, 2 (G) and/or 21, 22 (D)
	3	Gas, vapour, mist dust	Normal	Suitable for normal operation	Equipment remain energised and functioning in zone 2 (G) and/or 22 (D)

Most of the electrical and non-electical equipment from the installation component is certified as an individual item of equipment, e.g. the motor, switchgear etc., and meets its own marking requirements. This certification, however, does not deal with the interconnection of these items of equipment by cables or the machine electrical power system as an entity. The equipment and components, including their interconnections, should be assessed, from an ignition point of view, by the manufacturer or user.

When the installation is manufactured by a manufacturer as "Equipment assemblies" as specified in the technical specification IEC TS 60079-46 [6] (a pre-manufactured combination of Ex Equipment, together with other parts as necessary, that are electrically or mechanically interconnected that are pre-assembled prior to being placed into service at the end-user site, and that can be disassembled and then re-assembled at the end-user site), the ignition risk assessment is part of the conformity of the product with the essential health and safety requirements (EHSRs) of the Directive ATEX 2014/34/UE, in order to place the products on the market.

Issue of IEC TS 60079-46 Explosive atmospheres - Part 46: Equipment assemblies is a good opportunity for inspiration to clarify objectives and evaluation methods. This standard together with the series of standards SR EN 60079, SR EN 80079 on the types of protection, including SR EN 60079-14 [10], for the requirements for mounting equipment in ex areas and SR EN 15198 to the evaluation methods constitutes the minimum necessary information in order to be able to start an initiation risk assessment for an installation.

When the installation is made by assembling the component parts by the user (employer), he has to choose the equipment corresponding to their dangerous areas. Following, the installation as a whole shall be assessed with regard to possible ignition sources. All electrical and non-electrical equipment, the associated connected devices have to be taken into consideration.

Each ignition source according to EN 1127-1 or EN 1127-2 must be analysed.

The end user should always evaluate each individual part of the installation for potential ignition sources and monitoring needs, as performance can vary significantly from one installation to another, may have its own unique behavior.

Assessing the risk of initiation is not easy, it requires experience and professionalism. For equipment and components, the identification of potential ignition sources is the most important part of the ignition risk assessment. For identification of all possible ignition hazards it is important to proceed systematically and do it without any assessment aspects to avoid restrictions in thinking. For the analysis of the possible ignition hazards, all utilizable information sources should be used (discussions with experts from test houses, universities, users, other manufactures etc.) and all accessible examples should be examined to perceive analogy. The use of standards is only the starting point for compliance with the minimum requirements.

In order to meet these minimum requirements or to exceed them in order to ensure a higher level of security, complex hazard monitoring systems have been developed.

In this regard, employers should consider each installation and determine the possibilities for hazard monitoring, both in the domain of minimum ATEx requirements and outside them. Of course, the budgetary constraints of an organization in implementing a hazard monitoring system better than the minimum required by the rules, will always be a priority and management must assess the risk and cost of options acceptable to the company. However, it appears that the benefits of hazard monitoring versus the fairly reasonable cost of hazard monitoring equipment are a good assurance and a solid investment in reducing the risks of loss of life, property and product.

6. CONCLUSIONS

The assessment of installations on the risk of the ignition of explosive atmospheres is the responsibility of the employer, in accordance with GD 1058/2006 transposing Directive 1999/92 / EC or GD 1049/2006 transposing Directive 92/104/EEC

If the installation was placed on the market as an assembly by the manufacturer, who assessed the assembly for compliance with the requirements of the ATEx Directive 2014/34/EU, no further assessment is required, but if the installation was built by the user (employer) by assembling the components in situ, he must make an initial assessment, upon commissioning, as a manufacturer.

Initiation risk assessment is not easy, it requires experience and professionalism especially to identify potential ignition sources. The evaluation process cannot be generalized, it is specific to each case.

The ignition risk assessment is performed to verify that the probability of an ignition source occurring at the same time as the explosive atmosphere occurs is minimal according to the norms and standards in force.

The methods applicable for the assessment must consider the sensitivity of the explosive atmosphere (characteristics of the substances) and the probability of its occurrence together with the probability of ignition of the sources in relation to the requirements of applicable ATEx standards and norms.

REFERINCES

[1]. Părăian M., Burian S., Vătavu N., Păun F.A., *Aspects regarding the applicability of ATEx directives for the evaluation of products regarding the risk of explosion*, SESAM, 2019.

[2]. Council Directive 92/104/EEC of 3 December 1992 *on the minimum requirements for improving the safety and health protection of workers in surface and underground mineral-extracting industries* / **Hotărârea nr. 1049 din 9 august 2006** *privind cerinţele minime pentru asigurarea securităţii şi sănătăţii lucrătorilor din industria extractivă de suprafaţă sau subteran*, 1992/2006.

[3]. DIRECTIVE 1999/92/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 1999 *on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres* / **Hotărârea de Guvern nr. 1058/09.08.2006** *privind cerinţele minime pentru îmbunătăţirea securităţii şi protecţiei sănătăţii lucrătorilor care pot fi expuşi unui potenţial risc datorat atmosferelor explozive*, 1999/2006.

[4]. Directive 2014/34/EU of the European Parliament and the Council of 26 February 2014 *on the harmonization of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres*, Official Journal of the European Union. L 96/314, 2014.

[5]. EN 60079-10-1 *Atmosfere explozive. Partea 10-1: Clasificarea ariilor. Atmosfere explozive gazoase,* 2016.

[6]. IEC TS 60079-46 *Explosive atmospheres- Part 46: Equipment assemblies*, 2017.

[7]. SR EN 1127-1 *Atmosfere explozive. Prevenirea și protecția la explozie. Partea 1: Concepte fundamentale și metodologie*, 2019.

[8]. SR EN 1127-2 *Explosive atmospheres. Explosion prevention and protection Basic concepts and methodology for mining*, 2014.

[9]. SR EN 15198*Methodology for the risk assessment of non-electrical equipment and components for intended use in potentially explosive atmospheres*, 2008.

[10]. SR EN 60079-14: 2014 + AC:2016 *Atmosfere explozive. Partea 14: Proiectarea, alegerea şi construcţia instalaţiilor electrice*, 2014/2016.

[11]. SR EN IEC 60079-0:2018 +AC: 2020 *Explosive atmospheres - Part 0: Equipment - General requirements*, 2018/2020.

[12]. SR EN ISO 80079-36:2016 + AC 2020 *Explosive atmospheres - Part 36: Non-electrical equipment for use in explosive atmospheres - Basic methods and requirements*., 2016/2020.

THE STUDY AND EXEMPLIFICATION OF THE USE OF A MINI-PROGRAMMABLE LOGIC CONTROLLER IN THE COMMAND AND CONTROL OF A COAL TRANSPORT SYSTEM

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Abstract: In a modern economy, any automation or control aims to increase the competitiveness of a product, either directly, through cost and quality, or indirectly, through improving working conditions.

Control implies the management of some dynamic systems having continuous states. These systems are described by differential equations and generally have analog inputs and outputs. The mining industry cannot be an exception to this and in this paper the authors came up with an idea of a simple automation of a coal transport system using a mini- PLC. This idea consists in the development, with the help of the Ladder Diagram programming language (LD), of a simple program for the command, control and signaling of a transport system composed of three belt conveyors.

Key words: automation, PLC, Ladder Diagram, belt conveyors.

1. THE EVOLUTION OF AUTOMATION IN THE CONTEXT OF THE EMERGENCE AND EXPANSION OF PROGRAMMABLE LOGIC COMPUTERS

1.1. General

The industrial revolution of the late 19th and early 20th centuries led, among other things, to an exponential development of the electrotechnical industry. The use of

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electricity has become indispensable in all sectors of human activities. The advantages of using electrical equipment in industrial automation were soon discovered. A series of electrical and electromechanical command, control and protection elements were created and developed: relays, contactors, sensors, switches, limiters, controllers, actuators, fuses, circuit breakers etc [26]. Thus appeared the first fully electric automation panels that served to command and control various processes. Depending on the complexity of these processes, an automation panel could occupy surfaces of the order of tens or even hundreds of m^2. Electrical schemes have become more and more complex, which has led to difficulties in their practical implementation, but also in the maintenance of automation panels and cabinets [3].

Changing the control logic of a certain process was a difficult task to achieve, as it required extensive reconfiguration of electrical schemes and automation panels structures [1]. On the other hand, the tens or hundreds of coils in relays, contactors or actuators get warm during operation and, being in a relatively small space, raised serious problems regarding ventilation in order to ensure operating temperatures within permissible limits. The hundreds of meters of conductors and cables laid out in bundles, also contributed to the heating. Discovering an error in the automation systems required a lot of time, directly proportional to the complexity of the automation installation. Among the top causes of automation system failure is the electromagnetic relay, with a limited lifespan due to its construction and operating mode [20]. Therefore, the disturbances occuring in the installation were predominantly caused by the low reliability of the relays in the automation panel, a fact that required their frequent replacement, resulting in frequent production stoppages. Maintenance was expensive, overtaxing even the best trained electricians in detecting and removing defects.

Considering the emergence of more and more complex technological processes, sometimes situations were reached when implementation of their control through classical schemes, using electromechanical equipments, became almost impossible. Thus, the efforts of researchers and engineers to develop new alternative solutions to electromechanical equipment were absolutely natural, solutions that would simplify the schemes, facilitate the implementation of control solutions and thus allow the realization of more sophisticated control processes [2]. Equipment using programmed rather than hardwired logic has been the solution to all problems and to removing many of the impediments and limitation of classical hardwired logic made with electromechanical equipment. The use of electronic and Boolean logic in process control immediate showed its advantages over classical automation. A large amount of the physic electromechanical equipment have dissapeared as it became virtual, being implemented through the programming of the logic control devices, which are the Programmable Logic Controllers [7].

Programmable Logic Controllers (PLC) are simple microcomputers, specially built for solving, by program, sequential logic problems and to replace classic relays. They work with Boolean variables and have a simplified central unit. PLCs usually offer fewer options than process computers, but they can be used very easily by less specialized personnel, thanks to simple programming languages, such as relay language, Boolean equations language or graphic languages [26], [33].

Programmable Logic Controllers are today considered the main element of any automation. With their help, the most diverse and complex automation task can be implemented.

Considering the above, we can mention some PLCs advantages:

- compared to a classical automation panel, the number of necessary conductors is reduced by up to 80%;
- electricity consumption is substantially reduced, considering that a multitude of electromagnetic relays are replaced by a single electronic device with low energy consumption;
- changing the operating sequences within the application differs from one process to another and it can be easily done by modifying or changing the program written in the PLC's memory with the help of a computer, This operation does not involve changing the cables and redoing the connections, as in a classic automation panel, but only summarizes to the interconnection of the corresponding devices at the PLC's inputs and outputs;
- the operation of PLCs is very precise;
- the error detection function in the PLCs is very fast and easy to use;
- putting a PLC back to operation is much easier than in the case of any type of electromechanical relay;
- a control system with PLC is cheaper than the classic one with electromechanical relays, as it is equipped with a large number of inputs and outputs to which many control and execution elements can be connected to implement complex functions [5].

In addition to the mentioned advantages, there are also some disadvantages of PLCs [5]:

- fixed operation. This refers to the fact that, if no changes occur within the controlled process, the use of a PLC may become more expensive than a use of a classic automation system;
- some application have a very low degree of complexity, and in such cases the purchase of a PLC can be an uneconomical solution. However, for such situations, simpler and cheaper PLCs have also been developed, known as ”mini-PLCs”;
- there are some industrial applications with harsh environmental conditions, where PLCs cannot be used, due to the high risk of damage.

Most PLCs are built to replace relays, working with Boolean variables and having a simplified central unit. Thanks to the technological progress of the last decades, high-performance PLCs have been produced with a complexity similar to that of process computers, usable in very complex automations [25]. Fig.1 illustrates the range of use of different command and control equipment depending on the complexity of the commanded process and the number of identical equipment. It can be seen that the range of use of modern PLCs interferes in the lower part with the range of use of electromagnetic relays and in the upper part with the range of use of process computers [6].

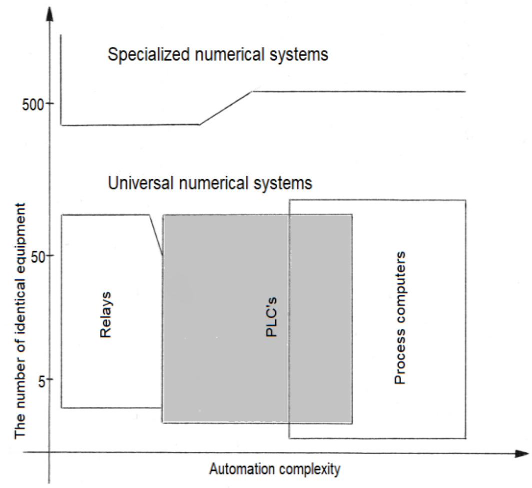

Fig.1. The range of PLC's use

The first PLC was designed in the USA in 1968 by a group of engineers led by Richard Morley, who is considered ”the father of PLCs” [26]. Their first creation was used in 1969 in the automotive industry, at General Motors, under the name of MODICON (MOdular DIgital CONtroller).

Around 1973, PLCs began to have communication facilities, one of the first such system being the MODICON MODBUS [11]. Through these facilities, PLCs could communicate with each other and could be located remotely from the controlled process.

Since their appearance, PLCs have spread rapidly across all industries, representing some of the most widely used equipment today. Their succes is primarily due to their affordable price and the fact that they can be commisioned and programmed by personnel without advanced IT training [9].

1.2. Mini- Programmable Logic Controllers

Mini- PLCs, also called ”*low-class PLCs*” are hardware structures with the same operating principle al PLCs, but with a smaller number of inputs and outputs [8]. These small PLCs are adapted for use in applications of low complexity level or where the programming logic does not change frequently. They can be programmed directly on their own mini-LCD screen, with the help of a small keyboard located on the front panel. The programming languages used are LD and FBD. All mini-PLCs have basic logic blocks (AND, OR, NOT) and types of timers and counters. The manufacturers of these mini-PLCs usually provide console programs free of charge, through which PLC programming and program simulation can be performed using a personal computer (PC) connected to a PLC via a serial interface.

Most of the mini-PLCs produced nowadays have the possibility of configuring the inputs so they can also take analog signals, having a built-in analog-digital converter.

In order to facilitate the use of mini-PLCs by individual users, their prices are low and usually they do not take into account the profit brought by their use, as in the case of ordinary PLCs. Also, the programming soft is, most often, free of charge [15].

1.3. Standardization of programming languages. Ladder Diagram programming language

The continuous development of PLCs has led, in just a few years, to the emergence of hundreds of PLC manufacturers. The programs they wrote for different systems were similar, but the instructions sets varied from a manufacturer to another. This situation tended to tie a user to a specific manufacturer, especially when creating complex applications.

To eliminate this dependence, a working group of the International Electrotechnical Commission (IEC) was created in 1979, which proposed a complete standardization of PLCs. This group elaborated the IEC 1131 standard, which later became IEC 61131, which became to be followed by the vast majority of PLC manufacturers [29].

Since the early days of PLCs, most manufacturers adopted the Ladder Diagram (LD) programming language. This language, included in IEC 61131-3 standard, was developed around schematic representations of classic contactors and relays circuits. LD is ideal for low to medium complexity automations because it is intuitive and requires only a short training period to be understood.

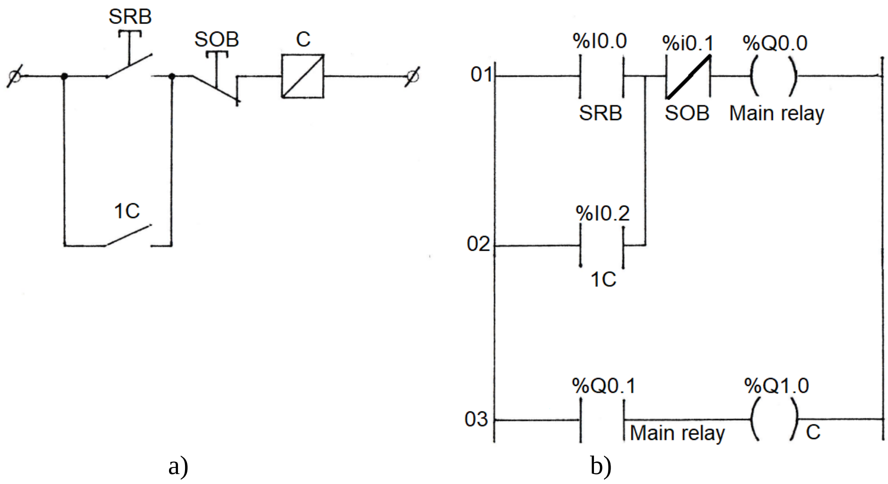

Fig.2. The starting of an electric motor with self-maintaining of the starting command: a) Classic hardware diagram; b) Ladder Diagram

LD is a graphical language, actually being a graphical representation of Boolean equations, making a combination of contacts (input variables) and coils (output variables). The graphic symbols of the language are placed in the diagram similar to the placement of contacts and relays in an electric schematic (hardware diagram) [24].

In Fig.2a we have illustrated the diagram for starting an electric motor with self-maintaining of the starting command and in Fig.2b the transposition of this diagram into LD. The Boolean operation performed by this diagram is as follows:

$$C=(SRB\ \mathbf{OR}\ 1C)\ \mathbf{AND}\ (\mathbf{NOT}\ SOB) \quad (1)$$

A program in LD is made up of network, which use graphic symbols. Each network consists of several language objects connected to each other, having several branches. The start of a network occurs at the left power bar and closes at the right bar using a coil object.

2. PROGRAMMABLE LOGIC CONTROLLERS OPERATION

The basic function of a PLC is to continuously scan the state of the executed program. This scan means continuously checking the conditions of the program over a period of time [23]. A scan cycle comprises the following three steps, as shown in Fig.3:

- *Step 1- Inputs testing*. The PLC probes each input to detect its ON or OFF status (active/inactive in case of discrete inputs or the value of an analog input). In other words, the PLC checks which sensor or switch is connected to which input and copies the information in binary form into the input registers, storing int for use in step no. 2;
- *Step 2- Program execution.* The PLC executes the program instruction by instruction. Depending on the state of the inputs stored in the previous step and the program logic, the PLC changes the configuration of the output registers in binary form;
- *Step 3- Outputs activation.* In this step the PLC also updates the state of the physical outputs based on the states of the inputs memorized in the previous step.

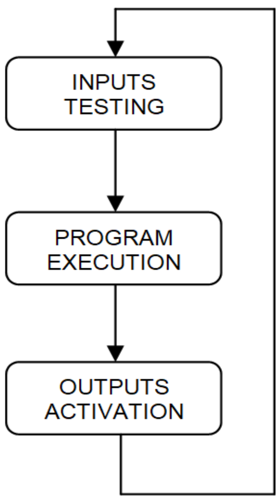

Fig.3. The duty cycle of a PLC

After executing the third step, the PLC returns to step no. 1 and repeats the entire cycle described above. A scan cycle is defined as the time during which the three steps are executed. Concurrent with the duty cycle, the PLC also performs system verification and updates the current internal clock and counter values [10].

3. THE CONTROL AND SIGNALING SYSTEM OF A COAL CONVEYING SYSTEM WITH 3 BELT CONVEYORS USING A MINI-PLC ZELIO SR2 B121FU

3.1. Mini- Programmable Logic Controller SR2 B121FU

In this chapter we did not intend to fully explore the features and possibilities of use of the PLC SR2 B121FU, as they are very vast and this is not the purpose of the paper. We will briefly refer only tot the information that concerns the topic of this paper.

The PLC SR2 B121FU is part of the „Zelio" range of smart relays manufactured by the French manufacturer Schneider Electric [28], [30], [31]. All of the PLCs belonging to Zelio range can be programmed in LD and FBD languages, with the help of Zelio Soft 2 software, which can be downloaded for free from the manufacturer's website [18].

Zelio SR2 B121FU is a compact mini-PLC that works in alternating current, at voltages from 100 to 240V and frequences of 50 and 60 Hz (Fig.4). This PLC has a LCD display, 8 discrete inputs and 4 relay outputs.

Fig.4. The SR2 B121FU Zelio PLC

In order to illustrate how the mini-PLC connects within the controlled process, in Fig.5 we will exemplify the hardware configuration of the scheme presented at the beginning of the paper, in Fig.1b. The operation of this hardware configuration is as follows (see Fig.1b and Fig.5):

- the a.c. voltage of 100…240 V is supplied to the PLC's power terminals L (live) and N (neutral);

- when pushing the Start button SRB, the voltage is applied to input I1, the line 01 becames TRUE, the main relay Q0.0 is activated and its contact Q0.1 is closed, the line 03 becames TRUE and the output Q1 is activated and thus the coil of contactor C is energised and the self-maintaining contact of control 1C in line 2 closes. The system is now in function;
- when pushing the Stop button SOB, line 01 becomes FALSE; the main relay Q0.0 de-energizes and its contact Q0.1 opens; line 03 becomes FALSE, output Q1 is disabled; contactor C is no longer supplied with voltage and contact 1C in line 02 opens. The system is now shut down [32] [34].

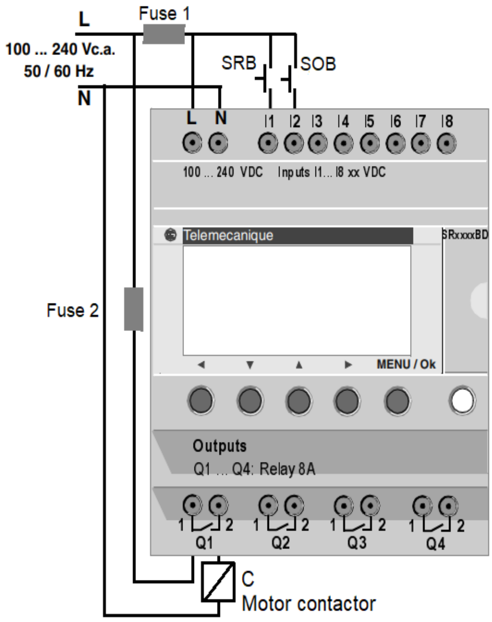

Fig.5. Hardware configuration of the scheme shown in fig.1

3.2. Defining the system and requirements for control

In order to be able to automate the coal transport system consisting of 3 belt conveyors, it was first necessary to define the requirements for command and control of the system [4].

We have considered a transport system composed of 3 conveyor belts, denoted with *CB1*, *CB2* and *CB3*, operating in cascade. Each of the three conveyors is driven separately by an electric motor controlled by a contactor. At the same time, each conveyor belt is equipped with safety rope pull switches (*SRPS*) and belt misalignment switches (*BMS*). The requirements we have proposed for command and control of transport system are as follows (see Fig.6 and Fig.7) [22]:

a) starting and stopping the transport system under normal conditions is done centrally from a dispatcher unit, by means of start (B_p) and stop (B_o) push buttons;

b) the ”OFF” state of the transport system will be signaled on the synoptic panel located at the dispatcher unit by lighting some red lamps (OFF) *RL1*, *RL2*, *RL3*, one for each conveyor;
c) when the start push-button B_p is pressed by the operator in the dispatcher unit, after a 2 seconds pause a sound pre-warning consisting of a series of 6 pulses, each lasting 1 second, will be emitted with a cadence of 2 seconds. On the synoptic panel in the dispatcher unit, the audible pre-warning will be doubled by the lighting of a yellow lamp, *YL7*. This audio and visual pre-warning sequence will have a total duration of 20 seconds and its purpose is to warn workers in the conveyor system area that the conveyors are about to start moving;
d) after 2 seconds from the end of the last pre-warning signal, the motors of the three belt conveyors will start in cascade, in the order *CB1*-*CB2*-*CB3*, with a delay of 10 seconds between them. The start of each motor will be signaled on the synoptic panel in the dispatcher unit by the corresponding red lamp *RL1*, *RL2* or *RL3* (OFF) turning off and the corresponding green lamp *GL1*, *GL2* or *GL3* (ON) turning on;
e) apart from the normal shut down of the transport system, carried out by the dispatcher operator by pressing the B_o push-button, the system can be stopped in two different emergency situations, independently of the will of the dispatcher operator. These emergency situation are as follows:
    - in case of a danger observed by any worker, this can activate the safety rope pull switch (*SRPS*) by pulling from any point the emergency steel rope installed along the conveyor [24]. The actuation of a conveyor’s SRPS must instantly stop the entire system and one of the corresponding yellow emergency lamps *YL1*, *YL3* or *YL5* will light up on the dispatcher’s synoptic panel. In this way, the dispatch operator will know where the dangerous situation occurred;
    - in the event of an abnormal lateral movement of any of the rubber belts on the rollers, a belt misalignment switch (*BMS*) will activate and cause the entire transport system to stop instantly. As in the case of SRPSs, the actuation of one of the BMSs must be signaled on the synoptic panel by the lighting of one of the yellow emergency lamps *YL2*, *YL4* or *YL6*;
    - the start-up of the transport system after the removal of the danger situations listed above must be done exclusively by the operator in the dispatch unit, following the steps described above in paragraphs c) and d).

3.3. System operation

Based on the requirements set up in the previous paragraphs, we designed the hardware configuration and then the Ladder Diagram for the command and control of the transport system using the Zelio SR2 B121FU mini-PLC. The hardware configuration is shown in Figure 6 and shows only the command circuits of the three

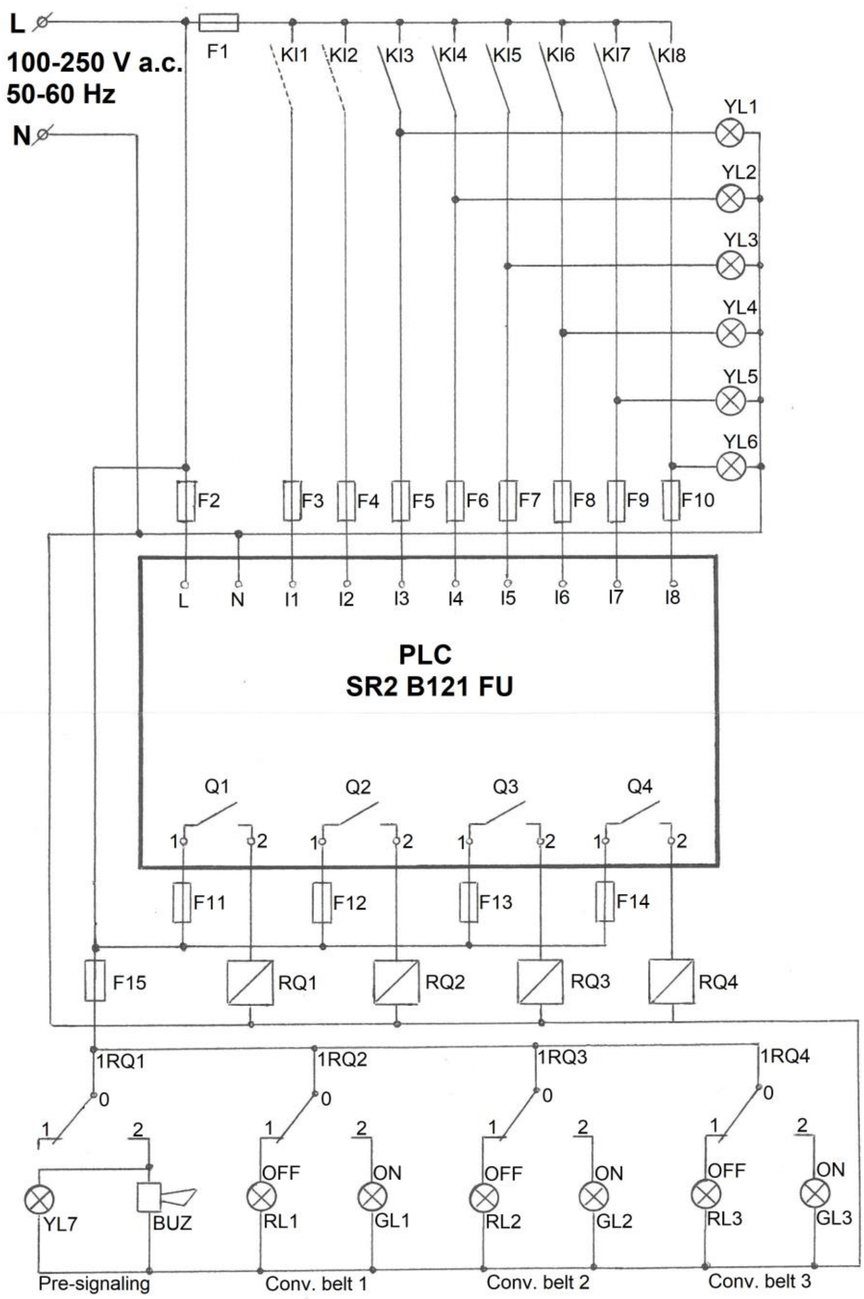

Fig.6. The hardware configuration of the command and control system

conveyor belts, without also illustrating the power circuits (conveyors contactors and motors) [12]. This hardware configuration contains the following components:

- F1…F15- fuses;

- KI1- start push-button (*B_p*)[7];
- KI2- stop push-button (*B_o*);
- KI3, KI5, KI7- contacts of the safety rope pull switches (*SRPS1*, *SRPS2*, *SRPS3*);
- KI4, KI6, KI8- contacts of the belt misalignment switches (*BMS1*, *BMS2*, *BMS3*);
- L, N- PLC’s power terminals for 100…250V, 50-60 Hz;
- I1…I8- PLC’s discrete inputs terminals;
- Q1.1, Q1.2…Q4.1, Q4.2- PLC’s relays terminals (*Q1…Q4*);
- RQ1…RQ4- electromechanical intermediate relays, connected to the corresponding outputs of the PLC Q1…Q4;
- 1RQ1…1RQ4- pairs of NO/NC contacts of the corresponding relays RQ1…RQ4;
- YL1, YL3, YL5- yellow lamps on the synoptic panel, for signaling emergency stops caused by safety rope pull switches (*SRPS1*, *SRPS2*, *SRPS3*) actuation by workers;
- YL2, YL4, YL6- yellow lamps on the synoptic panel for signaling emergency stops caused by belt misalignment switches (*BMS1*, *BMS2*, *BMS3*) actuation by the accidentaly lateral movements of the rubber belts on the conveyor’s rollers;
- YL7- yellow lamp on the synoptic panel, for optical presignaling;
- BUZZ- bell on the synoptic panel and horns on the route of the belt conveyors, for acoustic presignaling;
- RL1, RL2, RL3- red lamps on the synoptic panel, for signaling the ”OFF” state of the corresponding conveyor belts CB1, CB2, CB3;
- GL1, GL2, GL3- green lamps on the synoptic panel, for signaling the ”ON” stare of the corresponding conveyor belts CB1, CB2, CB3.

After completing the hardware configuration, the next step is to draw the LD diagram [22]. To do this, we first defined the PLC inputs and outputs as follows, capitalizing the direct contacts (NO) and lowercase negating (NOT) contacts (NC):

a) The inputs:
- I1- start button B_p;
- i2- (NOT) contact- stop button B_o;
- i3- (NOT) contact- safety rope pull switch of CB1 (SRPS1);
- i4- (NOT) contact- belt misalignment switch of CB1 (BMS1);
- i5- (NOT) contact- safety rope pull switch of CB2 (SRPS2);
- i6- (NOT) contact- belt misalignment switch of CB2 (BMS2);
- i7- (NOT) contact- safety rope pull switch of CB3 (SRPS3);
- i8- (NOT) contact- belt misalignment of CB3 (BMS3).

b) The outputs:
- Q1- contactor for optical and acoustic presignaling of the start of the transport system;
- Q2- contactor for operating the conveyor belt CB1;

[7] *Italic notations in parantheses are those of the Ladder Diagram shown in Figure 7*

- Q3- contactor for operating the conveyor belt CB2;
- Q4- contactor for operating the conveyor belt CB3.

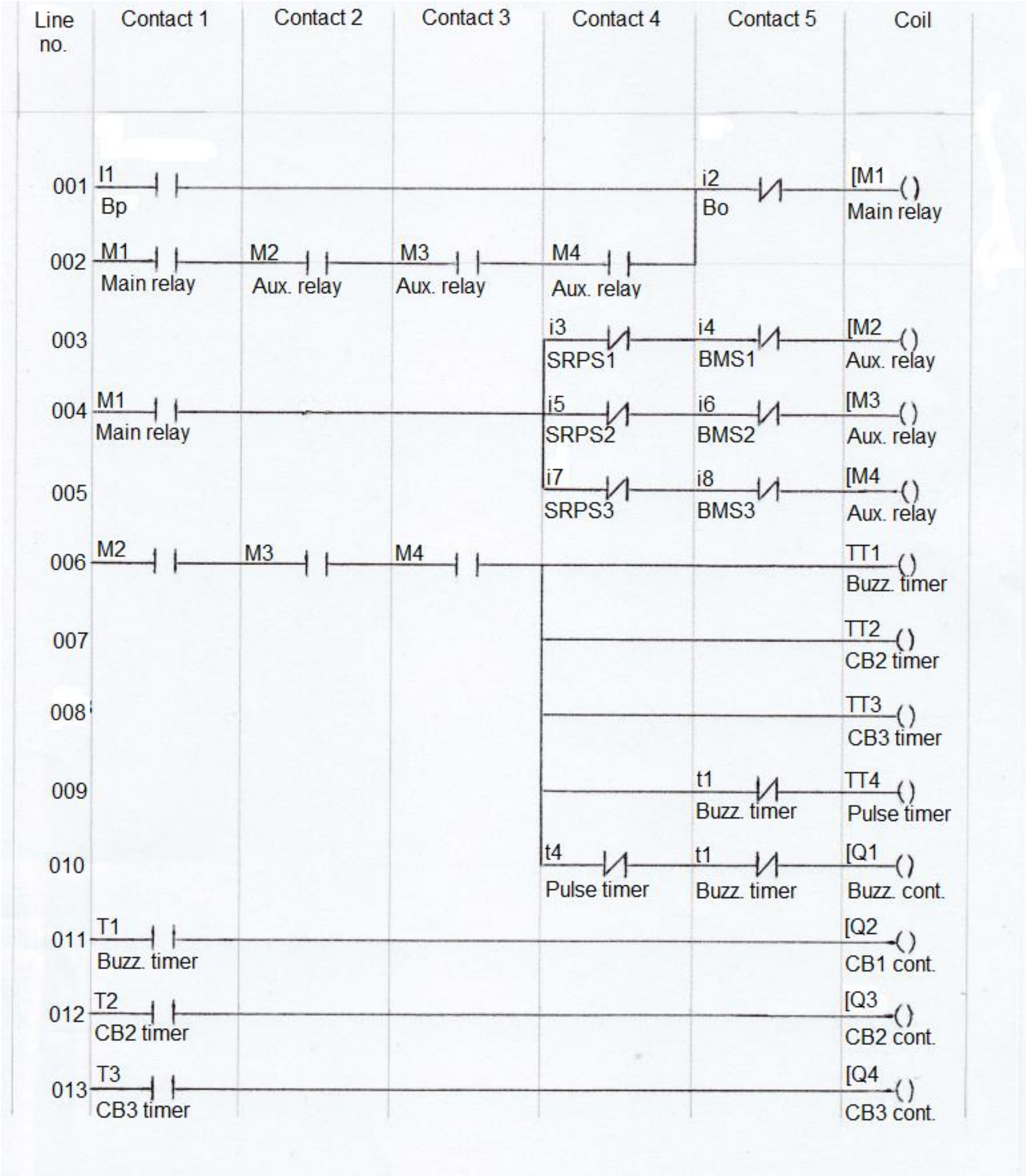

Fig.7. LD diagram for conveying system command and control

After establishing all the program reqirements and defining the PLC inputs and outputs, we practically implemented all of them, resulting in the LD diagram in Figure 7. The diagram consists of 13 program lines, including the following elements [13]:

a) *Elements of the controlled process that physically exist within it and are connected to the mini-PLC by wires:*

- the start button B_p connected to input I1: by its actuation, the transport system is started from the dispatcher unit;
- the stop button B_o, connected to input i2: by its actuation, the transport system is stopped under normal conditions, from the dispatcher unit;
- the contacts of the system's safety elements SRPS and BMS, connected to inputs i3…i8: they ensure the stop of the entire transport system in conditions of abnormal operating, preventing work accidents and technical breakdowns.

b) *components physically present in the mini-PLC housing:*
- output miniature electromagnetic relays, whose NO contacts are connected to the mini-PLC's output terminals, Q1…Q4.

c) *Command and execution elements created virtually by the program:*
- the main relay M1: executes start and stop commands received from the inputs I1 and i2;
- auxiliary relays M2, M3, M4: execute the commands received from the main relay M1 and from SRPSs and BMSs connected to inputs i3…i8;
- timers TT1…TT4, whose operation will be explained below in Fig.8 and Table 1.

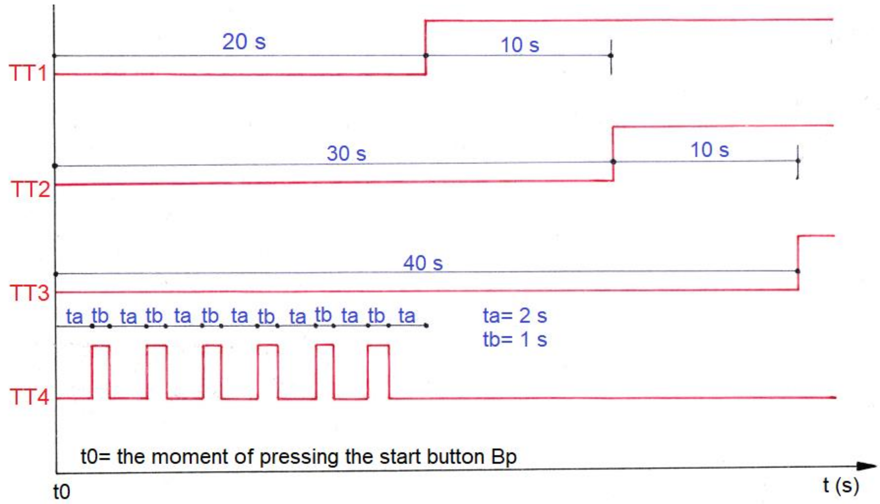

Fig.8. Diagram of timers parameters

Table 1. ***Timers configuration and executed sequences***

Timer	Configuration	Executed sequence
TT1	Active, control held down	After the time t is elapsed since activation, it changes the state of the contacts and remains in that state as long as it is activated
TT2		
TT3		
TT4	Flasher unit; control held down asynchronously	When activated it changes the state of the contacts for time duration t_a, then returns to the initial state for time duration t_b and repeats the cycle as long as it is activated

The program drawn up for commanding the transport system can be divided into several sequences, as follows [19]:

a) *Presignaling*

The purpose of presignaling is to alert the workers in the path of the conveyor belts that they must move away from moving items as the conveyors are about to start. The presignaling starts when the B_p start button is pressed by the operator at the dispatch point [14]. The sequence of operations performed by the mini-PLC is as follows:

- line 001 is energized through B_p-B_o-M1;
- the main relay M1 goes from logic level 0 to logic level 1;
- the contacts of relay M1 in lines 002 and 004 close, having the effect of simultaneously energizing the lines 003, 004, 005 through the SRPSs and BMSs NC contacts, connected to the inputs i3…i8;
- auxiliary relays M2, M3, M4 pass from logic level 0 to logic level 1;
- contacts M2, M3, M4 in line 002 close (command self-maintaining). By releasing the start button B_p, the main relay M1 remains energized through M1-M2-M3-M4 (line 002)-B_0 (line 001);
- the contacts M2,M3, M4 in line 006 close, having the effect of energizing lines 006, 007, 008, 009, 010;
- the timers TT1, TT2, TT3, TT4 become energized;
- the timer TT4 starts the pulsing control sequence of contactor Q1. Therefore, 2 seconds after pressing the start button B_p, the presignaling buzzer and horns emits 6 acoustic signals of 1 s duration each with a 2 s pause between the signals. The acoustic signals are duplicated by the optical signals of the warning yellow lamp YL7 on the synoptic panel at the dispatcher’s point.

b) *Starting conveyor belt no.1 (CB1)*

- in the 21^{st} s after pressing B_p, timer TT1 goes from logic level 0 to logic level 1;
- contacts t1 in lines 009 and 010 interrupt the energization of these lines;
- timer TT4 and contactor Q1 turn from logic level 1 to logic level 0 and the acoustic and optical presignaling sequence ends;
- contact TT1 in line 011 closes, energizing the line and switching output Q2 from logic level 0 to logic level 1. CB1 motor is energized ant the conveyor starts moving.

c) *Starting conveyor belt no. 2 (CB2)*

- after 30 s from pressing the start button B_p and 10 s after starting CB1, timer TT2 turns from logic level 0 to logic level 1;
- contact T2 in line 012 closes, energizing the line and changing the logic level of output Q2 from 0 to 1. CB2 motor is supplied with voltage and the conveyor starts moving.

d) Starting conveyor belt no. 3 (CB3)

- after 40 s from pressing the start button B_p and 10 s from starting CB2, timer TT3 turns from logic level 0 to logic level 1;
- contact T3 in line 013 closes, energizing the line and changing the logic level of output Q3 from 0 to 1. CB3 motor is supplied with voltage and the conveyor starts moving.

e) Stopping the transport system in normal conditions

Stopping the transport system in normal conditions is done from the dispatcher point by pressing stop button B_o as follows:

- the energization of the main relay M1 is interrupted and the relay turns from 1 to 0;
- contacts M1 in lines 002 and 004 open, turning the two lines from 1 to 0;
- auxilary relays M2, M3, M4 turn from 1 to 0;
- contacts M2, M3, M4 in lines 002 and 006 open, turning the lines from 1 to 0;
- contacts T1, T2, T3 in lines 011, 012, 013 open and outputs Q2, Q3, Q4 turn from 1 to 0 and the conveyor belts stop moving.

f) Emergency stopping of the transport system

The emergency stopping of the transport system can be done either by the workers in the conveyors area, by pulling the steel ropes that actuate the system rope pull switches (SRPS), or by the belt misalignment switches (BMS), independent of the will of the personnel [16]. We will exemplify this sequence by asuming that an abnormal lateral displacement of the rubber belt on the rollers occur at CB2, sensed by the belt misalignment switch no. 2 (BMS2) whose contact is connected to PLC's input i6. The sequence of operations performed by the PLC is as follows:

- contact BMS2 closes, turning the logic level of line 004 from 1 to 0;
- auxiliary relay M3 turns from 1 to 0;
- contacts M3 in lines 002 and 006 open, turning the two lines from 1 to 0;
- the self-maintaining of the starting command in line 002 is also turned from 1 to 0;
- the main relay M1 is turned from 1 to 0;
- next, the sequence of operations performed by the PLC is identical as in point e) and the entire transport system stops.

The writing of the program for the command and control of the transport system was carried out in the LD language with the help of the Zelio Soft 2 programming software, which can be downloaded for free from the manufacturer's website. In addition to the facilities for writing applications in LD and FBD programming languages, Zelio Soft also offers its users the posibility of simulating the operation of written programs [17].

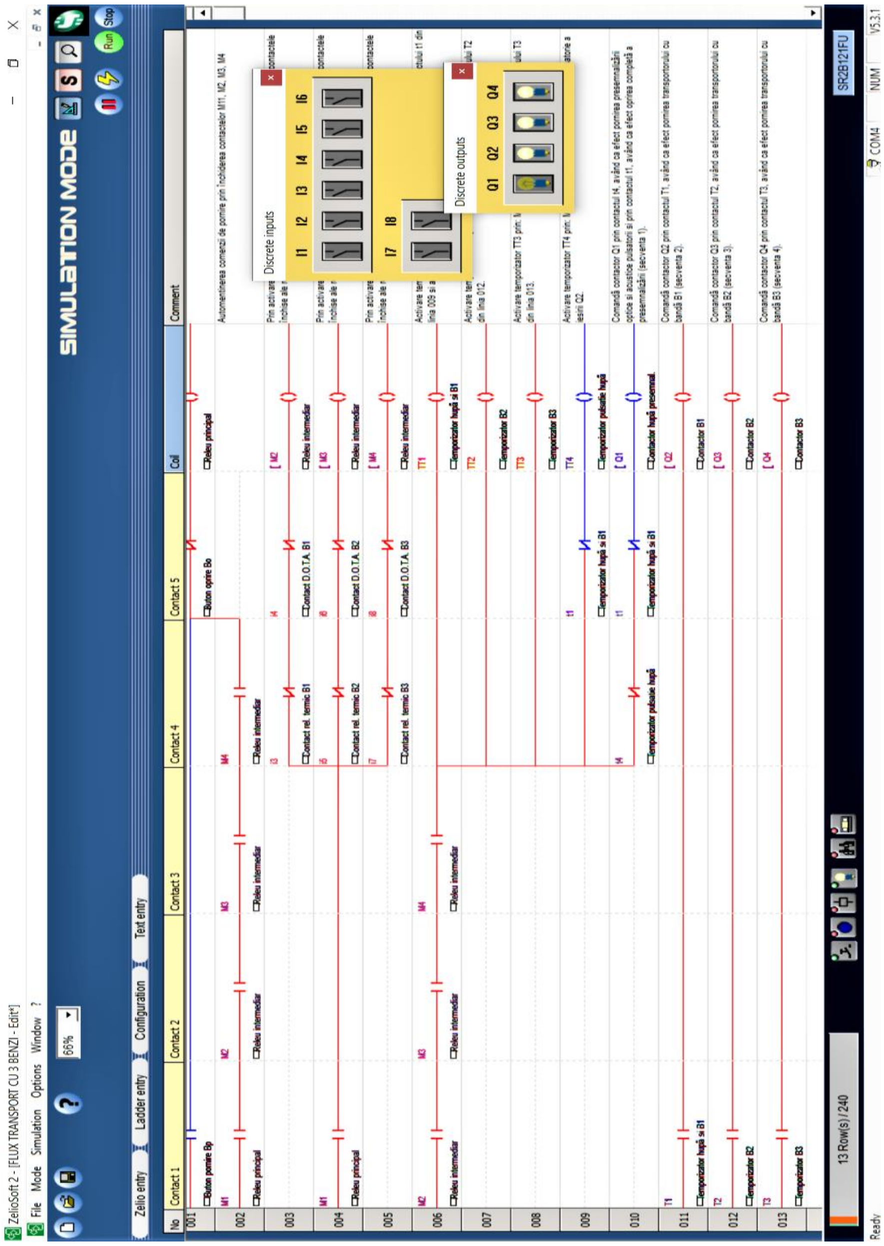

Fig.9. The simulation mode window of Zelio Soft 2

In order to illustrate how the simulation works, Fig.9 shows the Zelio Soft 2 simulation mode window at the CB3 conveyor start-up sequence.

4. CONCLUSIONS

It's been half a century since we can't even say the word "automation" without thinking of Programmable Logic Controllers. PLCs have simplified automation schemes, increased the accuracy and safety of industrial automation systems and generated billions of dollars in savings. In these circumstances, it was imposible for PLCs not to make their way beyond the walls of large industrial plants and not to migrate to residential and even domestic applications, once the ”mini” variants of these PLCs appeared.

Considering only the application presented in this paper, we can see that a number of 4 electromagnetic relays and 4 electromagnetic timers have been replaced by a simple PLC, which occupies in the electrical panel a space equal only to that occupied by 6 single-pole circuit breakers. PLCs will continue to be widely used in the future as they are ideal solutions for small, medium or large complexity applications.

REFERENCES

[1]. Bolton W., *Programmable Logic Controllers,* Fourth Edition, Elsevier Science, ISDN 978-0-7506-8112-4, 2006.

[2]. Bonfatti F., Monari P.D., Sampieri U., *IEC 1131-3 Programming Methodology: Software engineering methods for industrial automated systems,* ISBN 2-9511585-0-5, 2003.

[3]. Danning, G., *Introduction to Programmable Logic Controllers,* Clifton Park NY, Delmar Learning, 2001.

[4]. Fîță N.D., Lazăr T., Popescu F.G., Pasculescu D., Pupăză C., Grigorie E., *400 kV power substation fire and explosion hazard assessment to prevent a power black-out*, International Conference on Electrical, Computer Communications and Mecatronics Engineering - ICECCME, 16 – 18 November, Maldives, 2022.

[5]. Fîță N.D., Obretenova M.I., Pasculescu D., Tatar A., Popescu F.G., Lazar T., *Structure and analysis of the power subsector within the national energy sector on ensuring and stability of energy security*, Annals of the Constantin Brancusi University of Targu-Jiu, Engineering series, Issue 2 / 2022, pp.177-186, 2022.

[6]. Fîță N.D., Radu S.M., Păsculescu D., *Ensuring, controlling and stability of energy security in the context of increasing industrial and national security,* Academic Compendium, 2021.

[7]. Fîță N.D., Radu S.M., Păsculescu D., *National security- Energy sector optimization elements,* Chișinău, Republic of Moldova: Globe Edit Publisher, 2021.

[8]. Fîță N.D., Radu S.M., Păsculescu D., Popescu F.G., *Using the primary energetic resources or electrical energy as a possible energetical tool or pressure tool*, Proceedings of Sciendo International Conference Knowledge based organisation – “Nicolae Balcescu” Land Forced Academy Sibiu, Vol. XXVII, No. 3, pp. 21-26, 2021.

[9]. Gary D., *Introduction to Programmable Logic Controllers,* 2nd ed., Delmar, Albany, NY, 2002.

[10]. Hackworth J. R., Hackworth F. D., *Programmable Logic Controllers: Programming Methods and Applications,* Prentice Hall, ISBN-10: 0130607188, 2004.

[11]. Handra A.D., Popescu F.G., Păsculescu D., *Utilizarea energiei electrice - lucrări de laborator*, Editura Universitas, Petroşani, 167 pag., 2020.

[12]. Ionescu C., Larionescu S., Caluianu S., Popescu D., *Automatizarea instalațiilor. Comenzi automate,* Editura Matrix Rom, București, ISBN 973-685-460-4, 2004.

[13]. Niculescu T., Pasculescu D., Pana L., *Study of the operating states of intrinsic safety barriers of the electric equipment intended for use in atmospheres with explosion hazard*, WSEAS Transactions on Circuits and Systems, Volume 9, pp.430-439, 2010.

[14]. **Niculescu T., Păsculescu D., Păsculescu V.M.,** *Evaluation of electrical parameters of intrinsic safety barriers of the electrical equipment intended to be used in atmospheres with explosion hazard,* Int. Multidiscip. Sci. GeoConf. Surv. Geol. Min. Ecol. Manag., 2014.

[15]. **Parr E. A.,** *Programmable Controllers: an engineer's guide*, Oxford, ISDN 9780750657570, 2003.

[16]. **Pasculescu D., Romanescu A., Pasculescu V., Tatar A., Fotau I., Vajai Ghe.,** *Presentation and simulation of a modern distance protection from national energy system*, Proceedings of the 10 th International Conference on Environment and Electrical Engineering – EEEIC 2011, Rome, Italy, pp. 646-650, 2011.

[17]. **Pasculescu D., Slusariuc R., Popescu F.G., Fîță N.D., Tatar A., Lazar T.,** *Modeling and simulation of lighting of a road with 2 strips per direction to en 13201: 2015 Standard*, Annals of the University of Petrosani, Electrical Engineering, Vol.24, pp.65-74, Petrosani, 2022.

[18]. **Pasculescu, V. M., Radu, S. M., Pasculescu, D., Niculescu T.,** *Dimensioning the intrinsic safety barriers of electrical equipment intended to be used in potentially explosive atmospheres using the simpowersystems software package*, Papers SGEM2013/Conference Proceedings, 417- 422 pp, Vol. Science and technologies in geology, exploration and mining, Bulgaria, 2013.

[19]. **Petruzella D. F.,** *Programmable Logic Controllers,* McGrow-Hill, 2010.

[20]. **Popescu D.,** *Automate programabile: construcție, programare și aplicații*, Editura Matrix Rom, București, ISBN 973-685-942-8, 2005.

[21]. **Popescu F.G., Pasculescu D., Marcu M., Pasculescu V.M., Fîță N.D., Tatar A., Lazar T.**, *Principles of effective energy management and power control system*, Annals of the University of Petrosani, Electrical Engineering, Vol.24, pp.111-118, Petrosani, 2022.

[22]. **Rabiee M.,** *Programmable Logic Controllers: hardware and programming,* Goodhead-Wilcox, 2002.

[23]. **Regh A., Sartori J.,** *Programmable Logic Controllers,* Prentice Hall, 2007.

[24]. **Stenerson J.,** *Fundamentals of Programmable Logic Controllers, Sensors and Communication,* Prentice Hall, ISBN 10: 0-13-061890-X, 1998.

[25]. **Lazăr T., Marcu M.D., Uțu I., Popescu F.G., Păsculescu D.**, *Mașini electrice - culegere de probleme*, Editura UNIVERSITAS, Petroșani, pp.197, 2023.

[26]. **Păsculescu D., Uţu I.,** *Increasing the quality of protections for high-voltage power lines*. Publicat in Revista Calitatea, Supplement of "Quality - Access to Success" Journal, Vol.18, S1, January, pp. 234-239, 2017.

[27]. **Utu I., Marcu M., Popescu F.G., Stochitoiu M. D., Rada A.C.,** *Determination of the optimum operating regime for two power transformers 35 / 6,3 kV*, Annals of University of Petrosani, Electrical Engineering, Vol. 22, pp.71-76, Petroşani, 2020.

[28]. **Uţu I., Păsculescu D.,** *Power Quality Study in Order to Comply with European Norms*. Publicat in Revista Calitatea, Supplement of "Quality - Access to Success" Journal, Vol.18, S1, January, pp. 366-371, 2017.

[29]. https://download.schneider-electric.com/files?p_enDocType=User+guide&p_File_Name=EIO0000002690.01.pdf&p_Doc_Ref=EIO0000002690

[30]. https://en.wikipedia.org/wiki/IEC_61131-3

[31]. https://en.wikipedia.org/wiki/Ladder_logic

[32]. https://en.wikipedia.org/wiki/Programmable_logic_controller

[33]. https://www.se.com/ro/ro/product/SR2B121FU/releu-intel.-comp.-zelio-logic--12-i-o--100---240-v-c.a.--cu-ceas--cu-afisaj/

[34]. https://www.se.com/ro/ro/product-range/542-zelio-soft/#overview

ASPECTS CONCERNING THE ENERGY CRISIS IN ROMANIA

ILIE UȚU[1], MARIA DANIELA STOCHITOIU[2]

Abstract: The energy crisis and its far-reaching effects have led to a significant change in political priorities in EU. Important countries from EU have turned to coal to increase security of electricity supply. The EU electricity demand is expected to recover slightly from 2023 with an average annual growth rate of 1,4% based on expectations of lower energy prices and a boost to electrification.

Key words: renewable sources, efficiency, mix energetic, balance, security.

1 INTRODUCTION

Energy is a domain of strategic importance for the fact that its provision at reasonable prices influences competitiveness economic, domestic production capacity and political strength of a state. The future of energy sector is settled in decentralized of energy in using the energetical sources mix and also in storage and carbon usage in industry [1].

The energy market goes through profound transformations in order to deliver cleaner energy while ensuring continuity of supply. Nowadays, renewable sources will drive to sharpe decreasing of electrical energy production based on coal and fossil fuel from 2023 [2]. The electricity consumption recovered almost 5% in 2021 in the same time with economic recovery after a substantial decline of 4% year on year in 2021 in the EU. In 2022 when Russia`s invasion of Ukraine triggered an unprecedent energy crisis and the growth reversed in 2022.

2 THE ALTERNATIVES FOR ENERGY THROUGH DECENTRALIZATION

The rapid growth of solar and wind power in recent years has breathed hope into global efforts to reduce greenhouse gas emissions and limit the most dangerous effects of climate change.

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An important place is to concern about energy system decarbonization through promoting renewable sources with zero CO_2 emissions. Due to their unforeseeable character some renewable sources as wind and solar sources could affect the operating safe conditions of energetically system. So, it has to find an equilibrium well justified from technicum and economic point of view, between decarbonization through developing the renewable sources with their unforeseeable evolution and security of energetic system.

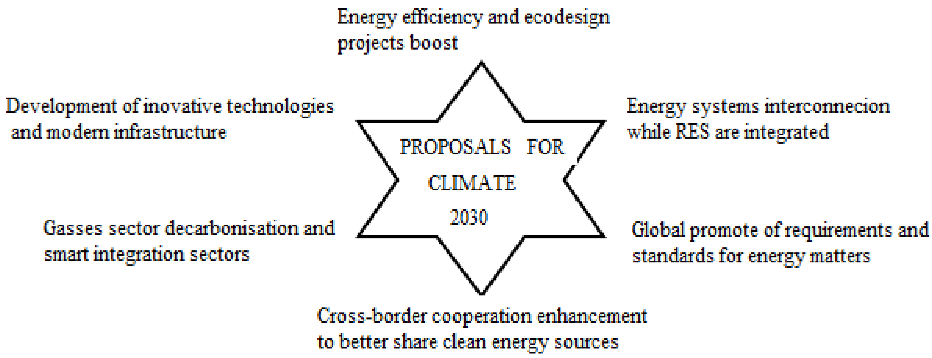

Fig.1. The objectives in the climate field

Taking into account the present conditions it is important to choose the right place of renewable sources installation even of point of view of their inclusion in electrical outlet grid structure to avoid network congestions. Also, the projects that involves renewable sources have important risks for financings determined by energy production dependency with variable phenomenon.

The attention is driven to green hydrogen made from hydrolysis, as energy carrier in energetically purpose. Since hydrogen is not occur freely in nature, it must be produced through the use of energy. Its H_2 energy is about 140MJ/kg at least three times more than a classic fuel, and by burning it does not cause polluting emissions.

Although the production of hydrogen by electrolysis of water is a known and easily accessible process, the reduction of resulting hydrogen costs will be essential in order to increase the share in the energy field. The most efficient way to power feed of electrolyzes is to use the energy produced in excess by unpredictable energy sources as solar and wind.

On the long term, the hydrogen can become competitive as a primary energy source in the same time with reduction of costs in an installation with electrolyzes.

It is considered that in 2050 Romania will allocate around 10TWh with purpose of suppling the electrolysis for the production of hydrogen; the construction of electrolysis about 1500MW will be required as a production of about 0,2Mt H_2/year. Making a comparation between emissions the hydrogen produced by electrolysis of water causes the lowest emissions as: solar 1,0kg $CO_{2\ equivalent}$/kg H_2; wind 0,5kg $CO_{2\ equivalent}$/kg H_2; nuclear 0,6 $CO_{2\ equivalent}$/kg H_2 and 0,115g nuclear waste; hydro 0,3 $CO_{2\ equivalent}$/kg H_2.

Due to the energy from renewable sources is more expensive than the obtained from classical sources, could determine competitive advantages for countries that do not make efforts to decarbonize the energy system Renewable sources could not exceed 30% weight in the total od sources in the system can be expected in the future.

The key to overcome this challenge is to pair the renewable energy sources with energy storage solutions. The energy storage systems assure several features from the point of view of their use in the energy: for frequency adjustment, the storage systems can assure essential services on electric system stability; the large power storage systems can be coupled with less predictable energy supply sources, getting an ensemble of predictable system to fulfil the load demand even when demand exceeds its generating capacity and supplies energy to the grid when the energy production from renewable sources is reduced, this type of aggregate is operating as a controllable source in the electricity market; the large power storage sources can also assure flattering of the load curve when connected to disturbances producing customers; the storage sources can assure the system services by providing necessary energy when the main energetic group is disconnected, as the large power storage sources can assure the optimal power flow in the electrical system

3. EFFICIENCY FOR TRANSITION

The energy efficiency has to preserve the same level of operating, safety and performances for energetical system and some possible measurements could be applied to diminish the energy crisis in Romania:

-the resources allocation by the central and local authorities for professionalisation and increase of the skills of the workers in the energy field and for combating climate change in the context where investments in these sectors are significant;

-updating by training institutions, including those of higher education, of curricula for energy and environment with an emphasis on cooperation and interdisciplinarity;

-significantly more consistent funding for fundamental and applied scientific research for energy efficiency technologies, renewable sources and low emission mobility;

-partnerships between professional associations with tradition and professional associations with an energy profile for information sessions in the field of energy transition towards decarbonize [1], [3].

The causes that set off the energy crisis are shared in external causes and internal causes. The external ones are generated by: the European Committee attitude for facilizing the production from renewable sources and a forced diminution for energy production from classical sources (which generates gas emission and CO_2) without a correlation between those two directions; also, the electrical energy European Unique Market which through the coupling the mechanism determining that the price to be the same in the coupling area without taking into account the purchasing power in Romania is lower than in western countries from Europe; another cause is the increasing the price of natural gasses due to diminution of Russian Federation delivery.

The internal causses which have determined the higher prices in Romania than in the rest of the Europe are: the organizational structure of producers in Romania as hydro, coal, nuclear, gas renewable sources under conditions of the liberalized electricity market; the lack of investment in the electric power plant with controlled production (as units 3 and 4 from Cernavoda nuclear power plant); the investment deficit in energy storage capacities (as Tarnita hydropower plant; the insufficient stage of transport network for facilizing the developing of wind power plants in favorable areas.

4. MEASUREMENTS TO AVOID THE ENERGY CRISSIS

On the short term, the measurements which can be taken consists in settlement of electrical energy market and increasing the coal production. Only into a regulation system it can be achieved an average price of energy for the final customer in nowadays production structure. The method of imposition of supply price limits determines to increase the acquisition price on the angro market because the suppliers are not longer interested in purchasing energy at the lowest possible price, the state guaranteeing them the return them the difference between the purchase price and limited supply price.

On the average and long term: approaches must be made to the European Commission to give up to establish the setting of reduction targets from classical sources (especially coal) remaining in actuality only renewable sources development targets. The way in which the production of classical sources is reduced remains at the each member state discretion depending on the specific conditions; must be approaches for implementation the mechanism which allow the capacities allocation to be reduced on borders between states; the investments in classical power plants and renewable sources into a balanced percent with maintain the coal production even of reserve of situations in which deficit occurs due to insufficient production of renewable sources; the storage capacities have to increase [4],[5].

The measurements that are required to be adopted for reducing the effects of the energy crisis on the economy, energy and wellbeing are:

-updating the national energy strategy as mandatory foreseeing investments in new capacity of electrical and thermal production as well as new capacities for national and transborder electrical energy transport;

-the development of electricity production from renewable sources to be continued within technical and economic limits allowed by the operation of National Electric Power System and the efficient operation of the electricity market;

-taking into account the domestic energy sources is necessary to achieve a balanced energy mix;

-increasing the energy efficiency as an important component of National Strategy;

-to be applied coherent energy politics and strategies for energy development and protection against geopolitical influences.

The energy efficiency has to preserve the same level of operating, safety and performances for equipment into a technological line, the efficiency standard IEC 60364-8-1 recommends the implementation of integrated management system or energy efficiency based on (fig.2) [4], [6]:

- user setting of main parameters, including of non-electrical parameters;
-suitable selection of the available energy sources, to assure customers supply at lowest costs;
-acquisition of available energy at hourly rates;
-acquisition of data related to energy quality;
-acquisition of data from the various sensors of installations (temperature, pressure, humidity)
-communication with user about information details related to energy consumption.

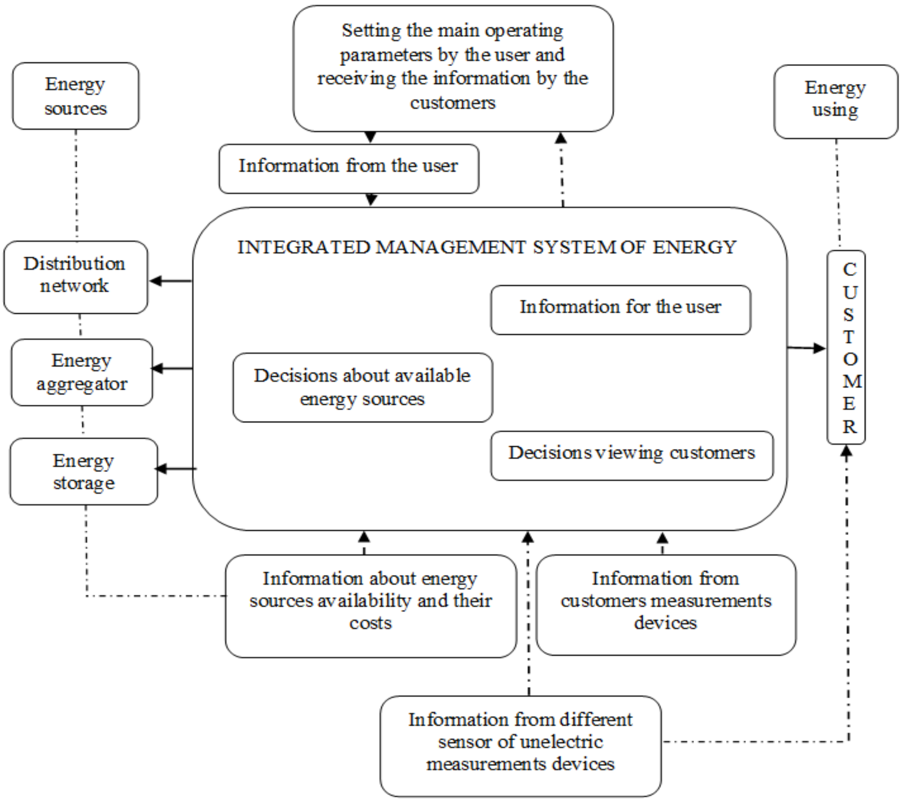

Fig.2. Implementation of integrated management system for energy efficiency

In the last years, almost of 3000MW were put out of operating another 1475MW till 2025 and 2300 MW will put out of operating till 2030 in Romania. It has to take account the tie between geography and existed resources of every state or region isolated. Poland and Germany have coal, Denmark, Finland and Romania have access and gas resources off-shore, states from the Carpathian and the Alps have hydroelectric potential as well as the states from North Sea have wind potential or the states from south of Europe have solar potential, so, not all states could have the same energetical mix.

The regulation applies from first December 2022 to 31 March 2023 adjusts the existing EU initiatives and legislation, to secure the EU's energy supplies, such as a gas storage regulation, a gas demand reduction regulation, the creation of an EU energy platform and outreach initiatives for the diversification of supply sources [7].

Romania is ready to meet tight deadlines for European funding, increasing energy independence from Russia, decrease the effects of the european energy crisis and decarbonize its economy. In Arad in Romania's west, will be installed the largest photovoltaic plant in Europe as it joined a 1.04 GW project developed by Monsson [8].

It is important that assuring a flexible equilibrium between renewable sources and classical sources in the same time with optimization of sustainability and stational system efficiency on the liberalized energy market conditions.

5. CONCLUSIONS

The energy system has to responsible rethink for assuring the energy independence. The renewable sources alone will not be able to ensure a constant and sufficient level of electricity supply and a flexible balance with classical sources will be ensured, avoiding their elimination before securing a replacement.

In the context of the drastic reduction of oil and natural gas reserved, with consequences on the prices of petroleum production and delays in finding solutions for storage electricity, obtained from renewable sources or the emergence of geopolitical events with major economic implications for national without immediate solutions to equilibrate the balance, coal remains a bridge in the medium term, during which adopting the problems of adapting the new types of resources must be gradually resolved.

REFERENCES

[1]. Cazacu E., Petrescu L., Ionita V., *Elemente de calitate si eficienta a energiei in instalatiile electrice modern* Editura Matrixrom, Bucuresti, 2020.

[2]. Golovanov N., Mogoreanu N., Toader C., Porumb R., *Eficienta energetica. Mediul. Economia moderna* , Editura Agir, Bucuresti, 2017.

[3]. Stochitoiu M.D., Utu I., *Aspects of energy efficiency in modern electrical installations*, SESAM 2021, MATEC Web of Conferences, 2021.

[4]. www. balkangreenenergynews.com

[5]. www.energynomics.ro

[6]. www.ec.europa.eu/environnement

[7]. www.consilium.europa.eu

[8]. www.mesagerulenergetic.ro

MODELING THE PERMANENT REGIME OF 220/110/20 kV SARDANESTI POWER SUBSTATION

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Abstract: The calculations of permanent regimes of high and very high voltage power substations are performed to predetermine the optimal operation of the analyzed power substation and the energy system from a technical point of view and economic. This paper presents the behavior of the 220/110/20 kV Sardanesti power substation for the current operating conditions, if the electricity consumption increases or decreases, checking the stability of the system in the Oltenia area and developing a strategy on the safety and security of the National Energy System.

Keywords: Modeling, permanent regime, power substation.

1. INTRODUCTION

The calculation of the permanent regime of an power system consists, in determining the values of all state quantities that define the regime, starting from certain primary information regarding the passive and active elements of the analyzed system. This information allows the elaboration of the mathematical permanent regime in the form of a system of algebraic equations, generally nonlinear, which describes the operation of the equivalent single-phase direct sequence scheme. System elements – generators, consumers, power lines, transformers, etc. and their connections conventionally represent a monofilament scheme. The equivalent single-phase equivalent connections of the elements form the equivalent scheme of the whole system a complex circuit, in which the neutral point, common to all component schemes, is chosen a reference node. The other nodes are independent nodes. They

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always appear explicitly and in the monofilament scheme.The calculation of the permanent regime is the most common CAD application both in design (planning of the development of power grid) and in operation (dispatcher). An power system includes all the equipment necessary for the transformation of “ non-electrical energy ” into electricity as well as its transport to consumption points. Specifically, the power system comprises the multitude of power plants, power substations (with the role of interconnection or transformation of the voltage level), transmission elements (transport or distribution) and means of adjustment and compensation.

The permanent regime, or *operating stationary* of the system is described by the following two categories of electrical quantities:

- *the powers introduced, or consumed, in the nodes of the power grid;*
- *the voltages of these nodes (measured from the reference node – earth), the distribution of powers and power losses through the transmission elements.*

The calculations of permanent regimes are performed to predetermine the optimal operation of the system from a technical and economic point of view. The main uses of the results of these calculations concern:

- *determining the development strategy of the system, as a result of the foreseeable increases of consumption;*
- *finding the optimal solution of operation, under normal conditions;*
- *analysis of the effects of decommissioning some elements in the system* [1], [3] [4].

2. DESCRIPTION OF THE PERMANENT REGIME MODELING PROGRAM

Paladin DesignBase 7.0. is a comprehensive power systems simulation platform for modeling, analyzing and optimizing power system performance. Regardless of the complexity of electrical infrastructure, Paladin DesignBase provides the technological richness to perfect infrastructure for superior system performance: 800-component library with more than 100,000 device-specific manufacturers' specifications; *a comprehensive range of integrated analysis modules; easy-to-navigate CAD-like user interface, allowing unprecedented ease of use; personal and team-based productivity features and data management tools.*

Paladin DesignBase 7.0. includes a family of 42 design and simulation features including: *Power Flow; Voltage Stability; Short Circuit; Arc Flash; Protective Device Coordination; Wire Sizing; Generator Sizing; Load Forecasting; Transmission Line Parameters; Cable Ampacity.*

Paladin DesignBase 7.0. offers users an unparalleled range of features and functions designed to increase their engineering capabilities, without adding technical complexity:

- *Rich-Object Component Library:* This comprehensive library of frequently-used design components allows users to easily “drag and drop” pre-defined symbols on their design workspace. Each Paladin DesignBase symbol is an intelligent object that is instructed to connect itself to the desired object, and to stay anchored once connected. If two branches are connected by the user, then the program automatically generates a physical node;

- *Complex Components:* This feature allows Paladin DesignBase users to save any part of a model as an object… no matter how many objects are contained within it. This allows sophisticated grouping of objects – say a collection of buses or equipment – to be saved as a single custom component… and used over and over in downstream design projects;
- *User-Customizable Symbols Catalog:* Paladin DesignBase has incorporated Autodesk’s “ActiveShapes® Editor,” allowing users to design the layout of any new catalog component, such as a new bus symbol or branch symbol;
- *Project Layout Management:* Paladin DesignBase users can organize the project layout as a single drawing model, as a multiple-page model, or as multiple drawings model. The drawings are electrically interconnected and operate on a single project database;
- *User-Customizable Working Environment Layout:* Paladin DesignBase users can customize the displayed tools, features and application, as well as customize the toolbars and the associated commands.
- *Comprehensive Library:* Paladin DesignBase has a comprehensive, verified and validated library with protective devices, control systems, battery data, transformers, cables, motors, generators, transmission lines, relays, etc.

This feature allows Paladin DesignBase 7.0. users to connect any Windows-based application to their Paladin. DesignBase project, including any website. This is a powerful feature that allows users to organize their Paladin DesignBase projects – stored in a single project database – as multiple page or multiple drawings project. For a given project, the hyperlink feature is a search, find, open the drawing model and locate the network component on the drawing.

Key Benefits: *DesignBase models become boundary-less, extending wherever necessary; Models are not constrained to CAD-only elements, but to all business applications; A single project database ensures manageability over the extended design model* [2], [5], [6].

3. MODELING OF 220/110/20 kV SARDANESTI POWER SUBSTATION

3.1. Description of the power substation

The 220/110/20 kV Sardanesti power substation is located in Plopsoru commune, Gorj county, belonging to the Center for the Exploitation of Electricity Transmission Networks Târgu-Jiu – Craiova Electricity Transport Unit [4], [5].

3.1.1. 220 kV Power Substation

The 220 kV power substation is of the external type and is equipped with simple bussbar systems, to which the following power cells (switchgears) are connected: *220/110 kV – 200 MVA AT (autotransformer); 220 kV Urechesti OHL* *(overhead power line); 220 kV Craiova Nord OHL (overhead power line); 220 kV Measures 1, according to fig.1.* [7], [8], [9].

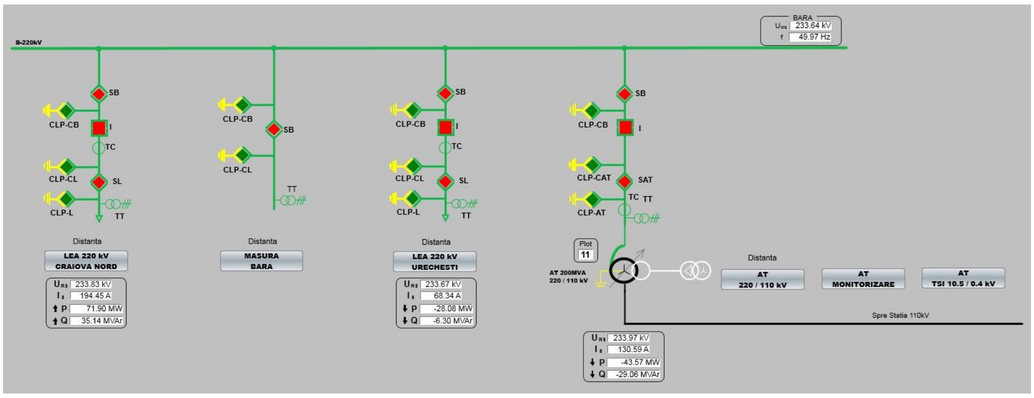

Fig.1. Scheme of the 220 kV Sardanesti power substation – SCADA

3.1.2. 110 kV Power Substation

The 110 kV power substation is of the external type and is equipped with double bussbar systems, with connection by transversal couple, to which the following power cells (switchgears) are connected: *220/110 kV – 200 MVA AT 1 (autotransformer); 220/110 kV – 200 MVA AT 2 (autotransformer); 110 kV Jilt OHL (overhead power line); 110 kV Dragotesti OHL (overhead power line); 110 kV Pinoasa OHL (overhead power line); 110 kV Rosia – Pesteana OHL (overhead power line); 110 kV SRA - Pesteana OHL (overhead power line); 110 kV Plopsoru – CFR 1 OHL (overhead power line); 110 kV Turceni T01 OHL (overhead power line); 110 kV Turceni T03 OHL (overhead power line); 110 kV Turceni T05 OHL (overhead power line); 110 kV Transversal couple, 110 kV Measure 1, 110 kV Measure 2, according to fig.2* [10], [11].

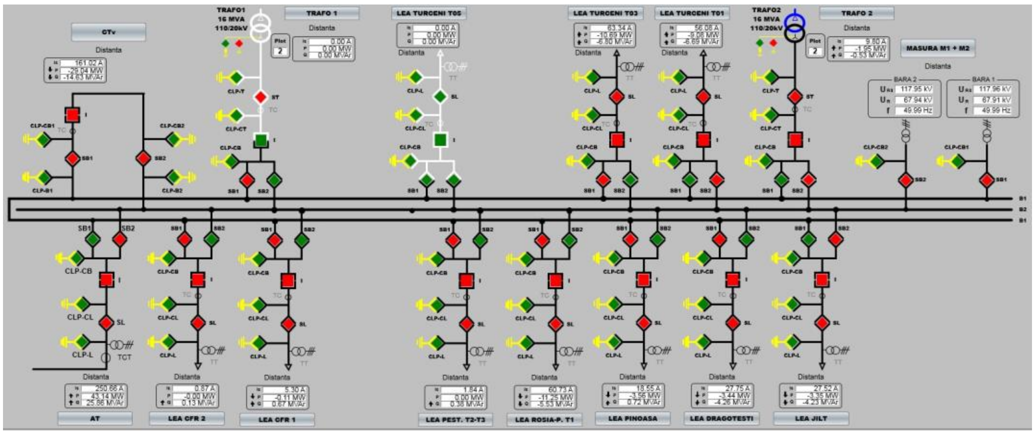

Fig.2. Scheme of the 110 kV Sardanesti power substation – SCADA

3.1.3. 20 kV Power Substation

The 20 kV power substation is of the internal type and is equipped with 2 simple bussbar systems conected with transversal couple, to which the following power cells (switchgears) are connected: *220/20 kV – 16 MVA AT 1 (autotransformer); 220/20 kV – 16 MVA AT 2 (autotransformer); 20 kV Turceni OHL (overhead power line); 20 kV Cocoreni OHL (overhead power line); 20 kV MHC 1 OHL (overhead power line); 20 kV MHC 2 OHL (overhead power line); 20 kV SI CHE OHL (overhead power line); 20 kV Transversal couple; 20 kV Measure 1; 20 kV Measure 2; 20 kV TSI 1 (intern services); 20 kV TSI 2 (intern services), according to fig. 3* [12].

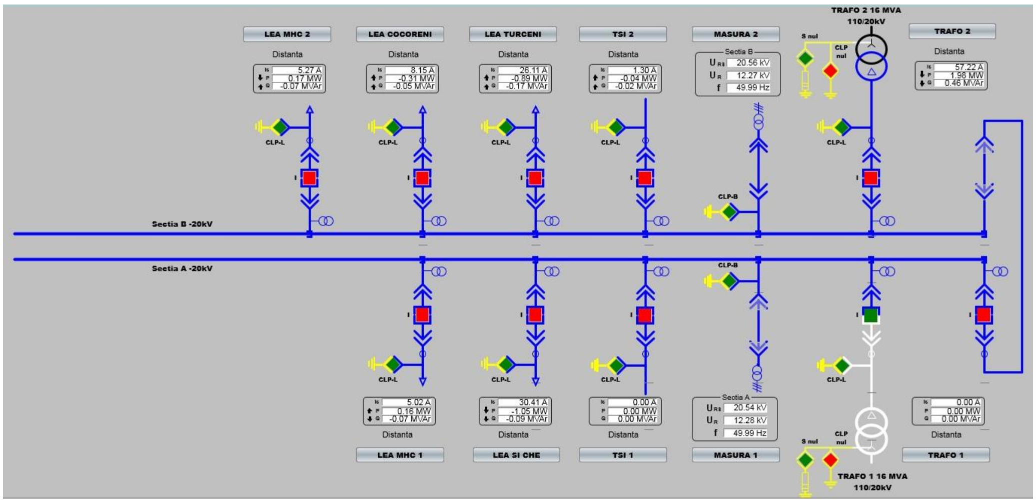

Fig.3. Scheme of the 20 kV Sardanesti power substation – SCADA

3.2. Modeling of permanent regime

3.2.1. Active and reactive losses

a)	Scenario 1	Power injection:	220 kV Craiova Nord OHL and 110 kV Turceni T01;
		Equilibrium connection:	220 kV Urechesti OHL;
		Consumers:	110 kV Plopsoru - CFR 1 OHL, 110 kV Plopsoru - CFR 2 OHL, 110 kV Rosia-Pesteana 1 OHL, 110 kV SRA-Pesteana 2 OHL, 110 kV Dragotesti OHL, 110 kV Jilt OHL, OHL 00 kV Pinoasa OHL, 110 kV Turceni T03 OHL, 110 kV Turceni T05 OHL.

Summary of Total Generation and Demand:
===============================

	P(MW)	Q(MVAR)	S(MVA)	PF(%)
Swing Bus(es):	5.283	-36.911	36.666	14.17
Generators:	-5.000	-16.000	17.482	15.00

Shunt:	0.000	-44.973	99.973	0.00
Static Load:	0.000	0.000	0.000	0.00
Motor Load:	0.000	0.000	0.000	0.00
Total Loss:	**0.283**	**-97.884**		

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b) Scenario 2

Power injection: 220 kV Urechesti OHL and 110 kV Turceni T03 OHL;

Equilibrium connection: 220 kV Craiova Nord OHL;

Consumers: 110 kV Pinoasa OHL, 110 kV Plopsoru – CFR 2 OHL, 110 kV Rosia-Pesteana 1 OHL, 110 kV SRA-Pesteana 2 OHL, 110 kV Dragotesti OHL, 110 kV Jilt OHL, 110 kV Turceni T01 OHL, 100 kV Plopsoru 1 OHL, 110 kV Turceni T05 OHL.

Summary of Total Generation and Demand:

===============================

	P(MW)	Q(MVAR)	S(MVA)	PF(%)
Swing Bus(es):	5.132	-36.912	36.666	14.17
Generators:	-5.000	-16.000	17.482	15.00
Shunt:	0.000	-45.973	98.977	0.00
Static Load:	0.000	0.000	0.000	0.00
Motor Load:	0.000	0.000	0.000	0.00
Total Loss:	**0.132**	**-98.885**		

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c) Scenario 3

Power injection: 220 kV Urechesti OHL and 110 kV Turceni T05 OHL;

Equilibrium connection: 220 kV Craiova Nord OHL;

Consumers: 110 kV Pinoasa OHL, 110 kV Plopsoru – CFR 1 OHL, 110 kV Plopsoru – CFR 2 OHL, 110 kV Rosia-Pesteana 1 OHL, 110 kV SRA-Pesteana 2 OHL, 110 kV Jilt OHL, 110 kV Turceni T01 OHL, 110 kV Turceni T03 OHL, 110 kV Dragotesti OHL.

Summary of Total Generation and Demand:

===============================

	P(MW)	Q(MVAR)	S(MVA)	PF(%)
Swing Bus(es):	5.131	-36.912	35.667	14.17
Generators:	-5.000	-16.000	17.482	15.00
Shunt:	0.000	-45.973	98.977	0.00
Static Load:	0.000	0.000	0.000	0.00
Motor Load:	0.000	0.000	0.000	0.00

Total Loss: 0.131 -96.888

3.2.2. Voltage drops (surges)

Bus Voltage Results

Bus Name	Type	V (KVOLTS)	DROP (%)	ANG (DEG)	P (MW)	Q (MVAR)	PF (%)
Urechesti OHL	Swing	232.821	0.00	-10000.0	-98.07	-168.64	50.27
Craiova Nord OHL	Gen	231.831	-5.83	79.8	-10.00	-7.00	81.92
Dragotesti OHL	Gen	112.831	-5.83	79.8	-10.00	-7.00	81.92
Pinoasa OHL	Gen	115.773	-0.94	79.7	40.00	26.00	83.84
Plopsoru - CFR 1 OHL	Gen	110.366	-1.09	79.6	60.00	39.00	83.84
Plopsoru - CFR 2 OHL	Gen	110.152	-5.98	79.7	20.00	10.00	89.44
Rosia-Pesteana 1 OHL	None	110.715	-0.68	79.8	0.00	0.00	
SRA-Pesteana 2 OHL	None	112.932	-5.88	79.8	19.98	15.50	79.00
Jilt OHL	None	112.634	-0.66	79.8	0.00	101.30	0.00
Turceni T01 OHL	None	112.675	-0.67	79.8	0.00	101.31	0.00
Turceni T03 OHL	None	110.594	-0.65	79.8	0.00	101.29	0.00
Turceni T05 OHL	None	110.922	-5.87	79.7	10.00	1.70	98.58
AT 220/110 - 200 MVA	ShuntR	231.554	-0.64	79.8	0.00	-101.28	0.00
AT 110/20 (1) - 16 MVA	ShuntR	231.554	-0.64	79.8	0.00	-101.28	0.00
AT 110/20 (2) - 16 MVA	ShuntR	231.554	-0.64	79.8	0.00	-101.28	0.00
0012	None	232.821	-0.70	79.8	39.81	83.61	42.99
0013	None	232.821	-0.64	79.7	99.31	95.13	72.21
0014	None	232.821	-0.69	79.8	39.81	83.60	43.00
0015	None	232.821	-0.68	79.8	0.11	11.27	0.93
0016	None	232.821	-0.67	79.7	99.33	95.17	72.21
0019	None	232.821	-0.68	79.8	0.00	0.00	
0020	None	232.821	-0.68	79.8	0.00	0.00	
0025	None	112.932	-5.87	79.7	0.03	12.09	0.24
0026	None	232.917	-5.87	79.7	0.03	12.09	0.24
0027	None	112.932	-5.87	79.8	0.03	12.09	0.24
0028	None	232.926	-5.88	79.8	19.98	15.50	79.01
0029	None	232.929	-5.88	79.8	19.98	15.50	79.01
0030	None	112.932	-5.87	79.7	10.00	1.70	98.58
0032	None	232.922	-5.87	79.7	10.00	1.70	98.58
0036	None	232.921	-5.87	79.7	10.00	1.70	98.58
0048	None	232.939	-5.88	79.8	19.98	15.50	79.00
0049	None	112.932	-0.69	79.8	59.62	101.67	50.58
0050	None	112.932	-0.70	79.8	59.62	101.68	50.58
0051	None	232.946	-5.88	79.8	19.98	15.51	79.00
0052	None	232.949	-5.89	79.8	19.98	15.51	79.00
0053	None	112.932	-0.71	79.8	59.62	101.70	50.57
0059	None	112.932	-0.70	79.8	39.81	83.60	43.00
0064	None	112.932	-0.65	79.7	99.31	95.15	72.21
100014	None	112.932	-0.68	79.8	0.11	11.27	0.93
100015	None	232.921	-0.68	79.8	0.11	11.27	0.93
100205	None	232.921	-5.87	79.7	10.00	1.70	98.58
100206	None	232.922	-5.87	79.7	10.00	1.70	98.58

3.2.3. Current flow

Branch Current Flow Values

Branch Name	C#	Type	Library CodeName	Current (KA)	Angle (Deg)	Ampacity (KA)	Loading (%)
Urechesti OHL	1	Breaker	L-V 1600 A ITR	0.133	195.2	1.600	8%

```
Craiova Nord OHL    1 Breaker  L-V 1600 A ITR      0.016  -10.8    1.600       1%
AT 220/110 - 200 MVA1 Switch   1600 SME 220KV      0.000   79.8    0.000
Dragotesti OHL      1 Switch   1600 SME 220KV      0.063   41.9    0.000
Pinoasa OHL         1 Breaker  L-V 1600 A ITR      0.145  -10.2    1.600       9%
Plopsoru-CFR 1 OHL  1 Breaker  L-V 1600 A ITR      0.197   36.0    1.600      12%
Plopsoru-CFR 2 OHL  1 Feeder   AL1600HIAMP-GF-I    0.145  169.8    1.600       9%
Rosia-Pesteana 1 OHL1 Breaker  L-V 1600 A ITR      0.000   79.8    1.600       0%
SRA-Pesteana 2 OHL  1 Breaker  L-V 1600 A ITR2     0.063  221.9    1.600       4%
Jilt OHL            1 Breaker  L-V 1600 A ITR2     0.169  200.1    1.600      11%
Turceni T01 OHL     1 Breaker  L-V 1600 A ITR2     0.030  169.6    1.600       2%
Turceni T03 OHL     1 Feeder   AL1600HIAMP-GF-H    0.025   70.1    0.644       4%
Turceni T05 OHL     1 Feeder   AL1600HIAMP-GF-H    0.025   70.1    0.644       4%
AT 110/20 (1)-16 MVA1 Feeder   AL1600HIAMP-GF-H    0.068   46.6    0.644      11%
AT 110/20 (2)-16 MVA1 Feeder   AL1600HIAMP-GF-I    0.282 -9879.8   0.644      44%
SB-AT 220/110       1 Switch   1600 SME 220KV      0.030  -10.4    1.600       2%
SB-Urechesti OHL    1 Switch   1600 SME            0.016  169.2    1.600       1%
SB-Craiova Nord OHL 1 Switch   1600 SME 220KV      0.025   70.1    1.600       2%
SB-Dragotesti OHL   1 Switch   1600 SME 220KV      0.025   70.1    1.600       2%
SB-Pinoasa OHL      1 Switch   1600 SME            0.145  169.8    1.600       9%
SB-Plopsoru-CFR 1 OH1 Switch   1600 SME 220KV      0.063   41.9    1.600       4%
SB-Plopsoru-CFR 2 OH1 Switch   1600 SME            0.133   15.2    1.600       8%
SL-Rosia-Pesteana 1 1 Switch   1600 SME            0.197  216.0    1.600      12%
SL-SRA-Pesteana 2 OH1 Switch   1600 SME 220KV      0.063   41.9    1.600       4%
SL-Jilt OHL         1 Switch   1600 SME            0.000   79.8    1.600       0%
SL-Turceni T01 OHL  1 Switch   1600 SME 220KV      0.063  221.9    1.600       4%
SL-Turceni T03 OHL  1 Switch   1600 SME            0.000   79.8    1.600       0%
SB2-Turceni T05 OHL 1 Switch   1600 SME 220KV      0.169   20.1    1.600      11%
SL-AT 110/20 (1)-16 1 Switch   1600 SME 220KV      0.030  -10.4    1.600       2%
SL-AT 110/20 (1)-16 1 Switch   1600 SME            0.145  169.8    1.600       9%
SL-AT 220/110 - 200 1 Switch   1600 SME 220KV      0.025   70.1    1.600       2%

Branch Name        C#    Type     Library CodeName Current  Angle  Ampacity Loading
                                                     (KA)   (Deg)    (KA)     (%)
----------------------- -- -------- ---------------- -------- ------ --------
AT 220/110 - 200 MVA1 Breaker  L-V 1600 A ITR2     0.025  250.1    1.600       2%
AT 110/20 (1)-16 MVA1 Breaker  L-V 1600 A ITR2     0.063   41.9    1.600       4%
AT 110/20 (2)-16 MVA1 Breaker  L-V 1600 A ITR2     0.063   41.9    1.600       4%
```

3.2.4. Power flow

```
                            Branch Power Flow Values
                            ========================
Branch Name               C#  Type    Library CodeName   From -> To Flow    To ->
From Flow    Losses
                              (MW)     (MVAR)     (MW)     (MVAR)     (MW)     (MVAR)
----------------------- -- -------- ---------------- -------- -------- --------
AT 220/110 -    1 Breaker  L-V   -39.81   -83.60    39.81    83.60    0.00   0.01
AT 110/20 (1)-11 Breaker  L-V   -20.81   -43.60    19.81    43.60    0.00   0.01
AT 110/20 (2)-11 Breaker  L-V   -19.81   -43.60    19.81    43.60    0.00   0.01
Urechesti OHL         1 Switch   1600 SME      0.00     0.00     0.00     0.00
0.00   0.00
Craiova Nord OHL      1 Switch   1600 SME      0.00     0.00     0.00     0.00
0.00   0.00
Dragotesti OHL        1 Breaker  L-V 1600 A IT 0.00   101.31     0.00  -101.30
0.00   0.01
Pinoasa OHL           1 Breaker  L-V 1600 A IT99.33    95.17   -99.31   -95.15
0.02   0.02
Plopsoru-CFR 1 OHL    1 Feeder   AL1600HIAMP-GF0.00  -101.28     0.00   101.29
0.00   0.01
Plopsoru-CFR 2 OHL    1 Feeder   AL1600HIAMP-GF0.00  -101.28     0.00   101.29
0.00   0.01
Rosia-Pesteana 1 OHL  1 Breaker  L-V 1600 A    0.00     0.00     0.00     0.00
0.00   0.00
```

```
SRA-Pesteana 2 OHL    1 Breaker  L-V 1600 A  -19.98   -15.50    19.98    15.51
0.00   0.00
Jilt OHL              1 Breaker  L-V 1600 A    0.03   -12.09    -0.03    12.09
0.00   0.00
Turceni T01 OHL       1 Feeder   AL1600HIAMP   10.00   1.70   -10.00    -7.00
0.00  -5.30
Turceni T03 OHL       1 Feeder   AL1600HIAMP    10.00   1.70    -10.00    -7.00
0.00 -5.30
Turceni T05 OHL       1 Feeder   AL1600HIAMP    40.00   26.00   -39.82   -83.61
0.19-57.61
SB1-AT 220/110-200 MVA1 Switch   1600 SME       -0.03   12.09     0.03   -12.09
0.00  0.00
SB1-AT 110/20(1)-16 MVA 1 Switch 1600 SME        0.11  -11.27    -0.11    11.27
0.00  0.00
SB1-AT 110/20(2)-16 MVA 1 Switch 1600 SME       10.00    1.70   -10.00    -1.70
0.00  0.00
SB2-Urechesti OHL       1 Switch 1600 SME       10.00    1.70   -0.00     -1.70
0.00  0.00
SB2-Craiova Nord OHL    1 Switch 1600 SME      -19.98  -15.50   19.98     15.50
0.00  0.00
SB2-COUPLE              1 Switch 1600 SME        0.00    0.00    0.00      0.00
0.00  0.00
SB-Dragotesti OHL       1 BreakerL-V 1600 A ITR  0.00  101.31    0.00   -101.30
0.00  0.01
SB-Pinoasa OHL          1 BreakerL-V 1600 A IT  99.33   95.17  -99.31    -95.15
0.02  0.02
SL-SB-Plopsoru-CFR1 OHL 1 Feeder AL1600HIAMP-GF  0.00 -101.28    0.00    101.29
0.00  0.01
SL-Plopsoru-CFR 2 OHL   1 Feeder AL1600HIAMP-GF  0.00  -101.28   0.00    101.29
0.00  0.01
SL-Rosia-Pesteana 1 OHL 1 Breaker L-V 1600 A     0.00     0.00   0.00      0.00
0.00  0.00
SL-SRA-Pesteana 2 OHL   1 Breaker  L-V 1600 A  -19.98   -15.50  19.98     15.51
0.00  0.00
SL-Jilt OHL             1 Breaker  L-V 1600 A    0.03   -12.09  -0.03     12.09
0.00  0.00
SL-AT 220/110-200 MVA   1 Switch   1600 SME     -0.03    12.09   0.03    -12.09
0.00  0.00
SL-AT 110/20(1)-16 MVA  1 Switch   1600 SME      0.11   -11.27  -0.11     11.27
0.00  0.00
SL-AT 110/20(2)-16 MVA  1 Switch   1600 SME     10.00     1.70 -10.00     -1.70
0.00  0.00
SL-Urechesti OHL        1 Switch   1600 SME     -0.03    12.09   0.03    -12.09
0.00  0.00
SL-Craiova Nord OHL     1 Switch   1600 SME      -0.00  -101.29  0.00    101.30
0.00  0.01
```

3.2.5. Voltage violation

```
                            Voltage Violation Report
                            ========================
 Bus Name            Type     Bus Voltage  UpperLim  LowerLim  Violation
                               (kvolts)      (pu)      (%)       (%)
------------------------ ------ -------- -------- -------- -------- ---------


Urechesti OHL         Gen       232.831    1.0582    105.0%     95.0%    over
Craiova Nord OHL      Gen       232.831    1.0584    105.0%     95.0%    over
Dragotesti OHL        Gen       232.832    1.0583    105.0%     95.0%    over
Pinoasa OHL           Gen       232.836    1.0581    105.0%     95.0%    over
Plopsoru-CFR 1 OHL    Gen       232.831    1.0583    105.0%     95.0%    over
Plopsoru-CFR 2 OHL    Gen       232.833    1.0583    105.0%     95.0%    over
Rosia-Pesteana 1 OHL  Gen       232.835    1.0583    105.0%     95.0%    ove
SRA-Pesteana 2 OHL    Gen       232.831    1.0589    105.0%     95.0%    over
```

```
Jilt OHL             Gen      232.839    1.0586    105.0%     95.0%    over
Turceni T01 OHL      Gen      232.838    1.0583    105.0%     95.0%    over
Turceni T03 OHL      Gen      232.833    1.0587    105.0%     95.0%    over
```

3.2.6. AutoTransformers loading:

```
                    AutoTransformers Loading
                    ========================

Branch Name                C#   Type Library CodeName  Capacity   Loading
F_Tap T_Tap
                                                        (MVA)      (MVA)     (%)
PU)  (PU)
------------------------ -- -------- ---------------- ---------- ---------- ----
- ----- -----

AutoTransformator          1          AT 220/110       200.00      12.22    3%
AutoTransformator          1          AT 110/20 (1)     16.00      11.12    3%
AutoTransformator          2          AT 110/20 (2)     16.00      10.27    3%
```

3.2.7. Total losses

```
                   Summary of Total Generation and Demand
                   ======================================
                      P(MW)         Q(MVAR)         S(MVA)        PF(%)
    Swing Bus(es):   -98.070       -168.641        195.083        50.27
    Generators   :   100.000         61.000        117.137        85.37
    Shunt        :     0.000       -101.281        101.281         0.00
    Static Load  :     0.000          0.000          0.000         0.00
    Motor Load   :     0.000          0.000          0.000         0.00
    Total Loss   :     1.935       -208.922
                   ----------     ----------
    Mismatch     :    -0.005         -0.000
```

4. CONCLUSIONS

This paper illustrate the functioning of 220/110/20 kV Sardanesti power substation during the permanent regime.

After simulation of 220/110/20 kV Sardanesti power substation by EDSA programme, the results is next:

a) Active and reactive power losses:

- Scenario 1 – 0.283 MW and 97.884 MVA;
- Scenario 2 – 0.132 MW and 97.885 MVA;
- Scenario 3 – 0.131 MW and 96.888 MVA.

b) Voltage drops (surges):

- Urechesti 220 kV OHL: 0.00 %;
- Craiova Nord 220 kV OHL: – 5.83 %;
- AT 220/110 – 200 MVA: 0.64 %;
- Dragotesti 110 kV OHL: – 5,83 %;
- Pinoasa 110 kV OHL: – 0.94 %;
- Plopsoru – CFR 1 110 kV OHL: – 1.09 %;
- Plopsoru – CFR 2 110 kV OHL: – 5.98 %;
- Rosia-Pesteana 1 110 kV OHL: – 0.68 %;
- SRA-Pesteana 2 110 kV OHL: – 5.88 %;

- Jilt 110 kV OHL: – 0.66 %;
- Turceni T01 110 kV OHL: – 0.67 %;
- Turceni T03 110 kV OHL: – 0.65 %;
- Turceni T05 110 kV OHL: – 5.87 %;
- AT 110/20 (1) – 16 MVA: – 0.64 %;
- AT 110/20 (2) – 16 MVA: – 0.64 %.

c) ***Current flow:***

- AT 220/110 kV – 200 MVA: 0.025 kA – 2 % loading;
- AT 110/20 (1) – 16 MVA: 0.063 kA – 4 % loading;
- AT 110/20 (2) – 16 MVA: 0.063 kA – 4 % loading.

d) ***Power flow:***

- AT 220/110 – 200 MVA: – 39.81 MW; 0.01 losses;
- AT 110/20 (1)–16 MVA: – 20.81 MW; 0.01 losses;
- AT 110/20 (2)–16 MVA: – 19.81 MW; 0.01 losses;
- Urechesti 220 kV OHL: 0.00 MW; 0.00 losses;
- Craiova Nord 220 kV OHL: 0.00 MW; 0.00 losses;
- Dragotesti 110 kV OHL: 0.00 MW; 0.01 losses;
- Pinoasa 110 kV OHL: 99.33 MW; 0.02 losses;
- Plopsoru–CFR 1 110 kV OHL: 0.00 MW; 0.01 losses;
- Plopsoru–CFR 2 110 kV OHL: 0.00 MW; 0.01 losses;
- Rosia-Pesteana 1 110 kV OHL: 0.00 MW; 0.00 losses;
- SRA-Pesteana 2 110 kV OHL: – 19.98 MW; 0.00 losses;
- Jilt 110 kV OHL: 0.03 MW; 0.00 losses;
- Turceni T01 110 kV OHL: 10.00 MW; – 5.30 losses;
- Turceni T03 110 kV OHL: 0.00 MW; – 5.30 losses;
- Turceni T05 110 kV OHL: 40.00 MW; – 57.61 losses.

e) ***Voltage violation:***

- Urechesti 110 kV OHL: 95.0% over;
- Craiova Nord 110 kV OHL: 95.0% over;
- Dragotesti 110 kV OHL: 95.0% over;
- Pinoasa 110 kV OHL: 95.0% over;
- Plopsoru–CFR 1 110 kV OHL: 95.0% over;
- Plopsoru–CFR 2 110 kV OHL: 95.0% over;
- Rosia-Pesteana 1 110 kV OHL: 95.0% over;
- SRA-Pesteana 2 110 kV OHL: 95.0% over;
- Jilt 110 kV OHL: 95.0% over;
- Turceni T01 110 kV OHL: 95.0% over;
- Turceni T03 110 kV OHL: 95.0% over.

f) ***AutoTransformers loading:***

- AT 220/110 – 200 MVA: 12.22 – 3%;

- AT 110/20 (1) – 16 MVA: 11.12 – 3%;
- AT 110/20 (2) – 16 MVA: 10.27 – 3%.

g) Total losses:

- 1.935 MW and – 208.922 MVAR.

Following the simulation of the permanent regime of the 220/110/20 kV Sardanesti power substation, it can be seen that the power substation falls within normal operating parameters, but it is proposed to modify the 220 kV power substation from a simple collector bussbar system, in a double collector bussbars, thus increasing the reliability of the 220 kV power substation.

REFERENCES

[1]. Ahmad I., Khan F., Khan S., Khan A., Tareen A.W., Saeed M. *Blackout Avoidance through Intelligent Load Shedding in Modern Electrical Power Utility Network.* J. Appl. Emerg. Sci. 8, 48–57, 2018.

[2]. Billinton R., Li W. *Basic concepts of power system reliability evaluation. In Reliability Assessment of Electric Power Systems Using Monte Carlo Methods.* Springer: New York, NY, USA, pp. 9–31, 1994.

[3]. Fîţă N.D., Băncilă N.A., *Identifying of vulnerabilities/risk factors of the critical infrastructure in the power installations of ultra high and high voltage from the national power system with international connections*, Revista „Calitatea-acces la succes" / „Quality-Access to Success" Journal, 18 (S1), January, pp. 103-108, 2017.

[4]. Fîţă N.D., Lazăr T., Popescu F.G., Pasculescu D., Pupăză C., Grigorie E., *400 kV power substation fire and explosion hazard assessment to prevent a power black-out*, International Conference on Electrical, Computer Communications and Mecatronics Engineering - ICECCME, 16 – 18 November, 2022.

[5]. Fîţă N.D., Obretenova M.I., Pasculescu D., Tatar A., Popescu F.G., Lazar T., *Structure and analysis of the power subsector within the national energy sector on ensuring and stability of energy security*, Annals of the Constantin Brancusi University of Targu-Jiu, Engineering series, pp.177-186, 2022.

[6]. Fîţă N.D., Radu S.M., Herbei R., *Global Security – European Energy Security*, LAP – Lambert Academic Publishing, 2023.

[7]. Fîţă N.D., Radu S.M., Păsculescu D., *The resilience of critical infrastructures within the national energy system in order to ensure energy and national security*, Bulletin of "Carol I" National Defence University, no. 2 / 2022, Publishing House "Carol I" National Defence University, Bucharest, pag. 57-65, 2022.

[8]. Lazăr T., Marcu M.D., Uțu I., Popescu F.G., Păsculescu D., *Mașini electrice - culegere de probleme*, Editura UNIVERSITAS, Petroșani, pp.197, 2023.

[9]. Păsculescu D., Fîţă N.D, Herbei R., *Power Substations - Critical Energy Infrastructures*, LAP Lambert Academic Publishing, 2021.

[10]. Salimian M.R., Aghamohammadi M.R., *A Three Stages Decision Tree-Based Intelligent Blackout Predictor for Power Systems Using Brittleness Indices.* IEEE Trans. Smart Grid, 9, 5123–5131, 2018.

[11]. Zhang Y., Xu Y., Dong Z.Y., *Robust Ensemble Data Analytics for Incomplete PMU Measurements-Based Power System Stability Assessment*, IEEE Trans. Power Syst., 33, 1124–1126, 2018.

[12]. Paladin DesignBase 7.0 www.easypower.com.

PHOTOMETRIC SIMULATION FOR PERFORMANCE IMPROVEMENT OF SOLAR ENERGY CONVERSION WITH FIXED PHOTOVOLTAIC PANELS AND REFLECTION MEMBRANE

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Abstract: For the transition to sustainable energies to happen in a relatively safe manner, there has to be as many improvements to actual capabilities that allows us to convert solar and wind energy into electric energy. For this reason, in this paper, we present a potential solution to rise the efficiency of solar irradiation conversion by using a cheap, highly reflective membrane under the already installed solar arrays. This solution can be used in order to maximize the radiation that falls on the photovoltaic cell, especially under the panel, by using bifacial photovoltaic panels.

Key words: renewables, photovoltaic, bifacial, efficiency, irradiance, simulation.

1. INTRODUCTION

Incidental solar radiation is the key factor that influences the performances of photovoltaic panels in order to produce electric energy. But all data from official sources are for horizontal surface. So, because PV panels are usually optimally inclined a prediction of solar radiation on inclined surfaces is necessary [1], [3], [6].

Empirical formulas were presented for prediction of the solar energy on the inclined surface and horizontal surface which mostly predicted the monthly and yearly solar irradiance [2], [7], [13].

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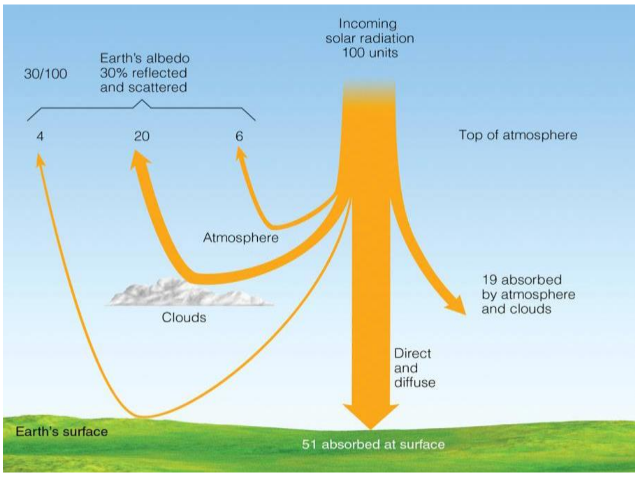


Fig.1. Total solar radiation on the Earth surface

2. GLOBAL IRRADIANCE

Direct radiation, diffuse irradiance and reflected irradiance are the components of global radiation on inclined surfaces.

$$R_{Tt} = R_{bt} + R_{dt} + R_{rt} \quad (1)$$

where
R_{Tt} is equivalent radiation,
R_{bt} is the direct beam,
R_{dt} is the diffuse irradiance
R_{rt} is the reflected irradiance

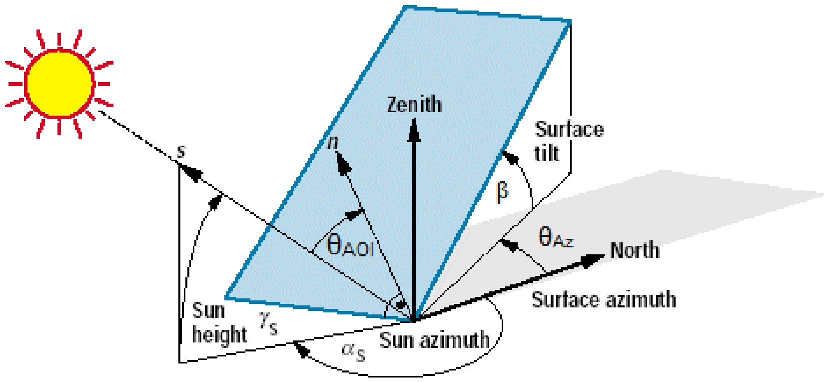


Fig.2. Solar Altitude angle

a) Direct Solar Irradiance (R_{bt})

Direct solar radiation on inclined plane is mathematically represented as follows:

$$R_{bt} = R_b cos\theta_{AOI} \quad (2)$$

Where R_b is the direct radiation on the horizontal surface and θ is the angle of incidence between the normal to the surface and the incoming solar direct beam.

Also the expression of R_b can be expressed:

$$R_b = Eexp\left(-\frac{k}{sin\gamma_s}\right) \quad (3)$$

b) Diffuse Solar Irradiance (R_{dt})

The model of the diffuse irradiance that arrives at a site on inclined solar systems with equal intensity from all direction as sky is considered as isotropic is expressed as:

$$R_{dt} = CR_b\left[\frac{1+cos\beta}{2}\right] \quad (4)$$

Where the sky diffuse factor C is approximated by the following expression as:

$$C = 0.095 + 0,04sin\left[360 * \frac{(N-100)}{365}\right] \quad (5)$$

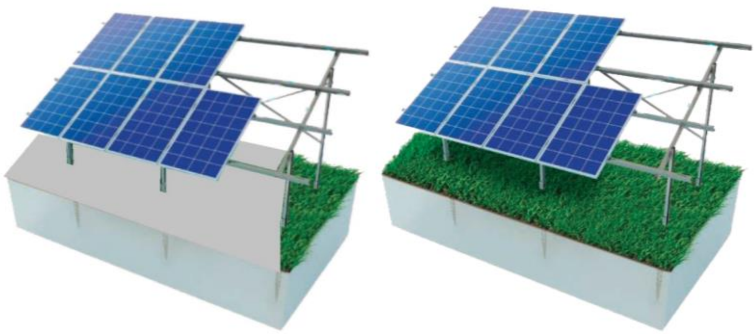
c) Reflected Solar Irradiance (R_{rt})

The reflected solar radiation is given by:

$$R_{rt} = \rho R_b(sin\gamma_s + C)\left[\frac{1-cos\beta}{2}\right] \quad (6)$$

ρ is the reflectance.

Equivalent solar radiation equation:



a) b)

Fig.3. a) Solar array over grass covered ground
b) Solar array with a white reflective membrane under the panels

In this comparison picture it is introduced a concept of increasing the solar radiation conversion performance by applying a reflexive white membrane under the photovoltaic panel. This membrane could be laid on very different support grounds like grass, gravel, roof bitumen isolation, etc. [5], [10], [17]

d) High Bifaciality

Bifaciality is the technology that uses two layers of glass on front and back side of the photovoltaic panel [4], [8], [11]. Performance will be affected by grid width of the back panel, bifaciality of the cell itself and test method which shall be analyzed through design and simulation in Dialux Evo [20].

HJT is considered one of the top cell technologies with highest bifaciality. Higher bifaciality allows more energy yield on the back [9], [14], [18].

Generally, this type of technology enables 5%-30% energy gain on the back, depending on the factors such as ground reflection, region type etc.

Fig.4. Solar panel array with bifacial technology

In these two images is presented a technical solution with the benefit of translucent backpanel that allows solar radiation to fall right underneath the solar array. This facilitates the reflection back to the panel, increasing overall solar conversion [12], [16], [19].

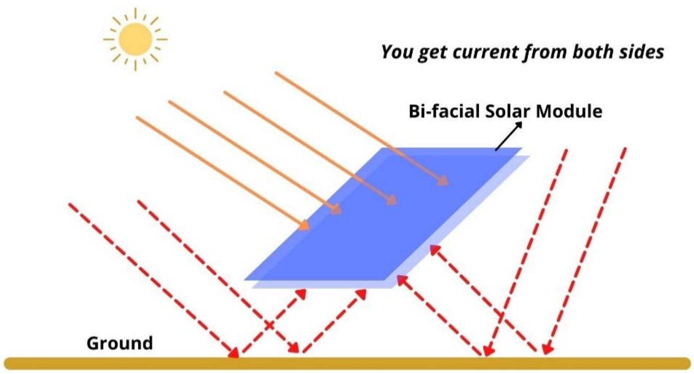


Fig.5. The directions of solar radiation: direct and indirect

Other radiation that is used by the bifacial solar panels is the indirect solar radiation that comes not directly from the Sun but reflected from the clouds, atmosphere and nearby objects.

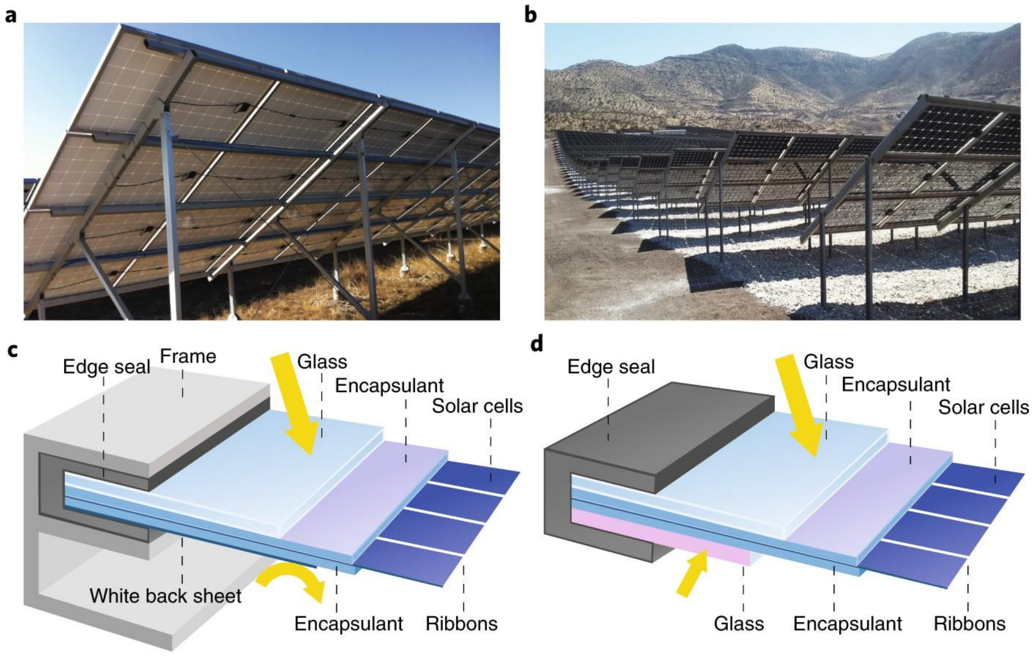


Fig.6. Difference between two types of technology, a) solar panel with a white opaque back panel, b) solar panels with glass technology c)-d) structure

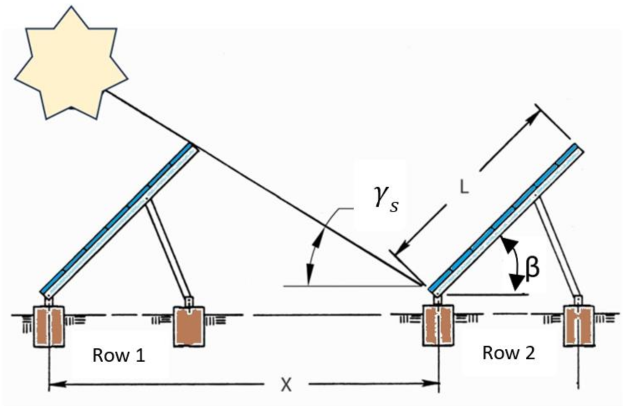


Fig.7. The solar array spacing variables

In order to know how to arrange the solar array, simple mathematical calculus is needed. The number of approaches for that matter is not low, but for this example one solution is to use Sun elevation, the angle of the solar panel to the ground and the location's latitude.

The system may be built with two or more rows of PV panel, so in this case the necessary preparations should be previously made to ensure that none of them cast a shadow onto the one behind it.

For this determination the image above is used.

There is no perfect solution because the solar trace on the sky and the elevation starts at zero in the morning and ends at zero when it sets. The irradiation on an array has three components, direct irradiation, diffuse (from blue sky and overcast), and reflected from the ground. Here it is considered only the direct irradiation that is subject to shadowing by the row in front or any other object that is placed there.

The elevation of the sun at noon at the winter solstice in December in the Northern Hemisphere is:

$$\gamma_s = 90° - 23.45° - t \tag{7}$$

where:
γ_s – the solar elevation
t - it the latitude of the construction site.

In most cases 90% of the unobstructed solar irradiation on the panel array occurs when the solar elevation is above half of the maximum winter elevation.

The elevation correction is therefore 50%. This may be excessive for rows that are less than about 4 times the height of the panel [15].

To solve for the minimum distance between the rows to fulfill the condition on nonshadowing, the following equation is used:

$$X = L\left\{cos(\beta) + [sin(\beta) \cdot tan[t + 23.5 + \tfrac{1}{2}\gamma_s]]\right\} \tag{8}$$

where:
L - solar panel length
β = panel tilt angle
t= geographic latitude of the solar array system

Calculated values are:
Winter minimum noon solar elevation = 90-23.45-latitude
90% of unobstructed elevation = 50% of Winter minimum solar elevation

3. PHOTOMETRIC SIMULATION

For this simulation we used Dialux Evo, a software tool that is used for photometric simulations of high accuracy. In the simulation we chose a powerful 1kW luminaire that was arranged in a rectangular array of 30p per 20p. So the total amount of luminaires is 600p on a surfaces of 15 by 10 meters, to simulate the parallel sunrays.

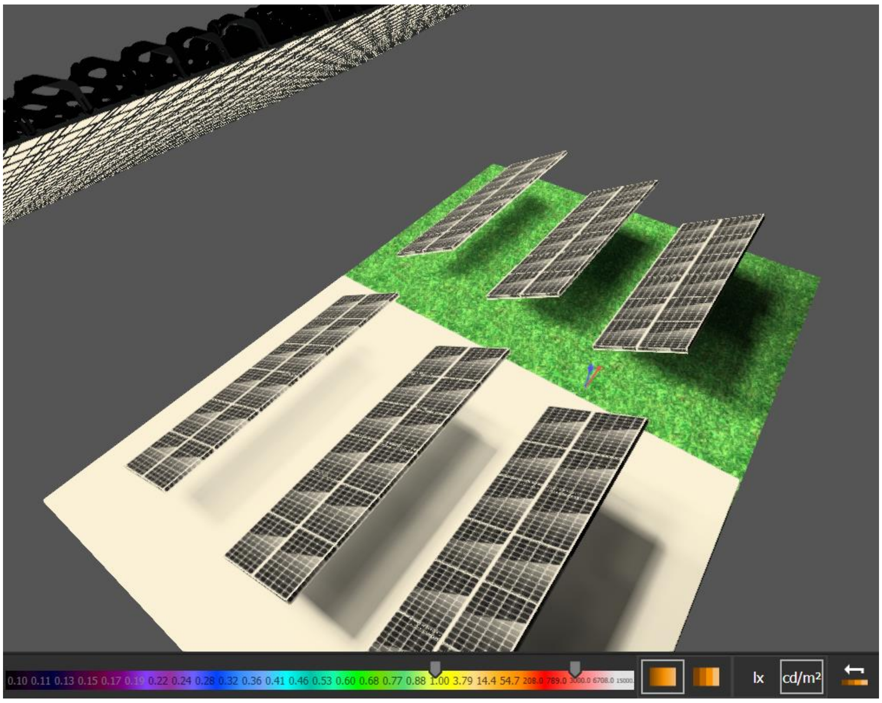


Fig.8. The comparison image with grass and white reflective membrane underneath the solar panels

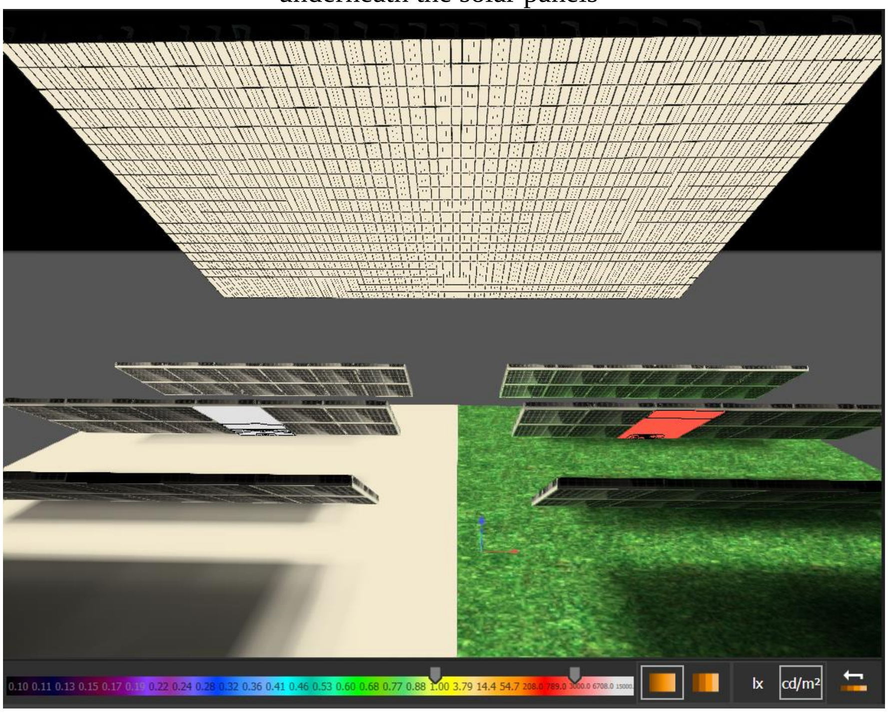


Fig.9. The two calculation surfaces selected in the middle of the solar panel arrays for accurate comparison

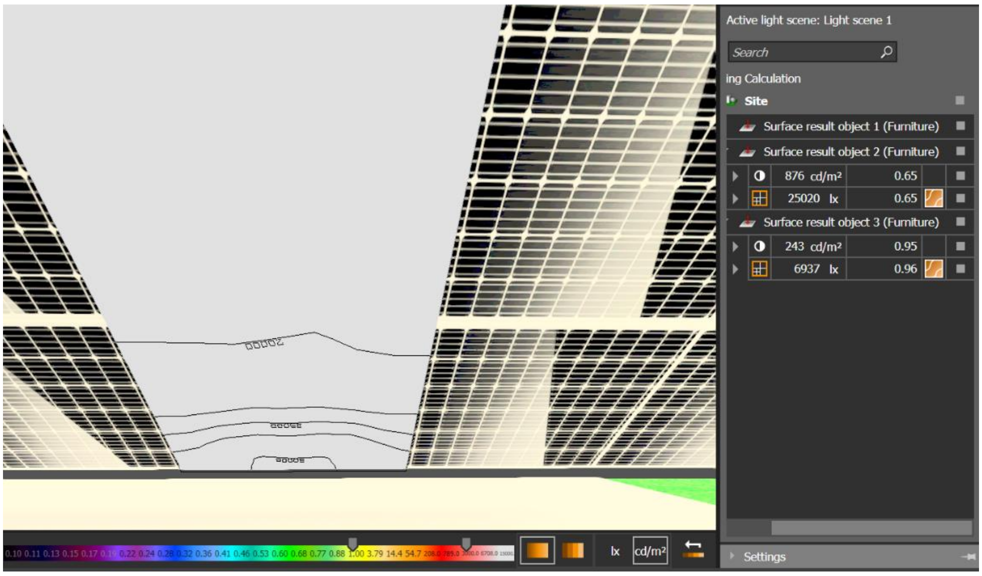


Fig.10. Calculation surface on the solar panel with the white membrane

By placing a calculation surface on the back side of the bifacial solar panel, the software is able to calculate the amount of light that is reflected from the ground under the panels. In the first control group of solar panels, the usual grass has a reflection factor of 14% while the tested reflective membrane which is white, has a 87% reflection factor.

This difference represents a good amount of solar energy, indirect energy that can be converted into electrical energy by the bifacial solar cells in the modules.

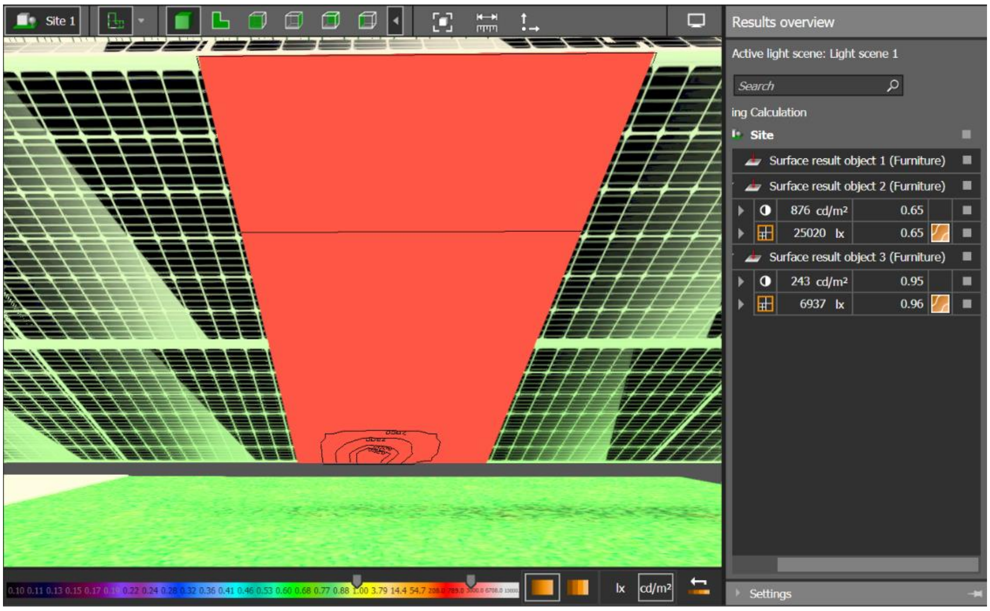


Fig.11. Calculation surface on the solar panel with grass covered soil

Given the comparison between the grass covered soil and the white reflective membrane, only the percentage of extra light is needed, so the simulated radiation level must not be an accurately determined due to the fact that the Sun gives a gradient radiation during a day.

Table 1. ***Surface results***

Ground type	Luminance	Performance	Illumination	Performance
Surface results (grass)	243 cd/m^2	100%	6937 lux	100%
Surface results (white reflective membrane)	876 cd/m^2	360%	25020 lux	360%

On a clear day, if the Sun is directly overhead, the intensity of the radiation hitting the ground **directly from the Sun** is around 1,050 W/m^2, on top of this a further 70 W/m^2 comes from the bright blue sky, giving a total of 1,120 W/m^2. If is it's cloudy the amount will be lower. This means that only about 6.2% of the radiation can be used by the solar cells, and adding the reflection factor of the white membrane the usable light is even lower, to 5.4%.

Another source of indirect radiation are the other solar modules or even walls, objects that are close to the panel rows.

4. CONCLUSIONS

Continued advancements in solar cell technologies, materials, and manufacturing processes may lead to more efficient and cost-effective bifacial solar panels. Improvements in the design and construction of these panels could enhance their performance and make them more competitive in the market.

Ongoing research and development in the solar industry may lead to breakthroughs in materials and design, further boosting the efficiency of bifacial solar panels. Research efforts may also focus on optimizing the panels for specific environments and applications.

Bifacial solar panels could be integrated with other emerging technologies, such as energy storage systems and smart grid solutions, to create more resilient and efficient solar energy systems. The percentage gain in energy production from using a white membrane under a solar array can vary based on several factors, including the local climate, the tilt and orientation of the solar panels, and the specific characteristics of the reflective surface. The reflectivity or albedo of the surface, which is a measure of its ability to reflect light, plays a crucial role in determining the impact on energy production.

REFERENCES

[1]. Antohe S., *Organic Materials and Electronic Devices,* Publishing house University of Bucharest, Bucharest, 1996.

[2]. Green M.A., *High Efficiency Silicon Solar Cells*, Trans Tech Publications, Switzerland, 1987.

[3]. Handra A.D., Popescu F.G., Păsculescu D., *Utilizarea energiei electrice - lucrări de laborator*, Editura Universitas, Petroşani, 167 pag., 2020.

[4]. Lazăr T., Marcu M.D., Uțu I., Popescu F.G., Păsculescu D., *Mașini electrice - culegere de probleme*, Editura UNIVERSITAS, Petroșani, pp.197, 2023.

[5]. Marcu M.D., Popescu F.G., Pana L., *Modeling and simulation of power active filter for reducing harmonic pollution using the instantaneous reactive power theory*. Environmental Engineering and Management Journal, June, Vol.13, No. 6, Pages: 1377-1382, DOI:10.30638/eemj.2014.148, 2014.

[6]. Marcu M.D., Popescu F.G., Pana L., Slusariuc R., *Modeling and simulation of solar radiation. Applied Mechanics and Materials*, Vol. 710, pp. 113-118, Trans Tech Publication, Switzerland, 2015.

[7]. Maric Dj.M., Meier P.F., S.K. Estreicher, *Materials Science Forum*, Vol. 83-87, p. 119-124, 1992.

[8]. Markvart T., Castaner L., *Technical Handbook of Photovoltaics,Fundamentals and Applications*, Elsevier, Ltd, 2003.

[9]. Niculescu T., Arad V., Marcu M., Arad S., Popescu F.G., *Safety barrier of electrical equipment for environments with a potential explosion in underground coal mines*. MINING OF MINERAL DEPOSITS. Volume: 14 Issue: 3 Pages: 78-86, DOI: 10.33271/mining14.03.078, 2020.

[10]. Niculescu T., Pasculescu D., Pana L., *Study of the operating states of intrinsic safety barriers of the electrical equipment intended for use in atmospheres with explosion hazard*, WSEAS Transactions on Circuits and Systems, Volume 9, pp.430-439, 2010.

[11]. Niculescu T., Păsculescu D., *Use of numerical simulation to study capacitive loads which is connecting to an AC power source,* 15th SGEM GeoConference on Informatics, Geoinformatics and Remote Sensing, SGEM2015 Conference Proceedings, Albena, Bulgaria, June 18-24, Vol. 1, pp. 391-398, 2015.

[12]. Pasculescu D., Dobra R., Ahmad M.A., *Dosimetric Quantity System for Electromagnetic Fields Bio-effects*, International Journal of Scientific Research (IJSR) 5, no. 2, pp. 28-32, 2016.

[13]. Pasculescu D., Romanescu A., Pasculescu V., Tatar A., Fotau I., Vajai Ghe., *Presentation and simulation of a modern distance protection from national energy system*, Proceedings of the 10 th International Conference on Environment and Electrical Engineering – EEEIC 2011, Rome, Italy, pp. 646-650, 2011.

[14]. Pasculescu D., Slusariuc R., Popescu F.G., Fîță N.D., Tatar A., Lazar T., *Modeling and simulation of lighting of a road with 2 strips per direction to en 13201: 2015 Standard*, Annals of the University of Petrosani, Electrical Engineering, Vol.24, pp.67-76, Petrosani, 2022.

[15]. Popescu F.G., Pasculescu D., Marcu M., Niculescu T., Handra A.D., *The technical and economic advantages of power factor correction*, Annals of University of Petrosani, Electrical Engineering, Vol. 21, pp.35-42, Petrosani, 2019.

[16]. Popescu F.G., Pasculescu D., Marcu M., Pasculescu V.M., Fîță N.D., Tatar A., Lazar T., *Principles of effective energy management and power control system*, Annals of the University of Petrosani, Electrical Engineering, Vol.24, pp.111-118, Petrosani, 2022.

[17]. Popescu F.G., Pasculescu D., Marcu M., Slusariuc R., Buica G., Lazar T., *Analysis of filtering and correction of the power factor in distorted balance*, Annals of University of Petrosani, Electrical Engineering, Vol. 23, pp. 77-82, Petroşani, 2021.

[18]. Popescu F.G., Păsculescu D., Păsculescu V.M., *Modern methods for analysis and reduction of current and voltage harmonics*, LAP LAMBERT Academic Publishing, ISBN 978-620-0-56941-7, pp. 233, 2020.

[19]. Tatar A, Pasculescu D., Marcu M., Lazar T., Popescu F.G, *Electric power production and national energy security considerations*, Annals of the University of Petrosani, Electrical Engineering, Vol.24, pp.5-16, Petrosani, 2022.

[20]. Zekai S., *Solar Energy Fundamentals and Modeling Techniques*, Springer, 2008.

BENEFITS OF STATCOM COMPENSATOR SUPPORTING THE AIMS AND OBJECTIVES OF EUROPEAN POWER SYSTEMS

MARIA DANIELA STOCHITOIU [1]

Abstract: Flexible AC transmission system (FACTS) plays an important role in raising the level of implementation of renewable energy resources, having ability in continuous controlling the active and reactive power in the network. The paper emphases that the increasing demands for a stable supply of electricity is rising which determine the need for sophisticated and more intelligent system control for power system. The STATCOM compensator provide the necessary features to avoid technical problems in the power systems that increase transmission capacity and system stability very efficiently and they assist in prevention of cascading disturbances.

Key words: transmission capacity, point of common coupling, system stability.

1. INTRODUCTION

When connecting new transmission lines and controlling power flow and voltage stability under a variety of operating conditions, the STATCOM device offers system operators an effective way to meet the financial and regulatory requirements for power systems (fig.1).

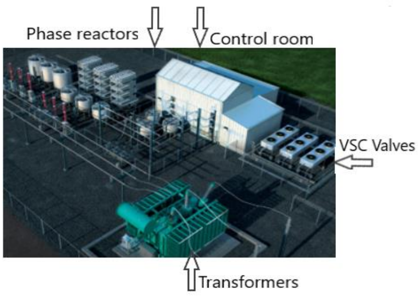


Fig.1. The STATCOM components are integrated within advantage facilities

The presence of perturbing users in the electrical distribution network is leading to a diminution of the energy quality level of the power supplied to other users

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connected to the same bars, so adopting of measurements for level in the limits accepted by international norms.

Fast-compensating reactive power sources like STATCOM, which can improve power factor and system voltage stability and offer real time voltage control, can help systems recover more quickly from unexpected events. A voltage-source converter (VSC) of a certain type, a dc capacitor, and a coupling transformer are used to link the VSC in shunt to the power network in a STATCOM.

An essential method for distributed supplier to perform dynamic reactive power compensation is by placing dynamic compensation devices at the point of common coupling (PCC).

Dynamic compensation device is static synchronous compensator (STATCOM). By using dynamic reactive power support from STATCOM, the transient voltage stability will be increased and the system voltage can be quickly restored after a grid fault.

An essential method for distributed supplier to perform dynamic reactive power compensation is by placing dynamic compensation devices at the point of common coupling (PCC). Dynamic compensation device is static synchronous compensator (STATCOM). By using dynamic reactive power support from STATCOM, the transient voltage stability will be increased and the system voltage can be quickly restored after a grid fault [1], [3].

The preferred nominee for rapidly voltages changes, system voltage control or frequent voltage variations is the efficient equipment STATCOM. It has an important role in distributed generation when the voltage can sudden decrease and the low levels of voltage can lead to instability in the power net.

2. FLICKER PHENOMENON COMPENSATION

The definition of flicker is like a visual impression of fluctuation of light intensity. This is caused by the voltage amplitude variations in the frequency range (0,5 and 25Hz). The voltage variations are the result of consumed power adjustment. The main cause of flicker appearance is electric arc furnace used in metal melting. These consumed active power and reactive power into stochastic state. The electric arc furnace are producing voltages perturbances that are the base of flicker appearance. Installing a STATCOM equipment in parallel with electric arc furnace is an efficient solution for resolving the flicker problems (figure2). Also, it is establishing a stable voltage level in the point of common coupling PCC ensuring the more efficient operating of furnace.

The STATCOM equipment can absorb inductive reactive power and also supply capacitive reactive power when capacitors are tied in parallel. These are settled for different harmonics frequency and have to prevent the harmonics amplifier due to resonance phenomenon in energetical systems [4], [5].

The STATCOM, which is coupled to the PCC, is used to regulate the voltage there in the desired range. The reactive power supplied to the power grid can be controlled, by controlling the ac output voltage magnitude of the STATCOM.

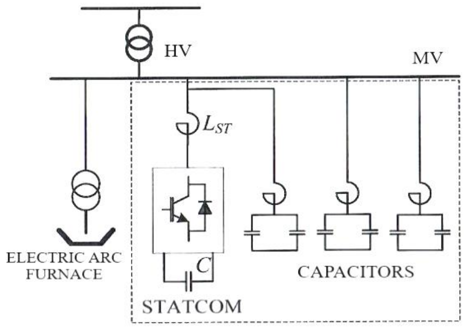

Fig. 2. Single wire STATCOM connection diagram

The regulator is in open loop and the voltage and current are measured. The reactive component is filtered through a pass down filter and the resulted current is a part of reference current. The second part of the filtered voltage and current is obtained from a closed loop regulator where are measured the values from electric grid. The reactive components are compared with a settled values and the difference are representing the inputs for PI controller [6].

3. INCREASING THE ELECTRIC GRID TRANSMISSION CAPACITY

STATCOM device can be described as a current source connected in parallel from point of view of electro - energetical system, because the area control current is not in dependence with the voltage $\underline{V}_{STATCOM}$, and the control parameter for STATCOM is I_Q.

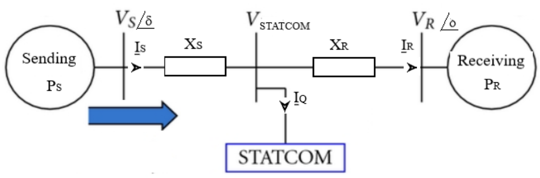

Fig. 3. Equivalent diagram of the electrical network with STATCOM for transmission system

$$\underline{V}_{STATCOM} = \underline{V}_S - j\underline{I}_S X_S \tag{1}$$

$$\underline{I}_R = \underline{I}_S - \underline{I}_Q \tag{2}$$

$$\underline{I}_R = \frac{\underline{V}_{STATCOM} - \underline{V}_R}{jX_R} \tag{3}$$

Taking into account the above relations it can obtain:

$$\underline{I}_S = \frac{\underline{V}_S - \underline{V}_R}{j(X_S + X_R)} + \underline{I}_Q \frac{X_R}{X_S + X_R} \tag{4}$$

In the above relation it can replace the first relation and obtain [4]:

$$\underline{V}_{STATCOM} = \underline{V}_S - \frac{\underline{V}_S - \underline{V}_R}{(X_S + X_R)} - j\underline{I}_Q \cdot \frac{X_S X_R}{X_S + X_R} = \underline{V}_{STATCOM0} - j\underline{I}_Q \cdot \frac{X_S X_R}{X_S + X_R} \tag{5}$$

$$\underline{V}_{STATCOM0} = \frac{\underline{V}_S\, X_R + \underline{V}_R X_S}{(X_S + X_R)} \quad (6)$$

$\underline{V}_{STATCOM0}$ – represents the voltage to STATCOM in case it isn`t connect to system, as $\underline{I}_Q = 0$.

Due to $\underline{I}_Q = jI_Q \cdot \frac{\underline{V}_{STATCOM0}}{V_{STATCOM0}}$, the equation (5) becomes:

$$\underline{V}_{STATCOM} = \underline{V}_{STATCOM0} + I_Q \cdot \frac{\underline{V}_{STATCOM0}}{V_{STATCOM0}} \cdot \frac{X_S X_R}{X_S + X_R} = \underline{V}_{STATCOM0}\left(1 + \frac{I_Q}{V_{STATCOM0}} \cdot \frac{X_S X_R}{X_S + X_R}\right) \quad (7)$$

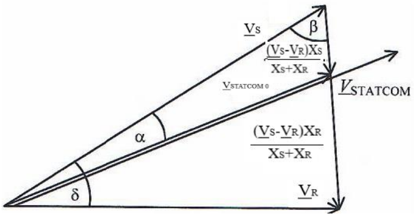

Fig. 3. Phasor diagram

The above relation shows that $\underline{I}_Q$ is phased with $\frac{\pi}{2}$. Aplying the sinus theorema for the figure 3, it can write:

$$\frac{sin\beta}{sin\delta} = \frac{V_R}{|\underline{V}_S - \underline{V}_R|} \quad (8)$$

$$\frac{sin\beta}{sin\alpha} = \frac{V_{STATCOM0}}{\frac{X_S|\underline{V}_S - \underline{V}_R|}{X_S + X_R}} \quad (9)$$

$$sin\alpha = \frac{V_R \cdot X_S \cdot sin\delta}{V_{STATCOM0}(X_s + X_R)} \quad (10)$$

The generated power and transmissed

$$P_S = P_R = \mathrm{P} = \frac{V_{statcom} \cdot V_S}{X_S} sin\alpha = \frac{V_{STATCOM} \cdot V_R \cdot V_S \cdot sin\delta}{V_{STATCOM0}(X_s + X_R)} \quad (11)$$

$$\mathrm{P} = \frac{V_R \cdot V_S \cdot sin\delta}{(X_s + X_R)} \cdot \left(1 + \frac{I_Q}{V_{STATCOM0}} \cdot \frac{X_S X_R}{X_S + X_R}\right) \quad (12)$$

The improvement of transmission capacity is direct proportionally with I_Q[4].For determining the maximum transmission power, the above relation has to derive with the ratio of $\frac{X_S}{X_R}$, matched null. Considering $V_s = V_R$, the efficient position for STATCOM equipment is in the middle of the electrical line.

4. INCREASING THE RESERVE OF TRANSITORY AND STATIC STABILITY

The transitory stability can be defined as the ability of supply synchronous generator to remain in synchronism after a major perturbance in the electrical network like shortcut in the transport network; out of operation of supply unit or overload. The reaction of the electrical grid after the perturbation is characterized by large variations of intern angles of generators, transmitted power, the level of voltages in common points, etc. A generator or a group of generators are becoming instable when appear large difference between intern angles of generators. If this difference is into a range, the system is remaining stable. Specialty literature treats this subject using the equal areas criterium. For a generator connected to an infinite power line, the difference angle between transitory voltage of generator and reference phasor (line voltage) is δ and the dependence P(δ) is shown below.

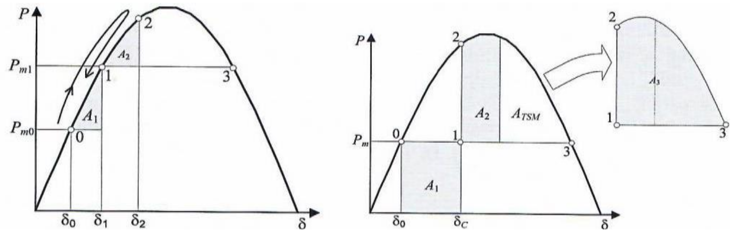

Fig. 4. Maximizing the area for optimal control

In case of growth of mechanical power, the operating points of systems are following the transitory characteristic between 0 and1. Due to excess of mechanical power to electric power, the rotating masses are accelerated. That determines the increasing of A_1 and kinetic energy, the angle δ is increasing to δ_2 where the excess of kinetic energy is no longer transformed in potential energy. The generator is decelerating when the electric power is more than mechanical power. In point 2 the rotor is changing the rotation direction trending to point 1. The rotor would oscillate around point1 between point0 and point 2 in a lack of attenuation. The recurrence is not possible in the point 3, over that, the electric power is smaller than mechanical power and the rotation masses are accelerated and the system becomes instable. The system is stable as well as area A_1 is smaller than A_3. The difference between A_3 and A_2 is the margins of transitory stability, and when this becomes negative the system also becomes instable. After elimination of defect the optimal behaviour is ensured through maximization of areaA_3 [2],[4],[9],[11].

The efficiency of STATCOM is in dependence with the defect period time. The STATCOM effective power is 25% less another equipment, for example Static Var Compensator.

5. HARMONICS ATTENUATION

Harmonic attenuation refers to the level of harmonic current emissions and how they affect harmonic voltages at the compensator's connection point. The currents add to the harmonic grid voltages already present at the connection site by creating harmonic voltages in grid impedances [6],[7]. Standards and transmission operators are setting limits for harmonic voltages at the connection point which are exceeded in some cases with the present current emissions. The explanation of obtaining better results with STATCOM can be explained by the fact these are better behaviour to low voltages being capable to supply more reactive power. As the problem of power oscillations appears especially in heavy loaded networks, where can appear in dynamic stage low levels voltages, the STATCOM utilisation is indicated [8],[10].

6. CONCLUSIONS

The advantages of STATCOM in comparation with fixed capacitors mounting in the derivation node involve high response speed and ability to maintain a constant reactive current and providing dynamic reactive power support, the system voltage can be established shortly after grid fault, and the transient voltage stability will be improved. The STATCOM responds like a voltage source, which may control the injected current almost independently of the network voltage. In addition, controllable-shunt compensators, like STATCOM may contribute to resolve the flicker phenomena and to the transient stability of the system and transmission capacity increasing for electrical grid.

REFERENCES

[1]. **Eremia M., s.a**, *Dispozitive FACTS Concepte si aplicatii in electroenergetica*, Editura Agir, Bucuresti, 2015.

[2]. **Eremia M., s.a**, *Electric Power System. Electric Networks,* Editura Academiei Romana, Bucuresti, 2006.

[3]. **Hossain M. J., Pota H. R., Ugrinovskii V. A., Ramos R. A.**, *Simultaneous STATCOM and pitch angle control for improved LVRT capability of wind turbines*, IEEE Trans. Sustain. Energy, vol. 1, no. 3, pp. 142_151, Oct. 2010.

[4]. **Jun Ql, S.a.**., *Comparative study of SVC and STATCOM reactive power compensation for prosumer microgrids with DFIG based wind farm integration*, IEEE Access 2020.3033058, 2020.

[5]. **Kumar A., s.a**, *Power system stability Enhancement using FACTS controllers*, International Conference on Emerging Trends in Electrical Engineering and Energy Management (ICETEEEM), 2021.

[6]. **Lei Y., s.a.** *Comparison of UPFC, SVC and STATCOM in improving commutation failure immunity of LCC-HVDC Systems,* IEEE Access 2020.3011113, 2020.

[7]. **Stochitoiu M.D., s.a.** *A brief review of approach the role of FACTS devices* , Annals of electrical engineering, 22, Petrosani, 2020.

[8]. **Stochitoiu M.D., s.a.** *Modern opportunities of power flow circulation control a.c. transmission systems,* DOI: 10.5593/sgem2019/2.1, SGEM, Bulgaria, 2019.

[9]. **Tibin J., Jun L.**, *Asset Management Strategies for Power Electronic Converters in Transmission Networks: Application to Hvdc and FACTS Devices* 10.1109/ACCESS.2018.2826360, 2018.

[10]. **Wang L., Prokhorov A. V.,** *Stability improvement of a multimachine power system connected with a large-scale hybrid wind photovoltaic farm using a supe***r***capacitor*, IEEE Trans. Ind. Appl., vol. 54, no. 1, pp. 50_60, Jan. 2018.

[11]. **Wessels C., Hoffmann N., Molinas M., Fuchs F.W.**, *StatCom control at wind farms with _xed-speed induction generators under asymmetrical grid faults*, IEEE Trans. Ind. Electron., vol. 60, no. 7, pp. 2864_2873, Jul. 2013.

[12]. **IEC/TR 61000-3-6,** *Limits – Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems*, IEC, 58 p., 2008.

[13]. https://www.gegridsolutions.com

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ASSESSMENTS ON THE SENSITIVITY TO IGNITION OF EXPLOSIVE ATMOSPHERES IN UNDERGROUND FIREDAMP MINES

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Abstract: This paper presents the results of a statistical analysis study for the influence of air humidity on the ignition sensitivity of gaseous explosive atmospheres in underground firedamp mines. The first half of the paper briefly presents the experimental results used. Since the results are probabilistic, methods of statistical analysis have been used. The second section presents the results of statistical analysis of experimental data.

Key words: sensitivity to ignition, moisture, firedamp mines.

1. INTRODUCTION

Coal mining in underground tunnels is always associated with a risk of explosion due to the presence of methane gas and coal dust.

According to the classification of explosive atmospheres [9], [11], the atmosphere of a subtenant firedamp mine has the highest ignition threshold, regardless of whether electrical criteria (260 μJ) or thermal criteria 450 °C (for suspended dust) are taken into account.

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Previous studies have shown that the probability of ignition in capacitive circuits depends almost exponentially on the value of the voltage. Other approaches have shown that the probability of ignition in inductive circuits depends exponentially on the logarithm of the current value [8], [12], [14].

Another factor affecting the ignition sensitivity of the underground atmosphere, characterized by the presence of methane, is the moisture content [1], [13].

Explosion propagation events lead to precompressive events and an increase in the propagation speed of the explosion wavefront in space, which is mainly characterized by one-dimensional development (galleries).

Such situations can have very serious consequences, including loss of human life and property [7], [10], [18].

In addition, explosions damage underground ventilation structures, reducing their ability to evacuate methane gas and also reducing the availability of oxygen needed by workers involved in related underground mining activities [2], [15], [19].

Analysis of experimental data showed that the probability distribution of the number of revolutions at which ignition of the test mixture occurs is variable.

2. BRIEF OVERVIEW OF EXPERIMENTAL DATA

The experimental data were obtained using a spark test apparatus (spark test apparatus). A transducer for measuring air humidity is connected to the intake path.

During the tests, a mixture of 8,3% air and methane was used, and the relative humidity of the air at the entrance to the mixture ranged from 11 – 38% RH.

The parameters of the electrical circuit to which the eclator was connected were : Uo=24Vcc, L=121mH, Io=110÷111mA.

During the test, the humidity of the intake air varied as shown in Figure 1 and the number of revolutions at which ignition occurred varied as shown in Figure 2.

The experimental procedure was conducted sequentially :

- conditioning the eclator according to B.1.3 at the beginning of the test process, then :
- each of the 15 tests is repeated as follows :
  - Purge the transducer chamber with air within 4 to 10 minutes;
  - Purge the eclator chamber and attached gas path with a gas mixture of 10 volumes;
  - The eclator is switched on in an electrical circuit whith the specified electrical parameters;
  - Record the number of revolutions at which ignition occurs;
  - Read off the specified value of incoming air humidity and record the same value for all tests performed in 15 test cycles.

Reserve a test interval of 15 times to stabilise the indicator of the humidity value.

The ignition probability values [3], [16], [20] were calculated according to the humidity of the incoming air that can be seen in Figure 1.

The regression curve is also shown in Figure 1.

According to regression curve trend analysis, it is appreciatiated that sensitivity increases when the relative humidity of incoming air is about 23%.

To identify the trends in the variability of ignition probability, the matrix of humidity and rotation value was first sorted. Then moving average was used for a predetermined number of values [4, 5].

Figure 2 shows the diagram of intake air humidity values (placed in order).

Figures 3 and 4 show the change in the moving average of the logarithm of the probability of ignition (according to relation 3) depending on the mean value of humidity in that range [6], [17].

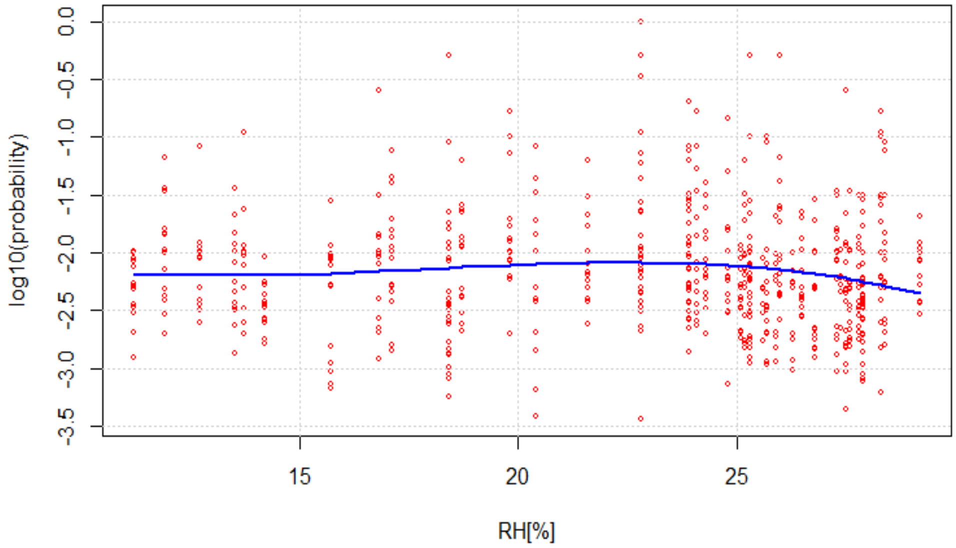

Fig.1. Decimal logarithmic variation in ignition probability as a function of intake air humidity

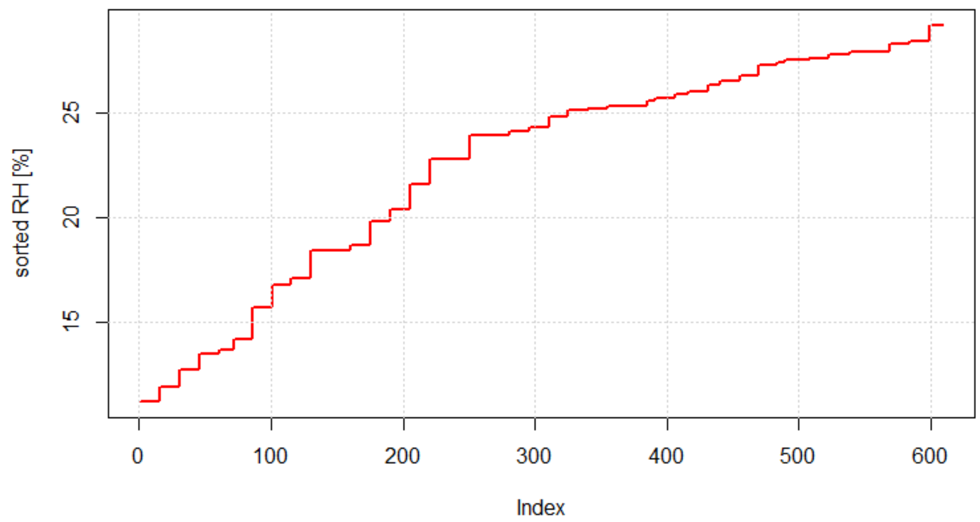

Fig.2. Sorted values of air humidity at intake

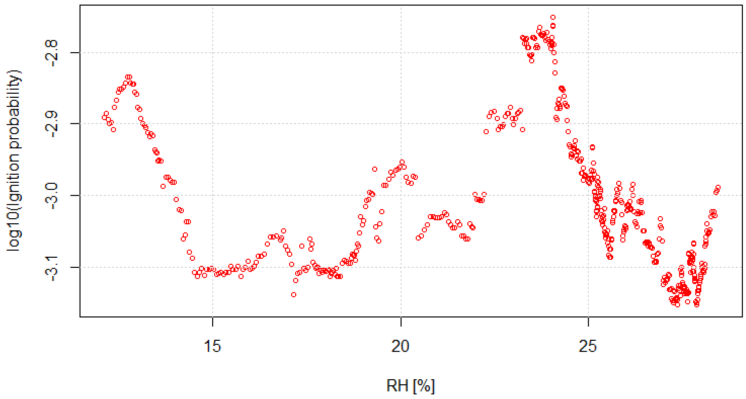

Fig.3. Variation of the decimal logarithm of the moving average of the probability of ignition as a function of air humidity at the intake with averaging interval = 50

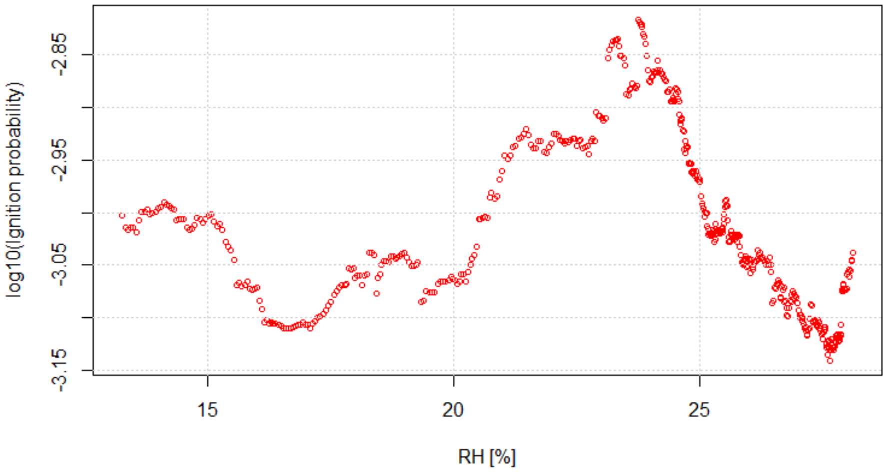

Fig.4. Variation of the decimal logarithm of the moving average of the probability of ignition as a function of air humidity at the intake with averaging interval = 100

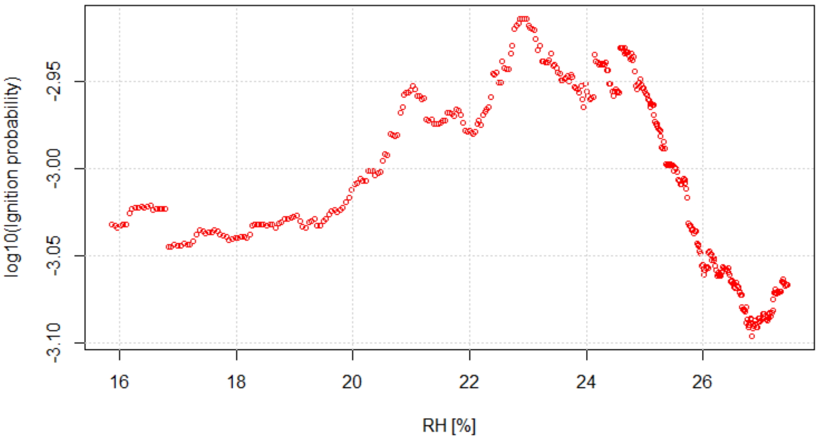

Fig.5. Variation of the decimal logarithm of the moving average of the probability of ignition as a function of air humidity at the intake with averaging interval = 200

$$log_{10}(p) = -log_{10}(mean(4 \cdot rotations)) \quad (1)$$

Analysis of the change in the decimal logarithm of the ignition probability obtained with the help of moving average confirms that the probability of ignition increases at an input air humidity of about 23% RH.

All other peaks disappeared when increasing averaging interval was performed.

3. CONCLUSIONS

Preliminary analysis of experimental data shows that ignition sensitivity, measured by the decimal logarithm of the ignition probability, is characterized by high static variability.

The cubic regression curve of ignition probability as a function of intake air humidity showed a maximum around 23% RH.

When using the moving average method as a means of reducing variation, it was observed that ignition sensitivity increased when the relative humidity of the intake air was about 23%.

When the relative humidity of the intake air exceeds 23%, the ignition sensitivity of the methane air atmosphere, quantified by the probability of ignition, decreases exponentially.

This paper summarizes a study on the effect on ignition sensitivity of the humidity of the air used to produce the air + methane test mixture of 8,3%.

REFERENCES

[1]. Burian S., Ionescu J., Darie M., Csaszar T., Andriş A., *Requirements for Installations in Areas with Explosive Atmosphere, Other than Mines, (in Romanian),* INSEMEX – Petroșani Publishing House, Romania, 2007.

[2]. Cioclea D., Găman A.G., Gherghe I., Rădoi F., Boantă C., Pasculescu V., *Possibilities to priorly establish the structures of ventilation networks affected by underground explosions,* The 24th International Mining Congress and Exhibition of Turkey, 14 – 17 April 2015, Antalya, Turcia, ISBN 978-605-01-0705-0, Pag. 991-997, 2015.

[3]. Darie M., Burian S., Ionescu J., Csaszar T., Moldovan L., Colda. C., Moldovan C., Andriş Adriana, *Investigation of air humidity influence over the ignition sensitivity of gaseous explosive atmospheres from the underground of firedamp mines*. Procedings of The sixth Balkan Mining Congress, 20-23 September 2015, Petroșani, Romania, 2015.

[4]. Fîță N.D., Radu S.M., Pasculescu D., *Ensuring, controlling and stability of energy security in the context of increasing industrial and national security–Academic Compendium*, 2021.

[5]. Fîță N.D., Radu S.M., Pasculescu D., *National security–Energy sector optimization elements*, Chisinau, Republic and Moldova: GlobeEdit Publisher, 2021.

[6]. Niculescu T., Pasculescu D., Pasculescu V.M., Stoica I.O., *Evaluation of electrical parameters of intrinsic safety barriers of the electrical equipment intended to be used in atmospheres with explosion hazard*, Int. Multidiscip. Sci. GeoConf. Surv. Geol. Min. Ecol. Manag. 2014.

[7]. Fîță N.D., Lazăr T., Popescu F.G., Pasculescu D., Pupăză C., Grigorie E., *400 kV power substation fire and explosion hazard assessment to prevent a power black-out*, International Conference on Electrical, Computer Communications and Mecatronics Engineering - ICECCME, 16 – 18 November, Maldives, 2022.

[8]. Fîță N.D., Obretenova M.I., Pasculescu D., Tatar A., Popescu F.G., Lazar T., *Structure and analysis of the power subsector within the national energy sector on ensuring and stability of energy security*, Annals of the Constantin Brancusi University of Targu-Jiu, Engineering series, Issue 2 / 2022, pp.177-186, 2022.

[9]. Fîță N.D., Radu S.M., Păsculescu D., Popescu F.G., *Using the primary energetic resources or electrical energy as a possible energetical tool or pressure tool*, Proceedings of Sciendo International Conference Knowledge based organisation – "Nicolae Balcescu" Land Forced Academy Sibiu, Vol. XXVII, No. 3, pp. 21-26, 2021.

[10]. Handra A.D., Popescu F.G., Păsculescu D., *Utilizarea energiei electrice - lucrări de laborator*, Editura Universitas, Petroşani, 167 pag., 2020.

[11]. Niculescu T., Pasculescu D., Pana L., *Study of the operating states of intrinsic safety barriers of the electric equipment intended for use in atmospheres with explosion hazard*, WSEAS Transactions on Circuits and Systems, Volume 9, pp.430-439, 2010.

[12]. Pasculescu D., Romanescu A., Pasculescu V., Tatar A., Fotau I., Vajai Ghe., *Presentation and simulation of a modern distance protection from national energy system*, Proceedings of the 10 th International Conference on Environment and Electrical Engineering – EEEIC 2011, Rome, Italy, pp. 646-650, 2011.

[13]. Pasculescu D., Slusariuc R., Popescu F.G., Fîță N.D., Tatar A., Lazar T., *Modeling and simulation of lighting of a road with 2 strips per direction to en 13201: 2015 Standard*, Annals of the University of Petrosani, Electrical Engineering, Vol.24, pp.65-74, Petrosani, 2022.

[14]. Pasculescu, V. M., Radu, S. M., Pasculescu, D., Niculescu T., *Dimensioning the intrinsic safety barriers of electrical equipment intended to be used in potentially explosive atmospheres using the simpowersystems software package*, Papers SGEM2013/Conference Proceedings, 417- 422 pp, Vol. Science and technologies in geology, exploration and mining, Bulgaria, 2013.

[15]. Popescu F.G., Pasculescu D., Marcu M., Pasculescu V.M., Fîță N.D., Tatar A., Lazar T., *Principles of effective energy management and power control system*, Annals of the University of Petrosani, Electrical Engineering, , Vol.24, pp.111-118, Petrosani, 2022.

[16]. Popescu F.G., Păsculescu D., Păsculescu V.M., *Modern methods for analysis and reduction of current and voltage harmonics*, LAP LAMBERT Academic Publishing, ISBN 978-620-0-56941-7, pp. 233, 2020.

[17]. ATEX Directive, Directive 2014/34/EU *of the European Parliament and the Council of 26 February 2014 on the harmonization of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres, Official Journal of the European Union,* L96/309, 29.03.2014.

[18]. NEx 01-06:2007 - *On explosion prevention for the design, installation, commissioning, use, repair and maintenance of technical installations operating in potentially explosive atmospheres,* indicative NEx 01-06, 2007.

[19]. SR EN 1127-1:2019 - *Explosive atmospheres - Explosion prevention and protection. Part 1: Fundamental concepts and methodology,* ASRO, 2019.

[20]. Romanian Government Decision no. 245/2016 *on establishing the conditions for making available on the market the equipment and protection systems intended for use in potentially explosive atmospheres,* 2016.

SOME ACHIEVEMENTS CONCERNING SECURITY SYSTEMS OF PREMISES

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Abstract: Securing premises against burglary has been a concern of people throughout history. The systems have evolved from simple devices to today's sophisticated, remotely controlled systems. In this paper, we present a designed and built system that ensures alarming in case of intrusion, which presents a high degree of security with low costs and low energy consumption. We also achieved a laboratory stand for the simulation of alarming when an intrusion occur in a certain space.

Key words: security, alarm, safety.

1. INTRODUCTION

A security alarm is designed to detect intrusion which is an unauthorized entry in a certain area [4], [7].

Family and property protection and security has always been important, but as technology has evolved over the last century, the function and capability of home security systems play the same role [3], [8].

From early moat and bridge security systems to today's systems that can be monitored, managed and captured with the phone in your pocket, home security has evolved greatly with technological progress and public demand for improvements.
Today's security systems are not only the product of the evolution of technology in recent years but the foundations of smart security systems have been established generations ago [5], [9].

At the end of the First World War, as the crime rate began to rise, Americans began to be increasingly open to the need for security and were eager to find new ways to protect themselves as well as their properties. In addition, several insurance companies began offering very high discounts for those installing alarm systems in their homes and company buildings. These things led to a very high demand for alarm systems [12].

Then, the owners used the services of Door Checkers, a service that consisted of checking the doors of customers by a group of night guards to ensure that they were locked. More advanced users used an installed alarm system that used electromagnetic

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contacts mounted on doors and windows that were connected to a battery and a bell. These systems were monitored by a dispatcher who sent a guard to that house when the alarm was triggered.

An intrusion detection system (IDS) is "a device or software application that monitors a network or systems for malicious activity or policy violations" [4], [10].

An alarm system consists mainly of the following components: alarm control panel; motion, vibration, shock, gas leakage, etc. sensors, an event signaling device, auxiliary components: spare accumulators, connectors, remote control. (Fig. 1).

Fig.1. Components of an alarm system

2. SOME HISTORICAL MILESTONES CONCERNING THE ALARM SYSTEMS

The history of alarm systems begins with a British inventor named Tildesley, who devised the first model for an alarm system. The system worked by connecting a series of bells to the door lock [6], [11].

The first patented alarm system was invented by Russell Augustus Pope in 1853 in Boston, Sommerville. He designed a closed electrical circuit that was based on a loop interrupted by parallel connected contacts mounted to doors and windows that were then connected to a battery and doorbell of electromagnetic type.

The Pope prototype was acquired in 1857 and further developed by Edwin Holmes who began to produce large-scale alarm systems. Because these systems at that time were very expensive, only rich people could afford their installation.

Monitoring the alarm systems was the idea of Holmes' son, Edwin T. Holmes, who managed to link security systems to existing telegraph lines in the city so he could monitor the loops of the alarm systems at night, when telegraph lines were not used. This was the beginning of today's dispatchers.

A huge leap in technology occurred in the 1970's when the first motion detectors based on ultrasonic technology were introduced, and later in the 1980's when motion detectors based on infrared technology appeared that greatly increased their ability to detect so-called positive forgeries. During the same time, alarm systems have also improved and have become cheaper and more accessible by the general public.

3. DEVELOPED OF AN ELECTRONIC SECURITY SYSTEM USING THE DSC PC585 INTRUSION CONTROL PANEL

3.1. Components

In order to achieve a closed space security system, regarding the anti-burglary security subsystem and electronic access control, we used the following equipment [1], [2], [3]:

a) Burglary control plant (DSC PC585);

b) LED Smart Keyboard (DSC PC1555 RK);

c) Magnetic contact (CM) - an active sensor consisting of a fixed REED relay and a rigidly mounted mobile magnet on the movable side of the door;

d) PIR Microwave Detector (Paradox Vision 525D) - combines passive infrared detection with microwave detection to detect people even behind glazed surfaces;

e) Shock/vibration detector DS (VIBRO) - has built-in piezoelectric type transducer;

f) Broken glass detector DGS (Crow GBD Plus) - it works on the principle of spectral analysis of the sound produced by the shattering of the glass surface (spectrum between 1 and 5 Khz);

g) Panic button with BP retention (Seco-Larm SS-077);

h) Burglary siren with flash SE (LD-95);

i) Battery (SP5A 12V, 5Ah);

j) Transformer 220V/16V, 20VA;

k) Electromagnetic lock Fail-SafeM

l) Auxiliary power supply 12V, 2A;

m) Relay 12V d.c.

The diagram of the system we have developed for securing closed premises is shown in fig.2.

3.2. Working principle

The system is supplied by the power grid through the transformer providing the specific voltage of16 V required by control panel.

When starting, the system self-diagnoses inputs and outputs to signal their states, through the smart keyboard, after which it is in the standby state - disarmed. The system was configured to monitor inputs with double end resistors (DEOL - that is, a 5.6 kΩ resistor in series with the detector and a 5.6 kΩ resistor in parallel).

The sensors were connected to the terminals of the alarm relays by the DEOL method.

It should be noted that if the resistors are not mounted in the detector housing, (they are protected with tamper contact when opening the housing), and they will be mounted at the terminals of the plant then security is compromised because it can sabotage the alarm signal right on the cable route.

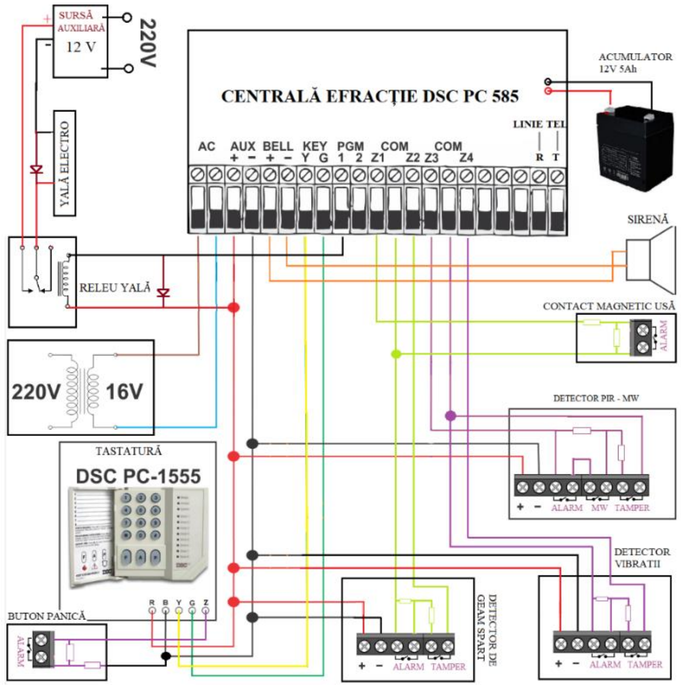

Fig. 2 Scheme of the system designed for securing premises

Inputs were programmed as follows:

- The input Z1 was programmed as Delay-type zone - timed input that gives the user the time (preset) it takes to enter the code. Not entering a valid code over the given time generates an alarm.
- Input Z2 was programmed as an Instant zone - activation of the input when the alarm system is armed causes the system to generate an alarm in the system, and, to feed, through the terminals Bell+ and Bell -, the inside siren and to open the communication relay for transmitting to the dispatcher the automatic alarm codes that distinguish the account and the type of alarm.
- Input Z3 has been programmed as an Inner zone - activation of the input when the alarm system is armed proceeds exactly like the Instant zone, less in the situations when there is a Delay-type zone that triggers before, tracking the input time. Here, the PIR-MW dual-tech detector was connected.
- Input Z4 was programmed as a 24H Seismic zone - activation of the input in any state of the system, (armed or disarmed), generates an audible alarm that sends to the dispatcher a seismic alarm signal. In this zone the VIBRO vibration detector was connected. This type of detector is mounted on each wall of the premises, including the ceiling and floor, as well as on the cash register.
- Keyboard input (Z5) has been programmed as a 24H Hold-up Panic zone - enabling input in any system state (armed or disarmed), it generates an alarm that can be silent or audible (as needed) and sends a panic signal to the dispatcher. On this zone the panic button with restraint SS-077 was connected.

✓ Scenario 1: If you try to penetrate the premises by forcing the door, then the input 1 is triggered by the magnetic contact, the control plant reads the resistance of 11.2 kΩ, and triggers the start of the input time after which, when it is over, not entering the code, the system will feed the siren and at the same time sends the alarm signal.

✓ Scenario 2: If you try to penetrate the premises by drilling the door or walls, the PIR-MW dual-tech motion detector will detect the movement and generate alarm on the 2nd input.

✓ Scenario 3: If you try to penetrate the premises by breaking a glazed surface, the broken glass detector will detect it and generate alarm on the 3rd input.

✓ Scenario 4: If attempting to break through any wall, floor or ceiling, seismic detectors detect the vibrations and trigger alarm on input 4.

✓ Scenario 5: If you attempt to rob staff in the premises, they have the silent panic button SS-077 for sending the panic signal to the dispatcher activating input 4, without the siren creating panic among the attackers.

4. LABORATORY STAND FOR THE SIMULATION OF AN ANTI-BURGLARY SECURITY SYSTEM

We have designed and achieved a laboratory stand for simulating an intrusion alarm in a space using an integrated circuit 4093 as well as magnetic and IR sensors.

Fig 3 shows the laboratory stand, also the electric diagram.

The scheme features the alarm system built on an integrated four-gate YES-NO circuit with Trigger Schmitt. In the circuit there are timing elements: resistors and capacitors, as well as an alarm siren.

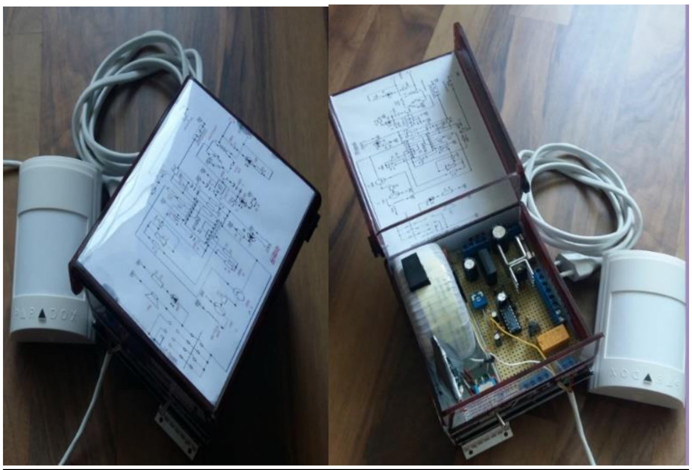

Fig.3. Laboratory stand for simulating an intrusion alarm

5. CONCLUSIONS

A burglary and access control detection and alarm system can be used in homes, commercial premises, industrial premises, etc., for the monitoring and detection of thieves, vandals and the protection of personnel against criminals.

The developed system can be part of a larger security project to which a video monitoring system can be added for increased efficiency.

The law obliges all small or large economic operators to install, by authorized personnel, a system of detection and warning of burglary as long as cash is used.

New generation security systems can be controlled using the phone or other equipment that allows interconnection with them. Using a local renewable energy source could give the system extra security.

REFERENCES

[1].Lazăr T., Marcu M.D., Uțu I., Popescu F.G., Păsculescu D., *Mașini electrice - culegere de probleme*, Editura UNIVERSITAS, Petroșani, pp.197, 2023.

[2].Păsculescu D., Uțu I., *Increasing the quality of protections for high-voltage power lines*. Publicat in Revista Calitatea, Supplement of “Quality - Access to Success” Journal, Vol.18, S1, January, pp. 234-239, 2017.

[1].Pătrăşcoiu N., *Senzori şi traductoare,* Editura Universitas, Petroşani, 2000.

[2].Popescu F.G., Slusariuc R., Utu I., Cucaila S., Stochitoiu M. D., *Study of the dependence of bending resistance in correlation to temperature of a conductive material*, International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM 18(4.1), pp. 643-650, 2018.

[3].Slusariuc R., Samoila L., Utu I., Popescu F.G., Handra A. D., *SCADA systems analysis for industrial processes,* Annals of University of Petrosani, Electrical Engineering, Vol. 21, Petroşani, pp.17-22, 2019.

[4].Stochitoiu M.D., Marcu M., Utu I., Niculescu T., Popescu F.G., *Modern concepts and its application for energetically security requirement at different connected sources*. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM Volume 18, Issue 2.1, pp. 591 – 596, 2018.

[5].Utu I., Marcu M., Niculescu T., Popescu F.G., Slusariuc R., *The use of semiconductor materials in the construction of modern equipment for adjustable drive of power equipment from a lignite open pit*. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM Volume 18, Issue 2.1, pp.805 – 812, 2018.

[6].Utu I., Marcu M., Popescu F.G., Stochitoiu M. D., Rada A.C., *Determination of the optimum operating regime for two power transformers 35 / 6,3 kV,* Annals of University of Petrosani, Electrical Engineering, Vol. 22, pp.71-76, Petroşani, 2020.

[7].Uţu I., Păsculescu D., *Power Quality Study in Order to Comply with European Norms*. Publicat in Revista Calitatea, Supplement of “Quality - Access to Success” Journal, Vol.18, S1, January, pp. 366-371, 2017.

[8].Samoilă L., Uțu I., *Senzori și traductoare – Principii de funcționare*, Editura Univeristas, Petroșani 2010.

[9].Pearson R., *Electronic Security Systems***,** Butterworth-Heinemann Publishing House, Oxford, 2006.

[10]. https://en.wikipedia.org/wiki/Intrusion_detection_system

[11]. https://vistodoorbell.com/the-evolution-of-home-security/

[12]. https://www.abus.com/eng/Guide/Break-in-protection/Alarm-systems/History-of-the-alarm-system

STUDY OF SIMPLE REACTIVE SERIES CIRCUITS USING MATLAB SOFTWARE PACKAGE

TITU NICULESCU [1]

Abstract: This paper presents a modern method for approaching the electrical circuits using the MATLAB-SIMULINK package programs. The simple series circuits which are switched on a DC voltage at the initial moment are presented below. We can determine the current variation forms and the reactive elements voltage, by using this virtual medium. Each presented case contains an analytical presentation of the problem, but it also contains electrical diagrams of electrical parameters. The diagrams were obtained by different methods which use this programs package.

Key words: Simulink, simulation model, differential equation, diagrams, SimPowerSystems.

1. INDUCTIVE SERIES CIRCUITS

We will consider the RL series circuit with concentrated parameters from. At the initial moment, the k circuit switcher is closed and we intend to study the behavior and variation of circuit electrical parameters after connection [4], [7].

The differential equation which corresponds to the transitory regime immediately after closing is the following:

$$Ri + L\frac{di}{dt} = E \tag{1}$$

The current expression through the circuit after closing is the solution of the differential equation of the circuit (1).

$$i(t) = \frac{E}{R}(1\text{-}e^{-\frac{t}{T}}) \tag{2}$$

where:

$$T = \frac{L}{R} \tag{3}$$

and it represents the time constant of the circuit.

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The voltage expression on the coil after connection is:

$$u(t) = L\frac{di}{dt} = E \quad e^{\frac{t}{T}} \tag{4}$$

1.1. SIMULINK model of the circuit

The SIMULINK model of the circuit after closing was done on grounds of equation (1) where the derivative of the current was separated.

$$\frac{di}{dt} = \frac{1}{L}(E - Ri) \tag{5}$$

The SIMULINK model obtained in this way is shown in Fig.1 and was created in order to allow the drawing of the current diagrams through the circuit and the voltage on the coil, for different values of the R resistance and the E D.C. voltage.

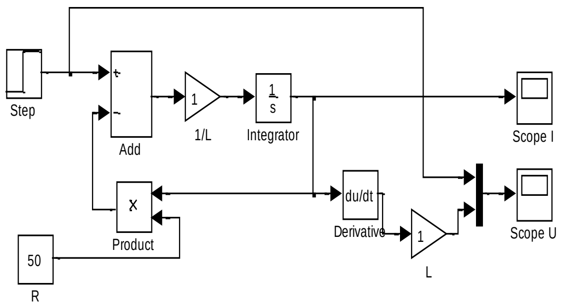

Fig.1. SIMULINK model of the inductive circuit at closing

The k switcher is realized using a voltage step signal which is applied at the terminal of the circuit, to simulate the closing of the k switcher [2].

We will obtain the diagrams from Fig.2 and Fig.3.

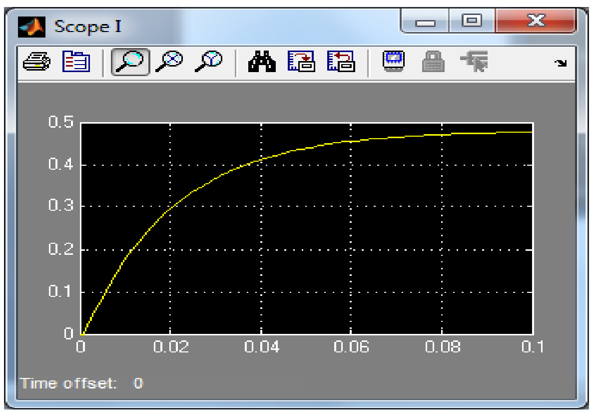

Fig.2. Voltage variation of the coil after closing

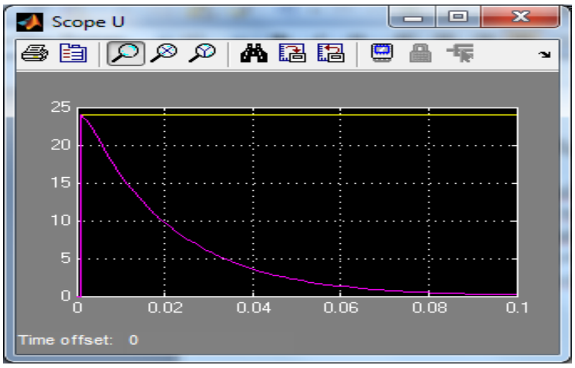

Fig.3. Current variation in the circuit

2. STUDY OF THE CAPACITIVE SERIES CIRCUITS

We will consider the RC series circuit with concentrated parameters. At the initial moment, the k circuit switcher is closed and we want to study the current variation through the circuit and the capacitor voltage variation, after connection.

The integral equation which corresponds to the transitory regime immediately after closing is given by:

$$Ri + \frac{1}{C}\int idt = E \quad (6)$$

Equation (6) is equivalent with differential equation:

$$RC\frac{du}{dt} + u = E \quad (7)$$

The expression of the capacitor voltage after closing is the solution of differential equation (7):

$$u(t) = E(1 - e^{\frac{t}{T}}) \quad (8)$$

where $T = RC$, represents the time constant of the circuit.

The circuit current after closing is given by:

$$i = C\frac{du}{dt} = \frac{E}{R}e^{\frac{t}{T}} \quad (9)$$

2.1 SIMULINK model of the circuit

The SIMULINK model of the circuit after closing was done on grounds of equation (7) where the voltage derivative was separated.

$$\frac{du}{dt} = \frac{1}{RC}(E - u) \qquad (10)$$

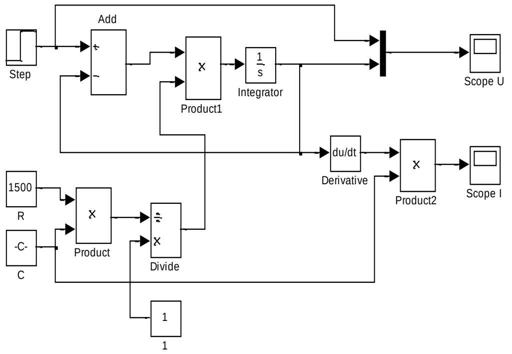

Fig.4. SIMULINK model of the RC circuit at closing

The k switcher is realized using the same voltage step signal which is applied at the terminal of the circuit, to simulate the closing of the k switcher.

The Simulink model from Fig.4 creates the diagrams from Fig.5 and Fig.6.

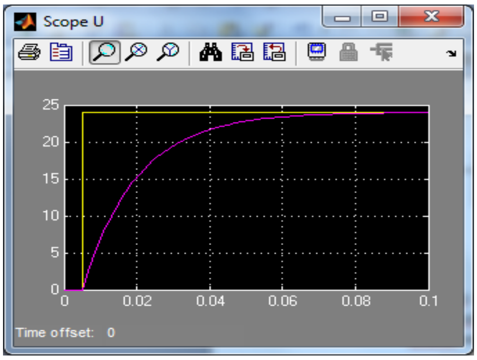

Fig.5. Capacitor voltage variation

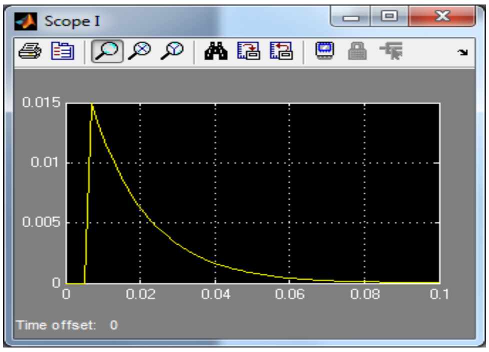

Fig.6. Current variation after closing

3. STUDY OF REACTIVE SERIES CIRCUITS

We will consider the RLC series circuit with concentrated parameters. At the initial moment, the k circuit switcher is closed and we intend to study the behavior and variation of circuit electrical parameters after connection [3], [5-6].

The integral-differential equation which corresponds to the transitory regime of the considered circuit is the following:

$$Ri + L\frac{di}{dt} + \frac{1}{C}\int idt = E \tag{11}$$

or:

$$LC\frac{d^2u}{dt^2} + RC\frac{du}{dt} + u = E \tag{12}$$

The following notations are made:

$$\delta = \frac{R}{2L} \tag{13}$$

The circuit amortization:

$$\omega_0 = \frac{1}{\sqrt{LC}} \tag{14}$$

The circuit personal pulsation.

$$\omega = \sqrt{\delta^2 - \omega_0^2} \tag{15}$$

We will consider the situation when $\delta > \omega_0$ or $R < 2\sqrt{L/C}$, which will be checked by the resistor in the circuit.

Consequently, the solving of the differential equation gives the following solutions:

$$u(t) = E\left[[1 - \frac{1}{2\sqrt{\delta^2 - \omega_0^2}}(r_1 e^{r_2 t} - r_2 e^{r_1 t})]\right] \tag{16}$$

$$i(t) = \frac{E}{2L\sqrt{\delta^2 - \omega_0^2}}\left(e^{r_1 t} - e^{r_2 t}\right) \tag{17}$$

where r1 and r2 are the roots of the characteristic equation:

$$\begin{aligned} r_1 &= -\delta + \omega \\ r_2 &= -\delta - \omega \end{aligned} \tag{18}$$

We will consider the situation when $\delta < \omega_0$ or $R < 2\sqrt{L/C}$. The following notation was made:

$$\omega_0^2 - \delta^2 = \omega'^2 \tag{19}$$

Consequently, the solving of the differential equation gives the following solutions:

$$u(t) = E\left[[1 - \frac{\omega_0}{\omega'} \bullet e^{-\delta t} \bullet \sin(\omega' t + \beta')]\right] \tag{20}$$

$$i(t) = \frac{E}{\omega' L} e^{-\delta t} \sin \omega' t \tag{21}$$

where: $$\beta' = \arccos \frac{\delta}{\omega_0} \tag{22}$$

3.1 SIMULINK model of the circuit

The SIMULINK model of the circuit after closing was done on grounds of the second order differential equation (12), which is put in the form (23) where the higher order derivative is separated:

$$\frac{d^2u}{dt} = \frac{1}{LC}\left[[E - RC\frac{du}{dt} - u]\right] \tag{23}$$

The SIMULINK model from Fig.7 generates the voltage capacitor and the current through the circuit during the transitory regime. To this purpose, two values of the R resistor are considered, which correspond to two important regimes:

- Aperiodic regime;
- Oscillatory regime.

For each regime the capacitor voltage and the circuit current variation diagrams are plotted.

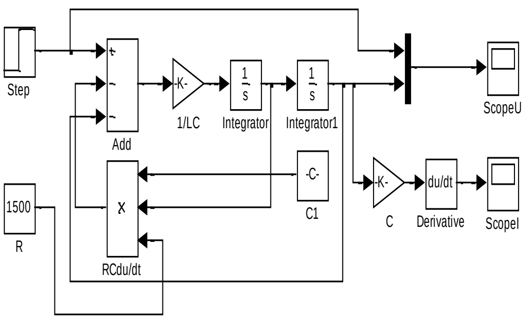

Fig.7. SIMULINK model of the circuit

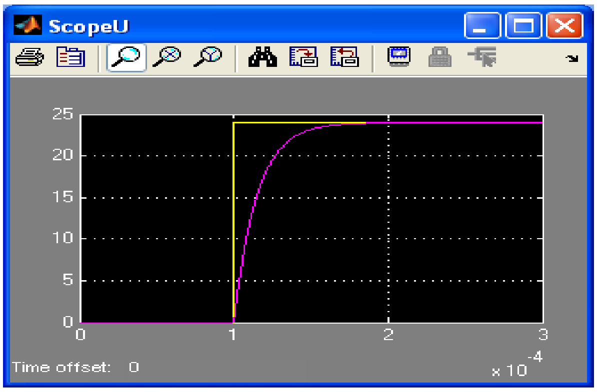

Fig.8. Voltage variation of capacitor in the a-periodic mode

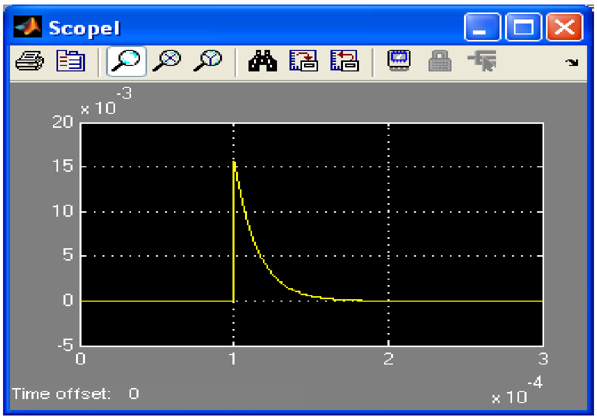

Fig.9. Current variation in the a- periodic mod

The SIMULINK model from Fig.7 lids to obtain the following MATLAB diagrams, Fig. 8, Fig.9 according to the equations (16) and (17) for a-periodic mode, and Fig.10, Fig.11 according to the equations (20) and (21) for oscillating mode [1].

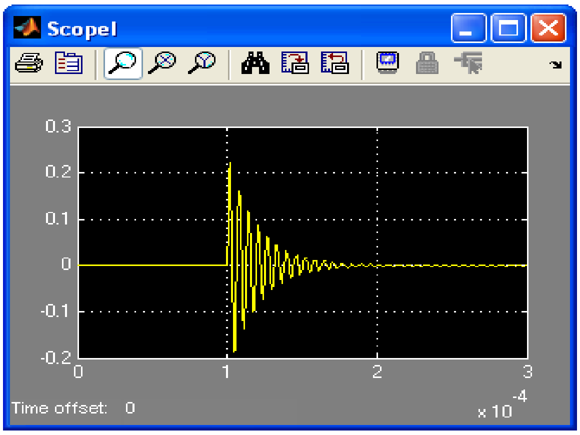

Fig.10. Voltage variation of capacitor in the oscillating regime

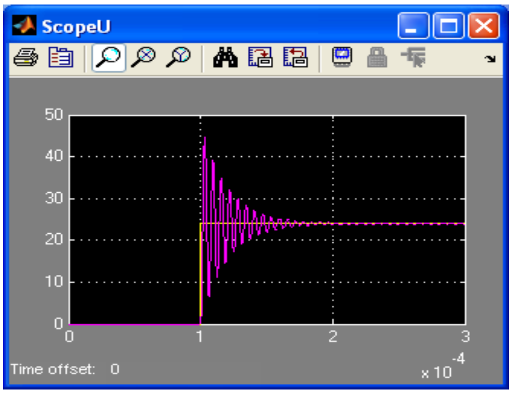

Fig.11. Current variation in the oscillating regime

The k switcher is realized by using a voltage step signal which is applied at the terminal of the circuit, to simulate the closing of the k switcher. Changing the value of resistance, automatically leads to the updating of the voltage and current charts

4. CONCLUSIONS

An important conclusion of this paper is that the study can be extended to some more complex circuits and these can be studied with this modern method which involves the use of virtual medium.

In order to realize the simulating model which integrates the differential equations, the basic idea is to separate in the left member of equation, the higher order derivative. The analytical expressions obtained in the right member of the equation underlie the achievement of the simulating model by means of specific blocks of the virtual medium. In the case of complex circuits, the simulating model is conceived on a differential equations system.

REFERENCES

[1]. Esfandiari R. S., *Numerical Methods for Engineers and Scientists Using MATLAB*, Publisher CRC Press, 2013.

[2]. Niculescu T., Pasculescu D., Pana L., *Study of the operating states of intrinsic safety barriers of the electric equipment intended for use in atmospheres with explosion hazard*, WSEAS Transactions on Circuits and Systems, Volume 9, pp.430-439, 2010.

[3]. Niculescu T., *Study of inductive-capacitive circuits using the Simulink software package*, ISBN 978-953-51-0635-7, Hard cover, Publisher InTech, Published: May 23, 2012.

[4]. Niculescu T., *Study of transient phenomena using NI-USB data acquisition systems in Matlab Simulink medium on 64 bit operating systems*, Journal of Advanced Computer Sciense & Technology, pp.198-203, 2015.

[5]. Rahimo M., Kopta A., Schlapbach U., Vobecky J., Schnell R., Klaka S., *The Bi-mode Insulated Gate Transistor (BiGT) A potential technology for higher power applications* Proc. ISPSD09, June, 2009.

[6]. Tudorache T., *Medii de calcul in ingineria electrica MATLAB*, Editura MatrixRom, Bucuresti, 2006.

[7]. Tyagi A. K., *MATLAB and SIMULINK for Engineers*. Publisher OUP India, 2011.

ASPECTS REGARDING THE USAGE OF APPROPRIATE ELECTRICAL EQUIPMENT IN POTENTIALLY EXPLOSIVE ATMOSPHERES GENERATED BY HYDROGEN

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Abstract: Evaluation of explosion-proof protected electrical equipment in scope of certification is extremely important considering the risk of explosion that has to be minimized in order to ensure life safety and health of workers and to prevent damaging of property and the environment, as well as free movement of goods when they meet the essential safety requirements at European level.

Electrical equipment that operates in potentially explosive atmosphere, have characteristics specially designed for operation in this area. For security reasons, it is essential that the integrity of these special features be preserved in these areas throughout the life of the installation.

Using electric equipment in potentially explosive atmospheres brings forward several particularities therefore the problems that appear during the design, construction and operation of electrical devices and installations brings forward numerous difficulties, their approach requiring special attention considering all the technical, economical and labor safety aspects.

The purpose of the paper is to reveal the importance of using appropriate electrical equipment design to be used in potentially explosive atmospheres generated by hydrogen.

Key words: electric equipment, explosive atmosphere, hydrogen.

1. INTRODUCTION

The use, production, processing and storage of petroleum products and gases generate hazardous atmospheres that can be ignited and generate explosions, causing serious damage both to materials and the environment, and especially to human health and integrity. The use of equipment in this environment requires compliance with

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certain well-defined parameters, which must be chosen in correlation with the potentially explosive atmosphere in which it is to be installed and the type of protection, temperature class and category of equipment [3], [6].

The risk of explosion may appear in all the fields of activity in which flammable substances are involved, such as gases, vapours, dusts, mists, which mixed with air may result in potentially explosive atmospheres [6], [2].

In order to increase the occupational health and safety level in potentially explosive atmospheres generated by flammable gases or explosive dusts we have to prevent the ignition of explosive atmospheres. In order to do this the electrical equipment used in such areas must be made with different types of protection so that it can not ignite the explosive mixture surrounding it [2], [11].

The type of protection means the specific measures applied to electrical equipment to avoid ignition of a surrounding explosive atmosphere [1], [12].

2. POTENTIALLY EXPLOSIVE ATMOSPHERES

Explosive atmospheres are defined as a mixture with air, under atmospheric conditions, of flammable substances in the form of flammable gases, mist vapors or combustible dusts, in which, after ignition, combustion is spread throughout the unburned mixture. To generate an explosive atmosphere, the flammable substance must be present in certain concentrations, between the Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL). Explosion limits of the substance may depend on pressure, oxygen concentration in the air and temperature. The mechanism of an explosion generated by a mixture of flammable gas, vapor or mist with air can be expressed by the well-known explosion triangle shown in Figure 1. Thus, the occurrence of an explosion is conditioned by the simultaneous presence of the following three factors:

1. fuel (flammable gases, vapours, mists);
2. oxygen (oxygen, oxidizing substances);
3. efficient ignition source for ensuring the activation of molecules in order to ignite and propagate the fast combustion reaction [4], [13].

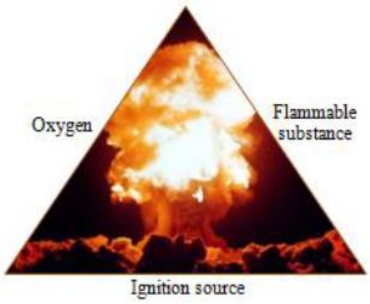

Fig.1. The explosion triangle

Ignition sources can be hot surfaces, sparks, short circuit, static energy, electric arcs, etc.

Directive 2014/34/EU defines several types of groups and categories of electrical equipment (EU Directive, 2014):

Equipment Group I: equipment used for underground mines and for parts of the installations located at the surface of these mines, susceptible to firedamp and/or combustible powders.

Equipment Group II: equipment intended to be used in explosive atmospheres, other than the ones in Group I.

New standards in the field divided Group II of non-mining equipment into Group II for gases, vapours and mists and Group III for flammable powders in air. These standards have also introduced the EPL (Equipment Protection Level) concept: Ga, Gb, Gc for gases and Da, Db, Dc for equipment intended to be used in potentially explosive atmospheres generated by flammable dusts in air, equivalent to categories 0,1,2.

Therefore, a new classification in groups and categories arises:

Gr I mining

Gr II (A, B, C) surface gases

Gr III (A, B, C) dusts

Table. 1. ***Correlation between the equipment category, the equipment EPL and corresponding area***

EPL	**Equipment group**	**Equipment Category (ATEX)**	**Zone**
Ga	II	1G	0
Gb		2G	1
Gc		3G	2

The ignition temperature of potentially explosive substances is another very important aspect in the choice of equipment in the installation. The temperature classes for equipment (maximum temperature), given in table 2, a must be below the ignition temperature of the substance in which it operates [3], [10].

Table. 2. ***The relationship between the gas or vapor ignition temperature and the temperature class of the equipment***

Temperature class required by zone classification	**Ignition temperature of gas or vapor (°C)**	**Allowed temperature classes for the equipment**
T1	450	T1 – T6
T2	300	T2 – T6
T3	200	T3 – T6
T4	135	T4 – T6
T5	100	T5 – T6
T6	85	T6

3. ELECTRICAL EQUIPMENT IN POTENTIALLY EXPLOSIVE ATMOSPHERES GENERATED BY HYDROGEN

Like any flammable fuel, hydrogen can combust. But hydrogen's buoyancy, diffusivity and small molecular size make it difficult to contain and create a combustible situation. In order for a hydrogen fire to occur, an adequate concentration of hydrogen, the presence of an ignition source and the right amount of oxidizer (like oxygen) must be present at the same time. Hydrogen has a wide flammability range (4-74% in air) and the energy required to ignite hydrogen (0.02mJ) can be very low. However, at low concentrations (below 10%) the energy required to ignite hydrogen is high--similar to the energy required to ignite natural gas and gasoline in their respective flammability ranges--making hydrogen realistically more difficult to ignite near the lower flammability limit. On the other hand, if conditions exist where the hydrogen concentration increased toward the stoichiometric (most easily ignited) mixture of 29% hydrogen (in air), the ignition energy drops to about one fifteenth of that required to ignite natural gas (or one tenth for gasoline) [4], [7].

Hydrogen is a gas of the IIC group and belongs to the temperature class T1, which makes it one of the hottest and most dangerous gases.

The most used electrical equipment in potentially explosive atmosphere is made with type of protection flameproof enclosure and type of protection increased safety [1], [14].

Flameproof enclosure “d”, is an enclosure in which the parts which can ignite an explosive gas atmosphere are placed and which can withstand the pressure developed during an internal explosion of an explosive mixture, and which prevents the transmission of the explosion to the explosive gas atmosphere surrounding the enclosure. In case of increased safety concept additional measures are applied to increase the level of safety, thus preventing the possibility of high temperatures and the occurrence of sparks or electric arcs within the enclosure or on exposed parts of electrical equipment [5], [8].

According to specific standards for electrical equipment with flameproof enclosure type of protection, for each group of explosion there is minimum width of joint and maximum gap for enclosures as shown in table 3 ant table 4.

Table. 3. ***Minimum width of joint and maximum gap for enclosures of Groups I, IIA and IIB***

Type of joint		Minimum width of joint L mm	Maximum gap mm														
			For a volume cm³ $V \leq 100$			For a volume cm³ $100 < V \leq 500$			For a volume cm³ $500 < V \leq 2\,000$			For a volume cm³ $2\,000 < V \leq 5\,750$			For a volume cm³ $V > 5\,750$		
			I	IIA	IIB	I	IIA	IIB	I	IIA	IIB	I	IIA	IIB	I	IIA	IIB
Flanged, cylindrical or spigot joints		6	0,30	0,30	0,20	–	–	–	–	–	–	–	–	–	–	–	–
		9,5	0,35	0,30	0,20	0,35	0,30	0,20	0,08	0,08	0,08	–	0,08	0,08	–	0,08	–
		12,5	0,40	0,30	0,20	0,40	0,30	0,20	0,40	0,30	0,20	0,40	0,20	0,15	0,40	0,20	0,15
		25	0,50	0,40	0,20	0,50	0,40	0,20	0,50	0,40	0,20	0,50	0,40	0,20	0,50	0,40	0,20
Cylindrical joints for shaft glands of rotating electrical machines with:	Sleeve bearings	6	0,30	0,30	0,20	–	–	–	–	–	–	–	–	–	–	–	–
		9,5	0,35	0,30	0,20	0,35	0,30	0,20	–	–	–	–	–	–	–	–	–
		12,5	0,40	0,35	0,25	0,40	0,30	0,20	0,40	0,30	0,20	0,40	0,20	–	0,40	0,20	–
		25	0,50	0,40	0,30	0,50	0,40	0,25	0,50	0,40	0,25	0,50	0,40	0,20	0,50	0,40	0,20
		40	0,60	0,50	0,40	0,60	0,50	0,30	0,60	0,50	0,30	0,60	0,50	0,25	0,60	0,50	0,25
	Rolling-element bearings	6	0,45	0,45	0,30	–	–	–	–	–	–	–	–	–	–	–	–
		9,5	0,50	0,45	0,35	0,50	0,40	0,25	–	–	–	–	–	–	–	–	–
		12,5	0,60	0,50	0,40	0,60	0,45	0,30	0,60	0,45	0,30	0,60	0,30	0,20	0,60	0,30	0,20
		25	0,75	0,60	0,45	0,75	0,60	0,40	0,75	0,60	0,40	0,75	0,60	0,30	0,75	0,60	0,30
		40	0,80	0,75	0,60	0,80	0,75	0,45	0,80	0,75	0,45	0,80	0,75	0,40	0,80	0,75	0,40

Table. 4. ***Minimum width of joint and maximum gap for Group IIC enclosures***

Type of joint		Minimum width of joint L mm	Maximum gap mm			
			For a volume cm³ $V \le 100$	For a volume cm³ $100 < V \le 500$	For a volume cm³ $500 < V \le 2\,000$	For a volume cm³ $V > 2\,000$
Flanged joints[a]		6	0,10	–	–	–
		9,5	0,10	0,10	–	–
		15,8	0,10	0,10	0,04	–
		25	0,10	0,10	0,04	0,04
Spigot joints (Figure 2a)	$c \ge 6$ mm	12,5	0,15	0,15	0,15	–
	$d \ge 0,5\ L$	25	0,18[b]	0,18[b]	0,18[b]	0,18[b]
	$L = c + d$	40	0,20[c]	0,20[c]	0,20[c]	0,20[c]
	$f \le 1$ mm					
Cylindrical joints Spigot joints (Figure 2b)		6	0,10	–	–	–
		9,5	0,10	0,10	–	–
		12,5	0,15	0,15	0,15	–
		25	0,15	0,15	0,15	0,15
		40	0,20	0,20	0,20	0,20
Cylindrical joints for shaft glands of rotating electrical machines with rolling element bearings		6	0,15	–	–	–
		9,5	0,15	0,15	–	–
		12,5	0,25	0,25	0,25	–
		25	0,25	0,25	0,25	0,25
		40	0,30	0,30	0,30	0,30

4. CONCLUSIONS

The process of selecting electrical equipment for use in areas with potentially explosive atmospheres, generated by mixtures of air and oil, flammable gases or vapours, requires in-depth knowledge in this field.

This paper aims to increase safety in the choice of equipment used in potentially explosive environments, helping users who have no knowledge in this field but are determining factors in their purchase or use.

Hydrogen mixed with air gives rise to one of the most dangerous explosive mixtures, because it has a very low ignition energy and a very high explosion pressure. At the global level, there is a great emphasis on the use of hydrogen as a fuel, both in the automotive industry and in other industries, and that is why it is important that the users of electrical installations that produce, store and use hydrogen, know very well the dangers generated by this gas.

Electrical equipment that operates in potentially explosive environments generated by hydrogen must be certified to be used in potentially explosive atmospheres included in subgroup IIC of gases or be certified for subgroup IIB+H2. If the equipment is included in other gas subgroups, they cannot be used in potentially explosive atmospheres generated by hydrogen.

For the proper functioning of electrical equipment used in potentially explosive atmosphere, the inspection, maintenance and proper repair of these is of great importance. These things must be done by personnel who know the principles of the types of protection, and also to have the necessary infrastructure for a proper repair.

This process takes time and to increase its quality and to facilitate the correct selection of electrical equipment intended for use in such atmospheres, an application has been developed to be a useful tool for personnel working in the industries that process, store or carries flammable substances.

The application presented in the paper provides technical staff with an easy-to-use, intuitive, fast and reliable tool for selecting explosion-proof electrical equipment. The equipment is selected in accordance with the safety and explosion protection in force and brings with it an increase in the level of health and safety at work in industries with potentially explosive atmospheres.

REFERENCES

[1]. Fîță N.D, Radu S.M., Pasculescu D., *Ensuring, controlling and stability of energy security in the context of increasing industrial and national security*–Academic Compendium, 2021.

[2]. Fîță N.D., Radu S.M., Pasculescu D., *National security–Energy sector optimization element*s, Chisinau, Republic and Moldova: GlobeEdit Publisher, 2021.

[3]. Niculescu T., Pasculescu D., Pasculescu V.M., Stoica I.O., *Evaluation of electrical parameters of intrinsic safety barriers of the electrical equipment intended to be used in atmospheres with explosion hazard*, 14th International Multidisciplinary Scientific Geoconference SGEM 2014, Albena, Bulgaria, 17-26 June, 169-176, 2014.

[4]. Pasculescu D., Niculescu T., Pana L., *Uses of Matlab Software to size intrinsic safety barriers of the electric equipment intended for use in atmospheres with explosion hazard*", EEETE, Bucharest, Romania, Aprilie 20-22, pag. 17-21, 2010.

[5].Handra A.D., Popescu F.G., Păsculescu D., *Utilizarea energiei electrice - lucrări de laborator*, Editura Universitas, Petroşani, 167 pag., 2020.

[6].Niculescu T., Pasculescu D., Pana L., *Study of the operating states of intrinsic safety barriers of the electric equipment intended for use in atmospheres with explosion hazard*, WSEAS Transactions on Circuits and Systems, Volume 9, pp.430-439, 2010.

[7].Pasculescu D., Romanescu A., Pasculescu V., Tatar A., Fotau I., Vajai Ghe., *Presentation and simulation of a modern distance protection from national energy system*, Proceedings of the 10 th International Conference on Environment and Electrical Engineering – EEEIC 2011, Rome, Italy, pp. 646-650, 2011.

[8].Pasculescu D., Slusariuc R., Popescu F.G., Fîță N.D., Tatar A., Lazar T., *Modeling and simulation of lighting of a road with 2 strips per direction to en 13201: 2015 Standard*, Annals of the University of Petrosani, Electrical Engineering, Vol.24, pp.65-74, Petrosani, 2022.

[9].Pasculescu, V. M., Radu, S. M., Pasculescu, D., Niculescu T., *Dimensioning the intrinsic safety barriers of electrical equipment intended to be used in potentially explosive atmospheres using the simpowersystems software package*, Papers SGEM2013/Conference Proceedings, 417- 422 pp, Vol. Science and technologies in geology, exploration and mining, Bulgaria, 2013.

[10]. Popescu F.G., Pasculescu D., Marcu M., Pasculescu V.M., Fîță N.D., Tatar A., Lazar T., *Principles of effective energy management and power control system*, Annals of the University of Petrosani, Electrical Engineering, , Vol.24, pp.111-118, Petrosani, 2022.

[11]. Popescu F.G., Păsculescu D., Păsculescu V.M., Modern methods for analysis and reduction of current and voltage harmonics, LAP LAMBERT Academic Publishing, ISBN 978-620-0-56941-7, pp. 233, 2020.

[12]. ATEX Directive, *Equipment for potentially explosive atmospheres (ATEX)*, available https://ec.europa.eu/growth/sectors/mechanical-engineering/atex_en, 2014.

[13]. Standard (SR) EN 60079-0 - *Explosive atmospheres - Part 0: Equipment - General requirements.*

[14]. Standard (SR) EN 60079-1 - *Explosive atmospheres - Part 1: Equipment protection by flameproof enclosure "d"*, 2015.

THE IDENTIFICATION AND APPLICATION OF SOLUTIONS TO INCREASE ENERGY EFFICIENCY IN AN AGRO-FOOD MARKET

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Abstract: The modernization and reconfiguration of the interior commercial of the agro-food hall in the Central Market of Petroșani, aiming to align with European regulations, increase the number of traders and a better sectorization of the market, have led to a continuous increase in electricity consumption. In order to stop this growth and to keep the dynamic of electricity consumption on a downward slope, in the past years a number of organizational and technical solutions have been implemented, which have led to a reduction of own electricity consumption by approximately 74%.

Keywords: installed power, demand coefficient, neutral power factor, energy balance.

1. INTRODUCTION

The development and analysis of electrical energy balances is a scientific method for assesing the energy-economic efficiency of technological processes, in order to improve the yelds of energy-consuming machines, raising the technical-economic level of their exploitation and perfecting the energy supply schemes for energy consumers [15], [18]. Balance sheets can be prepared for industrial installations, for lighting installations or for installations of administrative and residential buildings [11], [27]. One of the criteria for differentiating the balance sheets is the volume of the installation they refer to. In this sense, the notion of the balance outline is defined as the conventional surface that includes the limits of the installation against which the inputs and outputs of energy are considered [4], [19].

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Within the power balances, the basic information concerns the quantities related to the consumption of electricity and the conditions in which in takes place. It is therefore necessary that, depending on the configuration of the distribution installation, there is the posibility of measuring different electric parameters such as: active and reactive energy, voltages, currents, powers and especially maximum active powers, and for these, the proper measuring instruments should be provided [9]. The minimum list of parameters to be measured consists of active energies, reactive energies and voltages at certain points [13], [20].

If the balances are drawn up for a day, the variation of the parameters can be observed hourly, as the energies and voltages values can be read after each hour. In this way, determining the average powers, the active and reactive load curves can be drawn for each day which is set to perform the measurements. With these curves, a series of useful values and indicators can be determined such as: maximum / minimum / average powers, power factor, duration of instalation's functioning at maximum powers.

Electric lighting can be the subject of a separate balance sheet, in order to know the operating regimes of instalations that use lighting fixtures with gas discharges, measurements of active and reactive energy are performed in order to be able to draw the load curves and determine the power factor [1], [21].

2. PRESENTATION OF THE AGRO- FOOD HALL

Public Service Market Administration P.S.M.A. (or S.P.A.P. in Romanian) in Petroșani is a public institution that administrates the three agro-food markets located in the municipality of Petroșani. Of these, the Central Market is the largest, comprising an agro-food hall, a sector for the sale of fruits, vegetables and cereals, a sector for sale of non-food and industrial products and a parking lot.

The biggest consumer of electricity in the Central Market is the agro-food hall, which includes: administration offices and the sanitary group; two batteries of booths for selling meet, cheese, dairy and honey, located on the hall's ground level, on the eastern, respectively western side; two batteries of kiosks for selling non-food products, located at the two mezzanines; a platform with tables for selling fruits, vegetables and cereals, located in the central zone of the ground level.

A mechanical maintenance workshop can be found at the basement of the agro-hall, on the northern side.

3. THE PRE-EXISTING SITUATION

Between 2002-2013, the electricity consumption of the agro-food hall within the Central Market marked a significant increase compared to the period before 2002, an increase which had its main cause the appearance of new consumption points (new batteries of booths and kiosks built inside the hall, expansion of the Administration offices, expansion and reconfiguration of lighting instalations).

In addition to the electrical equipments necessary for carrying out commercial activities (mainly refrigeration equipments), the Administration's offices were heated during the winter with electrical radiators and convectors. In this way, the daily electricity consumption during the winter reached values of 3-400 kWh, making electricity bills to represent approximately 20% of the Administration’s total budget, which was totally unacceptable.

Back in 2013, the installed active powers of the facilities connected in the three-phase connection of the agro-food hall were those shown in table 1.

Table 1. ***The installed active powers of the electrical installation connected to the general power supply of the agro- food hall back in 2013***

No.	**Electrical Facilities**	**Installed Active Power (kWh)**
1	General lighting installations in common spaces and circulation paths in the agro- food hall	3,5
2	Electrical installations for lighting and power in 28 commercial booths	28
3	Electrical instalations for lighting and power in administrative spaces and for other purposes outside of commercial activities (Administration offices, mechanical maintenance workshop, toilets)	21,6
TOTAL INSTALLED ACTIVE POWER		53,1

Since there are no recorded data from that period regarding the operate regime of the electrical equipments and their simultaneity and demand coefficients can’t be determined, we can’t know precisely what was the average power absorbed instantaneously, but if we bear in mind that the maximum instantaneous power approved by contract is 30 kW, we can assume that this power was not exceeded at any time, since no overload tripping of the principal circuit breaker was reported. At the same time, the values of the power factor (cos φ) aren’t known and it’s not possible to estimate the consumption of inductive reactive energy [14], [22], [28].

4. ENERGY CONSUMPTION EFFICIENCY MEASURES

In the context of the situation already presented and given the fact that the price of electricity has continuosly increased, the need to find effective solutions to reduce electricity bills has become more and more important [6], [23]. The first solution was implemented at the beginning of 2014, through the purchase and installation of a centralized natural gas heating system for the area of the Administration offices and the sanitary group. In this way, the total installed active power decreased by approximately 10 kW.

In the summer of 2015, a number of 22 booths out of the 28 for agricultural producers were disconnected from the common three-phase electrical column which was connected to the Administration’s own electrical connection and were connected directly to the network of the local distribution operator *E-Distribuție Banat* through individual electrical connections [5], [25]. In this way, the producers using the booths pay for their own electricity consumption and the total installed active power of the market’s electrical connection decreased by another 22 kW.

Between 2018-2022, all the lighting fixtures installed on the common circulation paths, as well as those in the Administration's offices, mechanical maintenance workshop and toilets were modernized by replacing the classic electric bulbs and fluorescent tubes with bulb-type LED and LED tubes [4], [24]. In this way, the total installed active power has decreased by another 2 kW and at the end of 2022 the situation of installed active powers was as shown in table 2.

Table 2. ***The installed active powers of the electrical installation connected to the general power supply of the agro- food hall at the end of 2022***

No.	Electrical Facilities	Installed Active Power (kWh)
1	General lighting installations in common spaces and circulation paths in the agro- food hall	1,5
2	Electrical installations for lighting and power in 6 commercial booths	6
3	Electrical instalations for lighting and power in administrative spaces and for other purposes outside of commercial activities (Administration offices, mechanical maintenance workshop, toilets)	11,6
TOTAL INSTALLED ACTIVE POWER		13,7

The most recent measure undertaken to reduce electricity consumption was implemented in the fall of 2022 and aimed at reducing the demand coefficient in the electricity supply of lighting. Thus, the manual control of the lamp lines mounted on the common traffic paths was abandoned and an automatic control system was implemented by means of an hourly switch and a twilight switch. In this way, the switching on and off of the lamps is done according to an algorithm based on a combination of the level of the external natural lighting and the operating hours of the agro-food hall, independently of the human factor [7],[8].

5. RESULTS OBTAINED. PREPARATION OF THE ELECTRICAL ENERGY BALANCE

As can be seen by comparing the data in tables 1 and 2, the measures implemented and mentioned above led to a decrease of approximately 74% of the total installed active power on the three-phase connection of the agro-food hall. In order to have further confirmation of the effectiveness of these measures, we wanted to see if the efficiency of the use of electricity also improved with the decrease in consumption. For this, it was necessary to draw up an energy balance [2],[10]. The detailed outline of the balance included the following electrical installations:

- The electrical installation for lighting and power in the Administration's offices;
- The electrical installations for lighting and power for refrigerators, scales and cash registers in 6 commercial booths;
- The electrical installations for lighting and power in the mechanical maintenance workshop;

- The electrical installations for lighting on the main circulation paths of the agro-food hall;
- The electrical installations for lighting in the toilet rooms;
- The electrical security lighting installation for emergency evacuation, with light-blocks powered by local batteries.

Receptors consuming electricity consist of: electronic equipments (office-computers, faxes and printers- cash registers, electronic scales); different electrical tools; electrical appliances for refrigerating and heating; LED lighting fixtures.

a) b)

Fig.1. a) Digital meter CST 0410L D; b) Digital multimeter BENNING MM 1-1

Electricity is supplied from the transformer station belonging to *E-Distribuție Banat*, through a cable type ACYABY 3x50 mm^2 + 25 mm^2, about 20 m long. The cable is mounted on non-combustible building structures. The installed power aproved by the contract is P_i=30 kW. The measurement of the consumed energy is done at the connection point by means of a three-phase electronic meter CST 0410L D (fig. 1a), which allows succesive reading of 3 quadrants [16]:

- Installed power $\boldsymbol{P_i}$;
- Total active energy $\boldsymbol{E_a}$;
- Total reactive energy $\boldsymbol{E_r}$.

Apart from these parameters measured directly by the CST 0410L D meter, for drawing up the balance it is also necessary to measure the line voltage $\boldsymbol{U_l}$ and then to determine the instantaneous absorbed current (the demanded current) $\boldsymbol{I_c}$ at the connection point. For voltage measurements we used a BENNING MM 1-1 digital multimeter (fig. 1 b) [17].

The electric energy balance was drown up for the time interval 7:00h - 19:00h, which corresponds to the ”open for public” schedule of the agro-food hall. The measurements and data collection took place on December 15, 2022, every hour of the above mentioned time interval. We measured: total active energy, total reactive energy and line voltage. We considered the time interval between two measurements as operating time $\boldsymbol{T_f}$ of the installation; T_f = 1 hour [1],[2].

Based on these measurements we determined the following data for each individual hour:

- Hourly consumption of active energy ΔE_a, which is the difference between two consecutive hourly values of active energy shown by the meter;
- Hourly consumption of reactive energy ΔE_r, which is the difference between two consecutive hourly values of reactive energy shown by the meter;
- Hourly power factor ***cos φ***, calculated with the following formula:

$$\cos\varphi=\frac{1}{\sqrt{1+\left(\frac{\Delta Er}{\Delta Ea}\right)^2}} \quad (1)$$

- Instantaneous absorbed active power (demanded active power) P_c, calculated with the following formula:

$$P_c=\frac{\Delta Ea}{Tf} \quad (2)$$

- The demand coefficient K_c, calculated with the following formula:

$$K_c=\frac{P_c}{P_i} \quad (3)$$

- Instantaneous absorbed current (demanded current) I_c, calculated with the following formula:

$$I_c=\frac{P_c}{\sqrt{3}U_1\cos\varphi} \quad (4)$$

Determining the power factor as accurately as posible is very important, as it provides the user of electricity with information regarding a possible need to install equipments to compensate losses through inductive reactive energy. As we know, the National Energy Regulatory Authority (A.N.R.E.) issued Order no. 76/2016, valid from January 1, 2017, which amended and supplemented the ***Methodology regarding the establishment of payment obligations for reactive energy and the regulated price for reactive energy***, approved by the Order of the President of A.N.R.E., no. 33/2014 [12], [26].

Thus, a new reference value of the former neutral power factor (now renamed ***limiting power factor***) was established, decreasing from value 0,92 to the new value 0,9. This value represents the lower limit of the power factor from which invoicing of inductive reactive power consumption begins for non-domestic consumers connected to the public distribution network through three- phase connections.

The data obtained by measurements and calculations were sumarized in table 3.

Based on these summaries, we drew up a series of load graphs that illustrate the variations in active (fig. 2) and reactive (fig.3) energy consumption, but also the evolution of the demand coefficient (fig. 4) during a working day.

Analyzing the three graphs, it can be seen that their shapes are almost identical. This is due to the fact that the power factor remained constant during the entire working day. At the same time, the demand coefficient, although it recorded large variations during the entire working day, it reached at 1:00 PM its maximum value of

0,4, which corresponds to a maximum active power absorbed instantaneously of only 40% of the connection's installed active power [3].

Table 3. ***The data required for the preparation of the electrical energy balance, obtained through measurements and calculations on December 15, 2022***

Hour	**U_l (V)**	**E_a (kWh)**	**ΔE_a (kWh**	**E_r (kVAR)**	**ΔE_r (kVAR)**	**P_c (kW)**	**I_c (A)**	**K_c**	**cos φ**
7	422	647767	-	62353,98	-	-	-	-	-
8	423	647777	10	62357,98	4	10	14,70	0,33	0,93
9	421	647788	11	62362,36	4,38	11	16,24	0,37	0.93
10	423	647798	10	62366,34	3,98	10	14,70	0,33	0,93
11	424	647808	10	62370,32	3,98	10	14,66	0,33	0,93
12	419	647811	3	62371,52	1,52	3	4,45	0,1	0,93
13	422	647823	12	62376,29	4,77	12	17,67	0,4	0,93
14	420	647827	4	62377,88	1,59	4	5,92	0,13	0,93
15	423	647835	8	62381,07	3,19	8	11,76	0,27	0,93
16	424	647839	4	62382,66	1,59	4	5,86	0,13	0,93
17	422	647841	2	62383,45	0,79	2	2,95	0,07	0,93
18	425	647843	2	62384,24	0,79	2	2,92	0,07	0,93
19	420	647845	2	62384,03	0,79	2	2,96	0,07	0,93

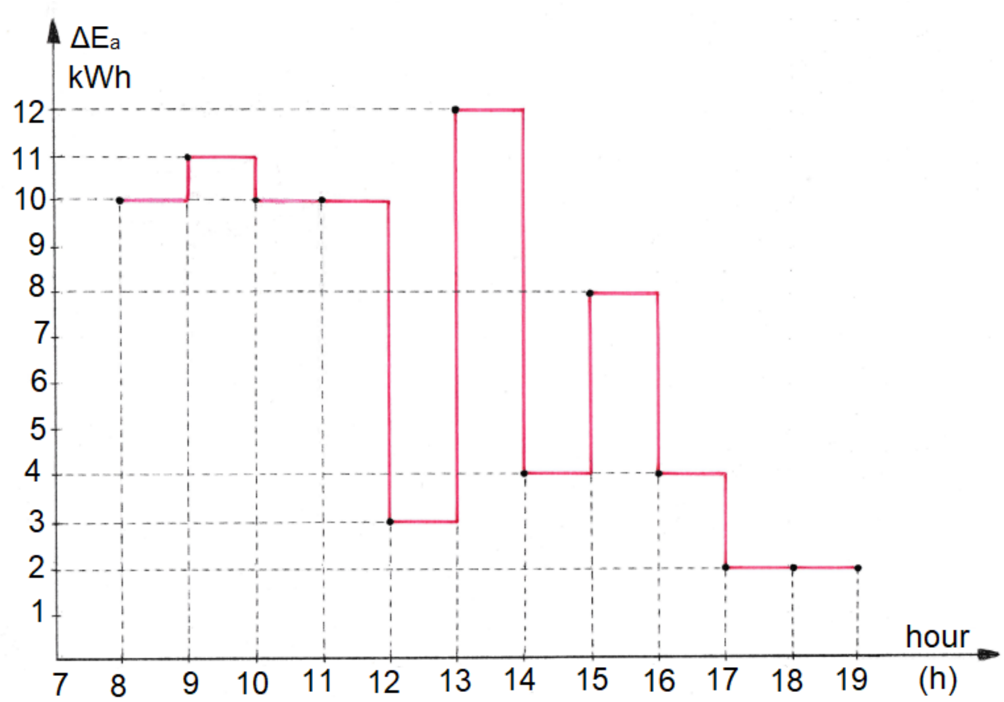

Fig.2. Active energy consumption variation graph

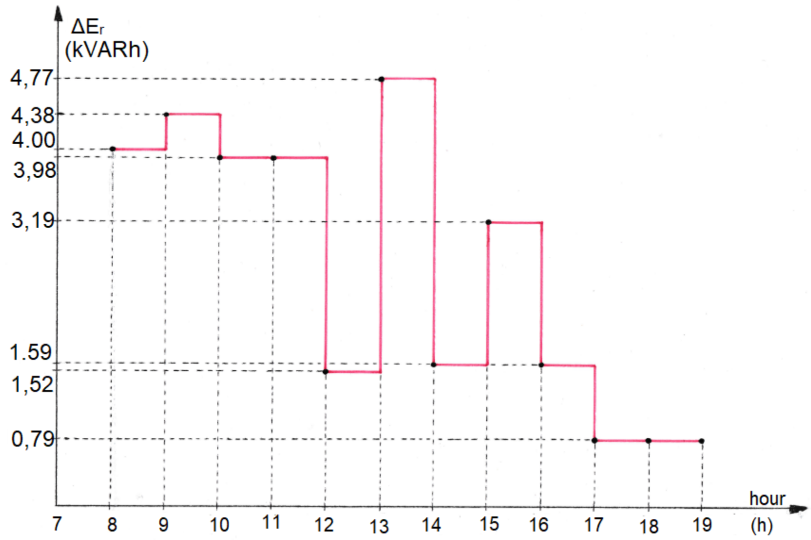

Fig. 3. Reactive energy consumption variation graph

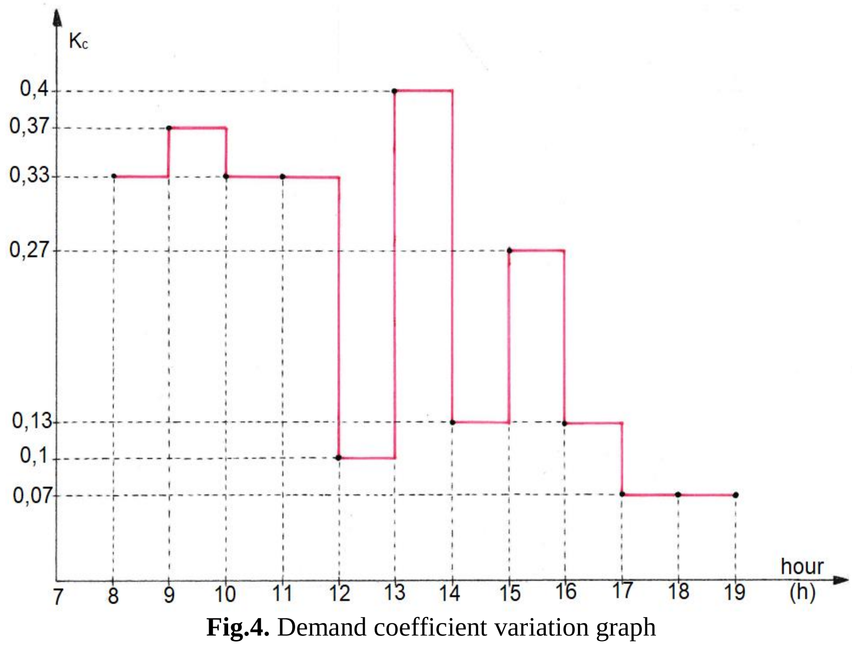

Fig.4. Demand coefficient variation graph

6. CONCLUSIONS

The data collected during the preliminary operations for drawing up the energy balance show unequivocally that all the actions taken in previous years, regarding the reduction of electricity consumption and the optimization of the operation of the electrical installations in the agro-food hall of the Central Market in Petroșani have achieved their goals, leading to:

- Raising the value of the power factor to 0,93, which is higher than the limit power factor of 0,9. This means that the consumption of reactive energy is not invoiced, thus achieving an important economy in the electricity expenses of the S.P.A.P. in Petroșani, especially in the current context of the huge increase in electricity costs;
- The sharp decrease in the instantaneously absorbed active power (demanded active power) during all operating hours of the electrical installations. Thus, the highest value of the demand coefficent was only 0,4. Due to this fact, we have reached the situation where there is no need to undertake any additional measures regarding the transfer of some electricity consumptions from an hourly interval to another in which the consumptions are lower;
- The complete elimination of the posibility of overloading the electrical installations, with beneficial effects in the technical conditions of the circuits, but also in the security of the electrical installations' users.

We can conclude, therefore, that the electrical installations in the agro-food hall of the Central Market in Petroșani are efficient and safe to operate.

REFERENCES

[1]. Albert H., Mihăilescu A., *Pierderi de putere și energie în rețelele electrice. Determinare. Măsuri de reducere,* Editura Tehnică, București, 1997.

[2]. Balaurescu D., *Îmbunătățirea factorului de putere,* Editura Tehnică, București, 1994.

[3]. Clement F., *Reducerea consumului energetic din locuință,* Editura Matrix Rom, București, 2014.

[4]. Fîță N.D., Lazăr T., Popescu F.G., Pasculescu D., Pupăză C., Grigorie E., *400 kV power substation fire and explosion hazard assessment to prevent a power black-out*, International Conference on Electrical, Computer Communications and Mecatronics Engineering - ICECCME, 16 – 18 November, Maldives, 2022.

[5]. Fîță N.D., Obretenova M.I., Pasculescu D., Tatar A., Popescu F.G., Lazar T., *Structure and analysis of the power subsector within the national energy sector on ensuring and stability of energy security,* Annals of the Constantin Brancusi University of Targu-Jiu, Engineering series, Issue 2 / 2022, pp.177-186, 2022.

[6]. Fîță N.D., Radu S.M., Păsculescu D., *Ensuring, controlling and stability of energy security in the context of increasing industrial and national security,* Academic Compendium, 2021.

[7]. Fîță N.D., Radu S.M., Păsculescu D., *National security- Energy sector optimization elements",* Chișinău, Republic of Moldova: Globe Edit Publisher, 2021.

[8]. Fîță N.D., Radu S.M., Păsculescu D., Popescu F.G., *Using the primary energetic resources or electrical energy as a possible energetical tool or pressure tool*, Proceedings of Sciendo International Conference Knowledge based organisation – "Nicolae Balcescu" Land Forced Academy Sibiu, Vol. XXVII, No. 3, pp. 21-26, 2021.

[9]. Handra A.D., Popescu F.G., Păsculescu D., *Utilizarea energiei electrice,* Editura Universitas, Petroșani, 2020.

[10]. Ionașcu T., Berinde T., Resiga R., *Întocmirea și analiza bilanțurilor energetice în industrie,* Editura Tehnică, București, 1976.

[11]. Lazăr T., Marcu M.D., Uțu I., Popescu F.G., Păsculescu D., *Mașini electrice - culegere de probleme*, Editura UNIVERSITAS, Petroșani, pp.197, 2023.

[12]. **Niculescu T., Pasculescu D., Pana L.,** *Study of the operating states of intrinsic safety barriers of the electric equipment intended for use in atmospheres with explosion hazard*, WSEAS Transactions on Circuits and Systems, Volume 9, pp.430-439, 2010.

[13]. **Niculescu T., Păsculescu D., Păsculescu V.M.,** *Evaluation of electrical parameters of intrinsic safety barriers of the electrical equipment intended to be used in atmospheres with explosion hazard",* Int. Multidiscip. Sci. GeoConf. Surv. Geol. Min. Ecol. Manag. 2014.

[14]. **Păcuraru C.G.,** *Energia. O problemă de securitate națională",* Editura Didactică şi Pedagogică, Bucureşti, 2022.

[15]. **Păsculescu D., A. Pădure P.,** *Instalații electrice*, Editura Universitas, Petroșani, 2010.

[16]. **Pasculescu D., Romanescu A., Pasculescu V., Tatar A., Fotau I., Vajai Ghe.,** *Presentation and simulation of a modern distance protection from national energy system*, Proceedings of the 10 th International Conference on Environment and Electrical Engineering – EEEIC 2011, Rome, Italy, pp. 646-650, 2011.

[17]. **Pasculescu D., Slusariuc R., Popescu F.G., Fîță N.D., Tatar A., Lazar T.,** *Modeling and simulation of lighting of a road with 2 strips per direction to en 13201: 2015 Standard*, Annals of the University of Petrosani, Electrical Engineering, Vol.24, pp.65-74, Petrosani, 2022.

[18]. **Pasculescu, V. M., Radu, S. M., Pasculescu, D., Niculescu T.**, *Dimensioning the intrinsic safety barriers of electrical equipment intended to be used in potentially explosive atmospheres using the simpowersystems software package*, Papers SGEM2013/Conference Proceedings, 417- 422 pp, Vol. Science and technologies in geology, exploration and mining, Bulgaria, 2013.

[19]. **Popescu F.G., Pasculescu D., Marcu M., Niculescu T., Handra A.D.**, *The technical and economic advantages of power factor correction*, Annals of University of Petroșani, Electrical Engineering, Vol. 21, pp.35-42, Petroşani, 2019.

[20]. **Popescu F.G., Pasculescu D., Marcu M., Pasculescu V.M., Fîță N.D., Tatar A., Lazar T.,** *Principles of effective energy management and power control system*, Annals of the University of Petrosani, Electrical Engineering, Vol.24, pp.111-118, Petrosani, 2022.

[21]. **Popescu F.G., Pasculescu D., Marcu M., Pasculescu V.M., Fîță N.D., Tatar A., Lazar T.,** *Principles of effective energy management and power control system*, Annals of the University of Petrosani, Electrical Engineering, , Vol.24, pp.111-118, Petrosani, 2022.

[22]. **Popescu F.G., Pasculescu D., Marcu M., Slusariuc R., Buica G., Lazar T.**, *Analysis of filtering and correction of the power factor in distorted balance*, Annals of University of Petrosani, Electrical Engineering, Vol. 23, pp. 77-82, Petroşani, 2021.

[23]. **Popescu F.G., Păsculescu D., Păsculescu V.M.**, *Modern methods for analysis and reduction of current and voltage harmonics*, LAP LAMBERT Academic Publishing, ISBN 978-620-0-56941-7, pp. 233, 2020.

[24]. **Popescu F.G., Păsculescu D., Păsculescu V.M.,** *Modern methods for analysis and reduction of current and voltage harmonics*, LAP LAMBERT Academic Publishing, ISBN 978-620-0-56941-7, pp. 233, 2020.

[25]. **Uțu I., Păsculescu D.,** *Power Quality Study in Order to Comply with European Norms*. Publicat in Revista Calitatea, Supplement of "Quality - Access to Success" Journal, Vol.18, S1, January, pp. 366-371, 2017.

[26]. https://www.cez.ro/ckfinder/userfiles/files/cez/cariere-in-cez/bibligrafie/2015-iu187-cst0410_mid_man.pdf

[27]. https://www.benning.de/products-en/testing-measuring-and-safety-equipment/digital-multimeter/multimeter-mm-1-1-mm-1-3.html

[28]. www.anre.ro

SIMULATION THE SHORT-CIRCUIT REGIME OF 220/110/20 kV SARDANESTI POWER SUBSTATION WITH THE PALADIN DESIGNBASED

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Abstract: The calculation of defects represents the analysis of the behavior of the energy system in short-circuits and/or phase outages, and the purpose of performing these calculations is to determine the current circulations and the values of the residual voltages in the nodes. This paper presents the behavior of the 220/110/20 kV power substation Sardanesti to certain types of short-circuits in order to verify the stability of the system in the Oltenia area and to develop a strategy on the safety and security of the National Energy System.

Keywords: Modeling, short-circuit regime, power substation.

1. INTRODUCTION

The calculation of defects represents the analysis of the behavior of the energy system in short-circuits and/or phase interruptions and the purpose of performing these calculations is to determine the current circulations and the values of the residual stresses in the nodes. This analysis makes it possible to highlight the following important aspects in the design and operation of the energy system: choosing the configuration of the transmission and distribution network, determining the load and the short-circuit ratio of generators, choosing the breaking capacity of the switches and checking the electrical switching equipment, designing and adjusting the protections and system automation, choosing the operating conditions of the system in terms of safety, analysis of fault conditions that take place in operation, determination of the

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operating conditions of the telecommunication lines in case of defects in the high voltage network [10].

Defects that can occur in power systems can be classified by the nature of the causes into two categories:

- *destruction of insulation, which leads to short circuits;*
- *destruction of integrity, which leads to interruption of the electrical circuit.*

Short-circuit means accidental contact without resistance or by a relatively low value resistance of two or more live conductors.

Among the causes of the short-circuit are:

- *damage to the insulation of the electrical installation;*
- *breaking the line conductors under the action of mechanical loads;*
- *touching uninsulated conductors (OHL) by birds or animals;*
- *wrong maneuvers during operation, etc.*

The value of short-circuit currents depends on:

- *the power of the sources that supply the short circuit;*
- *the electrical distance between the source and the short-circuit, the value of the equivalent impedance of the electrical circuit between the source and the place of the short-circuit;*
- *time elapsed from the moment of short-circuit;*
- *short circuit type: single-phase, biphasized, earth-biphased, three-phase.*

The short-circuit mode in a network is characterized by the fact that by the disappearance of the electrical charge of the source receiver will be connected only on the connection network, having a relatively small impedance and a pronounced inductive character (X > > R) (fig.1).

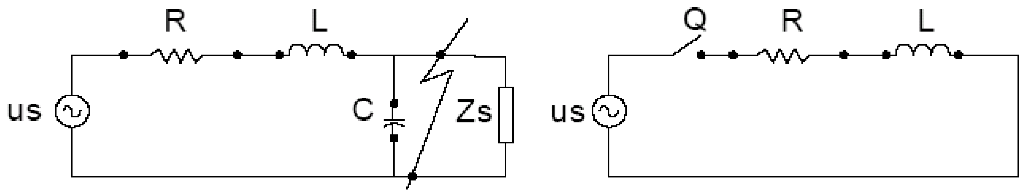

Fig.1. Short-circuit mode in a network

This can be followed, by modeling the short circuit, according to the theory of electrical circuits. At the time of short-circuit, the electric charge, modeled by the Zs impedance, is short-circuited, and the u (t) source impedance closes on the impedance of the connection line between the source and the short-circuit site. Given that the short-circuit current values are approximately two orders of magnitude greater than the load current, the short-circuit can be modeled by a calculation scheme represented only by the longitudinal parameters of the short circuit path: source (generator/system bar) represented by the electromotive voltage in the Eδ interneck behind the X "supratanding reactance" - variable over time, during the transient short circuit regime, and the equivalent impedance of the current path represented by the resistance R respectively the reactance X. The short-circuit as a transient regime is modeled by a K circuit breaker that can be closed controlled in time [1], [3], [5].

1.1. Factors influencing the severity of the short-circuit

Severity conditions can be analyzed based on the damage caused by short-circuit currents, the amplitude of short-circuit currents and their duration. The factors that should normally be considered are:

- *Power supplies;*
- *Electrical system configuration;*
- *Earth system;*
- *Nature and type of defect* [2], [9], [11].

2. MODELING OF 220/110/20 kV SARDANESTI POWER SUBSTATION

2.1. Presentation of the 220/110/20 kV Sardanesti power substation

The 220/110/20 kV Sardanesti power substation is located in Plopsoru commune, Gorj county, belonging to the Center for the Exploitation of Electricity Transmission Networks Târgu-Jiu – Craiova Electricity Transport Unit, *according to fig.2* [4], [7].

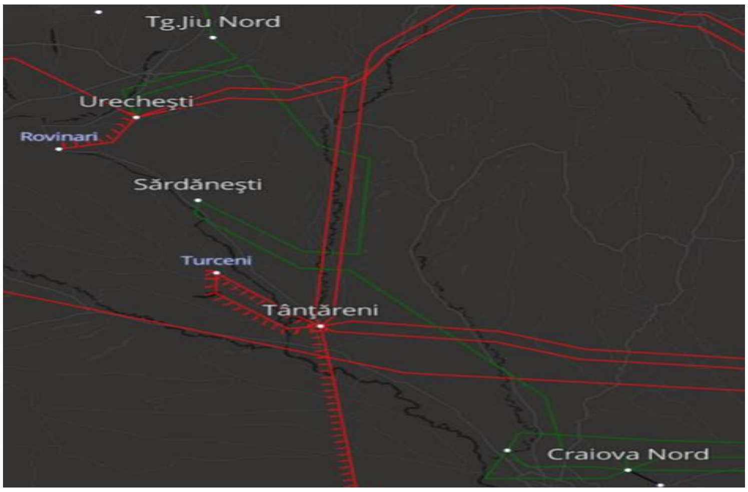

Fig.2. Single diagram of the 220/110/20 kV Sardanesti power substation (source:www.entsoe.eu)

2.1.1. 220 kV Power Substation

The 220 kV power substation is of the external type and is equipped with simple bussbar systems, to which the following power cells (switchgears) are connected: *220/110 kV – 200 MVA AT (autotransformer); 220 kV Urechesti OHL (overhead power line); 220 kV Craiova Nord OHL (overhead power line); 220 kV Measures 1, according to fig. 3* [6], [8].

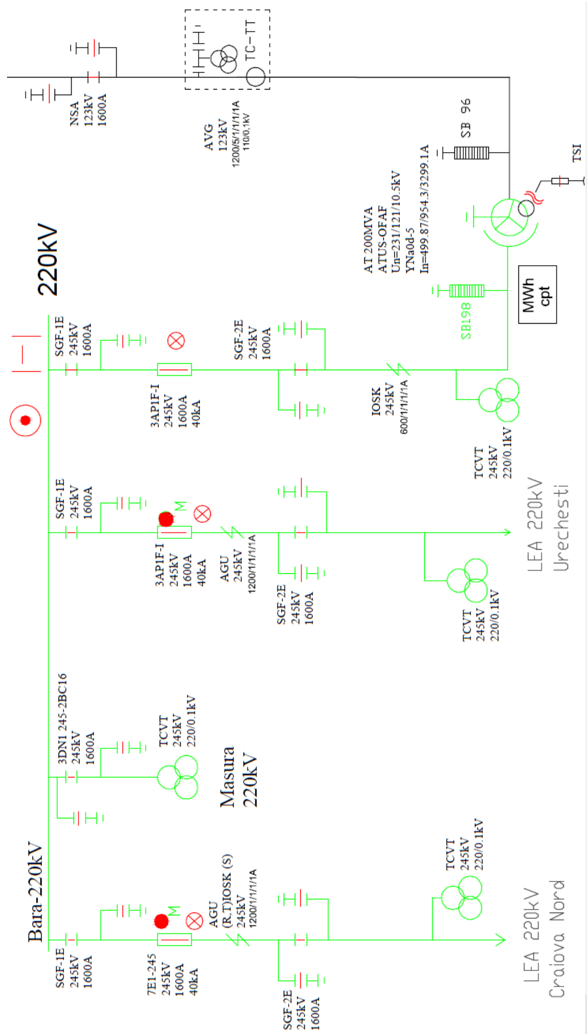

Fig.3. Single diagram of the 220 kV Sardanesti power substation

2.1.2. 110 kV Power Substation

The 110 kV power substation is of the external type and is equipped with double bussbar systems, with connection by transversal couple, to which the following power cells (switchgears) are connected: *220/110 kV – 200 MVA AT 1 (autotransformer); 220/110 kV – 200 MVA AT 2 (autotransformer); 110 kV Jilt OHL (overhead power line); 110 kV Dragotesti OHL (overhead power line); 110 kV Pinoasa OHL (overhead power line); 110 kV Rosia – Pesteana OHL (overhead power line); 110 kV SRA - Pesteana OHL (overhead power line); 110 kV Plopsoru – CFR 1 OHL (overhead power line); 110 kV Turceni T01 OHL (overhead power line); 110 kV Turceni T03 OHL (overhead power line); 110 kV Turceni T05 OHL (overhead power line); 110 kV Transversal couple, 110 kV Measure 1, 110 kV Measure 2, according to fig.4.*

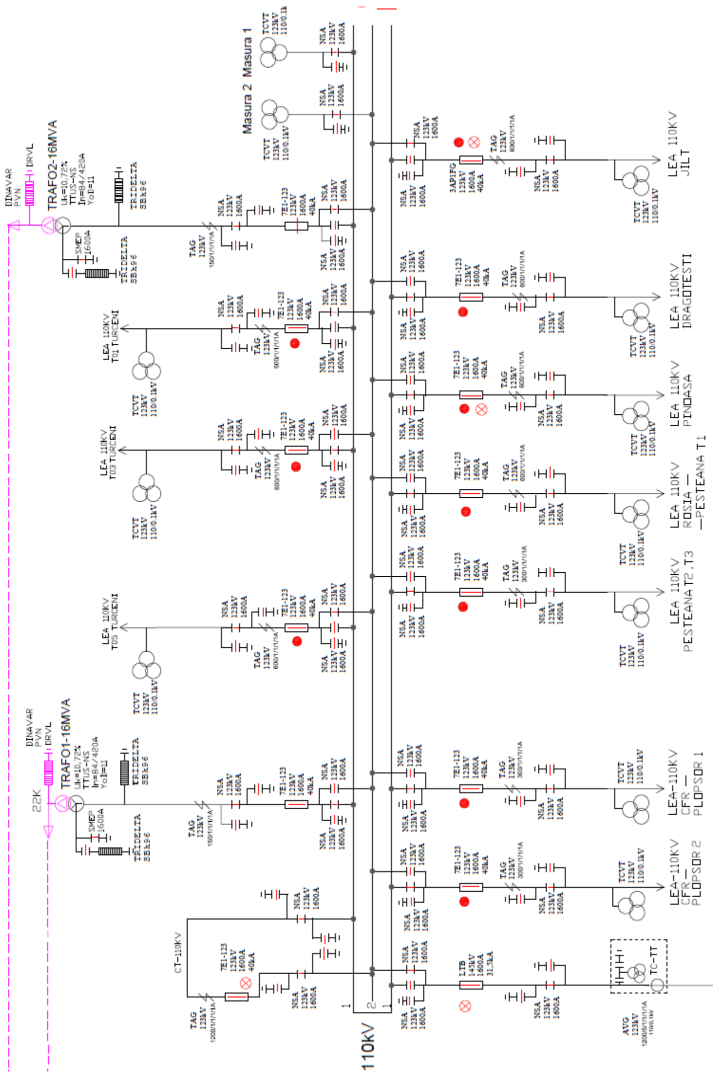

Fig.4. Single diagram of the 110 kV Sardanesti power substation

2.1.3. 20 kV Power Substation

The 20 kV power substation is of the internal type and is equipped with 2 simple bussbar systems conected with transversal couple, to which the following power cells (switchgears) are connected: *220/20 kV – 16 MVA AT 1 (autotransformer); 220/20 kV – 16 MVA AT 2 (autotransformer); 20 kV Turceni OHL (overhead power line); 20 kV Cocoreni OHL (overhead power line); 20 kV MHC 1 OHL (overhead power line); 20 kV MHC 2 OHL (overhead power line); 20 kV SI CHE OHL (overhead power line); 20 kV Transversal couple; 20 kV Measure 1; 20 kV Measure 2; 20 kV TSI 1 (intern services); 20 kV TSI 2 (intern services), according to fig.4* [3], [6].

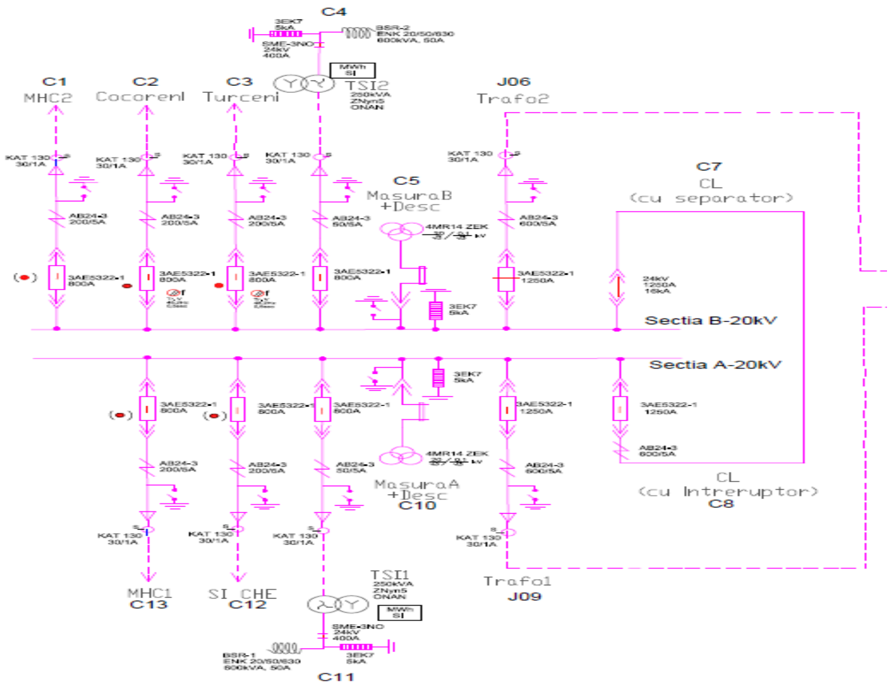

Fig.5. Single diagram of the 110 kV Sardanesti power substation

2.2. Simulation of short-circuit regime of 220/110/20 kV Sardanesti power substation

a) Short-circuit – 220 kV buss bar:

Short Circuit Detailed Report

Bus Current (A)-**3P Fault** - IEC60909 Method at the Following Times

Bus Name	Pre-Flt kV		I"k	ip	--1/2-Cycle--- Isym	Iasym	Steady-State- Isym	Iasy
2	220	A	8670	24402	8670	12322	8670	8670
		B	8670	24402	8670	12322	8670	8670
		C	8670	24402	8670	12322	8670	8670

Short Circuit Detailed Report

Bus Current(A)-**LL Fault** - IEC60909 Method at the Following Times

Bus Name	Pre-Flt kV		I"k	ip	--1/2-Cycle--- Isym	Iasym	Steady-State-- Isym	Iasym
2	220	A	0	0	0	0	0	0
		B	7507	20990	7507	10580	7507	7507
		C	7507	20990	7507	10580	7507	7507

Short Circuit Detailed Report

Bus Current(A)-**LG Fault** - IEC60909 Method at the Following Times

Bus Name	Pre-Flt kV		I"k	ip	--1/2-Cycle--- Isym	Iasym	Steady-State-- Isym	Iasym
2	220	A	7886	22304	7886	11627	7886	7886
		B	0	0	0	0	0	0
		C	0	0	0	0	0	0

Short Circuit Detailed Report

Bus Current(A)-**LLG Fault**- IEC60909 Method at the Following Times

Bus Name	Pre-Flt kV		I"k	ip	--1/2-Cycle--- Isym	Iasym	Steady-State-- Isym	Iasym
2	220	A	0	0	0	0	0	0
		B	8154	23063	8154	11739	8154	8154
		C	8506	24060	8506	12247	8506	8506

b) Short-circuit – 110 kV buss bar:

Short Circuit Detailed Report

Bus Current(A)-**3P Fault** - IEC60909 Method at the Following Times

Bus Name	Pre-Flt kV		I"k	ip	1/2-Cyc Isym	Steady- Isym
II	110	A	9511	26901	9511	9511

```
                                 B    9511   26901    9511    9511
                                 C    9511   26901    9511    9511
-------------------------------------------------------------------

                        -------------------------------
                         Short Circuit Detailed Report
                        -------------------------------
Bus Current(A)-LL Fault - IEC60909 Method at the Following Times

                         Pre-Flt                   1/2-Cyc Steady-
Bus Name                   kV       I"k      ip    Isym    Isym
------------------------ -------   ------- ------- ------- -------
II                           110 A       0       0       0       0
                                 B    8249   23331    8249    8249
                                 C    8249   23331    8249    8249
------------------------------------------------------------------

                        -------------------------------
                         Short Circuit Detailed Report
                        -------------------------------

Bus Current(A)-LG Fault - IEC60909 Method at the Following Times
                         Pre-Flt                   1/2-Cyc Steady-
Bus Name                   kV       I"k      ip    Isym    Isym
------------------------ -------   ------- ------- ------- -------
II                           110 A   11215   31720   11215   11215
                                 B       0       0       0       0
                                 C       0       0       0       0
-------------------------------------------------------------------
                        -------------------------------
                         Short Circuit Detailed Report
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Bus Current(A)-LLG Fault- IEC60909 Method at the Following Times
                         Pre-Flt                   1/2-Cyc Steady-
Bus Name                   kV       I"k      ip    Isym    Isym
------------------------ -------   ------- ------- ------- -------
II                           110 A       0       0       0       0
                                 B   10652   30128   10652   10652
                                 C   10728   30344   10728   10728
```

c) Short-circuit all power substation:

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                        -------------------------------
                         Short Circuit Detailed Report
                        -------------------------------

Bus Current (A )-3P Fault - IEC60909 Method at the Following Times

                         Pre-Flt                   1/2-Cyc Steady-
Bus Name                   kV       I"k      ip    Isym    Isym
------------------------ -------   ------- ------- ------- -------
II                           110 A    9511   26901    9511    9511
                                 B    9511   26901    9511    9511
                                 C    9511   26901    9511    9511
-------------------------------------------------------------------

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                         Short Circuit Detailed Report
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Bus Current(A)-LL Fault - IEC60909 Method at the Following Times
```

Bus Name	Pre-Flt kV		I"k	ip	1/2-Cyc Isym	Steady-Isym
II	110	A	0	0	0	0
		B	8249	23331	8249	8249
		C	8249	23331	8249	8249

Short Circuit Detailed Report

Bus Current(A)-**LG Fault** - IEC60909 Method at the Following Times

Bus Name	Pre-Flt kV		I"k	ip	1/2-Cyc Isym	Steady-Isym
II	110	A	11215	31720	11215	11215
		B	0	0	0	0
		C	0	0	0	0

Short Circuit Detailed Report

Bus Current(A)-**LLG Fault**- IEC60909 Method at the Following Times

Bus Name	Pre-Flt kV		I"k	ip	1/2-Cyc Isym	Steady-Isym
II	220	A	0	0	0	0
		B	10652	30128	10652	10652
		C	10728	30344	10728	10728

Short Circuit Detailed Report

Branch Flow (A)-**3P Fault** - IEC60909 Method
Fault At Bus:II / X/R :15.9862
* Stands for Secondary or Tertiary Side of Transformer

From Bus / To Bus		Pre-Flt kV		I"k	ip	1/2-Cyc Isym	Steady-Isym
0029		110	A	548	1551	548	548
0028			B	548	1551	548	548
			C	548	1551	548	548
0015		220	A	2860	8090	2860	2860
0027			B	2860	8090	2860	2860
			C	2860	8090	2860	2860
0015	*	110	A	5201	14709	5201	5201
0027			B	5201	14709	5201	5201
			C	5201	14709	5201	5201

Short Circuit Detailed Report

Branch Flow (A)-**LL Fault** - IEC60909 Method
Fault At Bus:II / X/R:15.6195

* Stands for Secondary or Tertiary Side of Transformer

From Bus / To Bus		Pre-Flt kV		I"k	ip	1/2-Cyc Isym	Steady-Isym
0029		110	A	4	10	4	4
0028			B	479	1354	479	479
			C	478	1352	478	478
0015		220	A	6	16	6	6
0027			B	2475	7001	2475	2475
			C	2478	7010	2478	2478
0015	*	110	A	10	29	10	10
0027			B	4500	12728	4500	4500
			C	4506	12745	4506	4506

Short Circuit Detailed Report

Branch Flow (A)-**LLG Fault**- IEC60909 Method
Fault At Bus: II / X/R:16.4002
* Stands for Secondary or Tertiary Side of Transformer

From Bus / To Bus		Pre-Flt kV		I"k	ip	1/2-Cyc Isym	Steady-Isym
0029		110	A	2464	6970	2464	2464
0028			B	2896	8190	2896	2896
			C	2891	8177	2891	2891
0015		220	A	818	2313	818	818
0027			B	2752	7785	2752	2752
			C	2781	7866	2781	2781
0015	*	110	A	1487	4205	1487	1487
0027			B	5004	14154	5004	5004
			C	5057	14302	5057	5057

Short Circuit Detailed Report

Voltage (kV)-**3P Fault** - IEC60909 Method
Fault At Bus: II

Bus Name	Pre-Flt kV		1/2-Cyc Voltage	Steady-Voltage
I	110	A	0	0
		B	0	0
		C	0	0
II	110	A	0	0
		B	0	0
		C	0	0

Short Circuit Detailed Report

Voltage (kV)-**LL Fault** - IEC60909 Method
Fault At Bus:II

Bus Name	Pre-Flt kV	1/2-Cyc Voltage	Steady-Voltage

```
I                             110 A     127     127
                                  B      63      63
                                  C      63      63
II                            110 A     127     127
                                  B      63      63
                                  C      63      63
--------------------------------------------------

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                         Short Circuit Detailed Report
                        ------------------------------

Voltage (kV)-LG Fault - IEC60909 Method
Fault At Bus: II
                         Pre-Flt   1/2-Cyc Steady-
Bus Name                    kV     Voltage Voltage
------------------------ -------   ------- -------
I                             110 A       0       0
                                  B     118     118
                                  C     117     117
II                            110 A       0       0
                                  B     118     118
                                  C     117     117
--------------------------------------------------

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                         Short Circuit Detailed Report
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Voltage (kV)-LLG Fault- IEC60909 Method
Fault At Bus: II
                         Pre-Flt   1/2-Cyc Steady-
Bus Name                    kV     Voltage Voltage
------------------------ -------   ------- -------
I                             110 A      99      99
                                  B       0       0
                                  C       0       0
II                            110 A      99      99
                                  B       0       0
                                  C       0       0
--------------------------------------------------
```

3. CONCLUSIONS

This paper illustrate the functioning of 220/110/20 kV Sardanesti power substation during the short-circuit regime.

After simulation of 220/110/20 kV Sardanesti power substation by the Paladin DesignBase programme, the results is next:

a) Short-circuit – 220 kV buss bar:

- Buss bar 2, 3P fault: A = 8670 Ik; B = 8670 Ik; C = 8670 Ik;
- Buss bar 2, LL fault: A = 0 Ik; B = 7507 Ik; C = 7507 Ik;
- Buss bar 2, LG fault: A = 7886 Ik; B = 0 Ik; C = 0 Ik;
- Buss bar 2, LLG fault: A = 0 Ik; B = 8154 Ik; C = 8506 Ik.

b) Short-circuit – 110 kV buss bar:

- Buss bar II, 3P fault: A = 9511 Ik; B = 9511 Ik; C = 9511 Ik;
- Buss bar II, LL fault: A = 0 Ik; B = 8249 Ik; C = 8249 Ik;
- Buss bar II, LG fault: A = 11215 Ik; B = 0 Ik; C = 0 Ik;

- Buss bar II, LLG fault: A = 0 Ik; B = 10652 Ik; C = 10728 Ik.

c) ***Short-circuit all point in power substation:***
   - Branch flow Buss bar II, 3P fault: A = 9511 Ik; B = 9511 Ik; C = 9511 Ik;
   - Branch flow Buss bar II, LL fault: A = 0 Ik; B = 8249 Ik; C = 8249 Ik;
   - Branch flow Buss bar II, LG fault: A = 11215 Ik; B = 0 Ik; C = 0 Ik;
   - Branch flow Buss bar II, LLG fault: A = 0 Ik; B = 10652 Ik; C = 10728 Ik.

Following the simulation of the short-circuit regime of the 220/110/20 kV Sardanesti power substation, it can be seen that the power substation falls within normal operating parameters, but it is proposed to modify the 220 kV power substation from a simple collector bussbar system, in a double collector bussbars, thus increasing the reliability of the 220 kV power substation.

REFERENCES

[1]. Ahmad I., Khan F., Khan S., Khan A., Tareen A.W., Saeed M. *Blackout Avoidance through Intelligent Load Shedding in Modern Electrical Power Utility Network.* J. Appl. Emerg. Sci. 8, 48–57, 2018.

[2]. Billinton R., Li W. *Basic concepts of power system reliability evaluation. In Reliability Assessment of Electric Power Systems Using Monte Carlo Methods.* Springer: New York, NY, USA, pp. 9–31, 1994.

[3]. Fîță N.D., Lazăr T., Popescu F.G., Pasculescu D., Pupăză C., Grigorie E., *400 kV power substation fire and explosion hazard assessment to prevent a power black-out*, International Conference on Electrical, Computer Communications and Mecatronics Engineering - ICECCME, 16 – 18 November, 2022.

[4]. Fîță N.D., Obretenova M.I., Pasculescu D., Tatar A., Popescu F.G., Lazar T., *Structure and analysis of the power subsector within the national energy sector on ensuring and stability of energy security*, Annals of the Constantin Brancusi University of Targu-Jiu, Engineering series, pp.177-186, 2022.

[5]. Fîță N.D., Radu S.M., Herbei R., *Global Security – European Energy Security*, LAP – Lambert Academic Publishing, 2023.

[6]. Fîță N.D., Radu S.M., Păsculescu D., *The resilience of critical infrastructures within the national energy system in order to ensure energy and national security*, Bulletin of "Carol I" National Defence University, no. 2 / 2022, Publishing House "Carol I" National Defence University, Bucharest, pag. 57-65, 2022.

[7]. Lazăr T., Marcu M.D., Uțu I., Popescu F.G., Păsculescu D., *Mașini electrice - culegere de probleme*, Editura UNIVERSITAS, Petroșani, pp.197, 2023.

[8]. Popescu F.G., Păsculescu D., Păsculescu V.M., *Modern methods for analysis and reduction of current and voltage harmonics*, LAP LAMBERT Academic Publishing, ISBN 978-620-0-56941-7, pp. 233, 2020.

[9]. Salimian M.R., Aghamohammadi M.R., *A Three Stages Decision Tree-Based Intelligent Blackout Predictor for Power Systems Using Brittleness Indices.* IEEE Trans. Smart Grid, 9, 5123–5131, 2018.

[10]. Zhang Y., Xu Y., Dong Z.Y., *Robust Ensemble Data Analytics for Incomplete PMU Measurements-Based Power System Stability Assessment*, IEEE Trans. Power Syst., 33, 1124–1126, 2018.

[11]. Paladin DesignBase 7.0 www.easypower.com.

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CURRENT SITUATION IN THE ENERGY SECTOR AT INTERNATIONAL AND NATIONAL LEVEL

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Abstract: The energy sector has long established itself as a strategic area of social and economic development for most countries in the world. So it has also become established in our country. The dependence of the whole of society on this sector and its complex impact on the environment have led to its position as the leading national infrastructure. Nowadays the concept of sustainable development has a global significance and ensures a dynamic balance between the components of natural capital and socio-economic systems. Choosing a strategy for energy development is a political decision that must be based on the development directions of the other industrial sectors that will become future energy users.

Key words: energy efficiency, sustainable development, energy trilemma, effective energy management, cogeneration.

1. INTRODUCTION

The energy sector in any country, including globally, is today facing three fundamental challenges that unfortunately appear to be divergent.

The concept of the energy trilemma, which recognises these challenges, was launched by the World Energy Council (WEC), which has studied in detail the conditions and how to address them [3, 5].

Improved favourable response to any one of these challenges inevitably affects the other two. Ways must therefore be found that lead to a compromise acceptable to the whole "trilemma" and - moreover - achieve sustainable energy systems [3].

Continuous technology development is an integral part of any business model, both for production and consumption. Technology is one of the main factors affecting the competitiveness of the final product on the global market.

Each new generation of products is implicitly more energy efficient than the previous generation because energy efficiency is an important cost factor over the lifetime of the product.

Energy efficient technologies can be found throughout the energy conversion chain. So from exploration and production of primary energy resources to electricity generation and from oil refineries to power grids and end-use in industry, buildings and transport.

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But it is not only the technical potential that is crucial for the successful introduction of energy-efficient technologies. Assessing the full potential of such technologies is essential. In order to identify the route to successful market introduction, it is necessary to consider the economic, feasible and also realistic potential.

The technical potential of Best Available Technology (BAT) requires certain conditions [6].

Oil and gas exploration should be done in such a way that the energy efficiency of the upstream power system is about 20%, ranking last in the whole energy value chain. By implementing a system-wide approach, energy efficiency could be increased by up to 50%.

The overall average efficiency of power plants (LHV) (net calorific value) in electricity generation is about 34% compared to BAT for coal-fired plants (46%) and gas-fired plants (61%).

Losses related to electricity transmission and distribution networks amount to 12% of the global average; BAT for high voltage transmission is less than 4% per 1000 km.

Energy efficiency management systems increase energy efficiency by at least 5% regardless of size, technology or process.

Buildings account for about 40% of total global energy conversion. It is estimated that energy savings in buildings can range from 20 to 40%, or between 1 and 2 Mtoe per year, equivalent to the annual energy demand of a country like Namibia.

The economic and realistic potential of best available technology (BAT) requires a wide range of measures [6].

In many cases a full system analysis is required to optimise the full potential for energy conservation.

The IEA (European Association of Electrical Contractors) presented in Scenario 450 that improving energy efficiency is the least costly energy reduction option [8].

Energy efficiency accounts for half of the overall cumulative reduction share associated with the New Policy Scenario or 73 Gt between 2011 and 2035 (Fig.1).

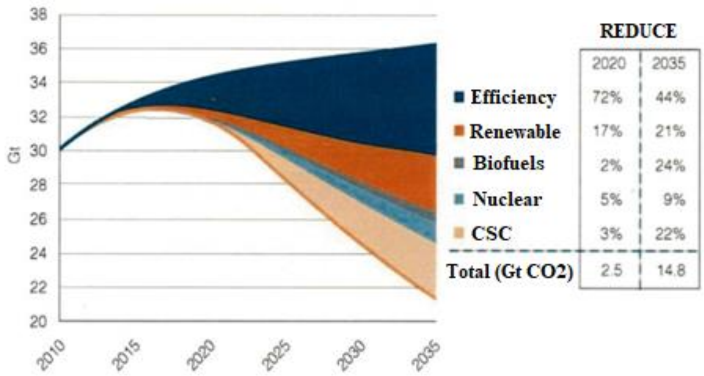

Fig.1. Scenarios for the evolution of CO_2 emissions

The role of energy efficiency varies from country to country in terms of remaining potential, energy pricing and other parameters.In OECD (Organisation for Economic Co-operation and Development) countries, despite the significant efficiency improvements that already exist, the efficiency improvements in the 450 Scenario represent about 42% of the reduction potential associated with the New Policy Scenario.

Their share amounts to 54% in non-OECD countries (including Romania) where efficient energy production and use of technologies are generally not widely implemented. This is due to higher costs of efficient technologies and energy subsidies that do not encourage energy efficiency.

Smart metering, efficient buildings, heat pumps, efficient motors, LED lighting and other applications can also contribute to high energy efficiency. Life cycle analysis can help define the specific contribution of each technology and analyse the cost-effectiveness of technologies. That is, reducing total energy costs provides a positive return on investment. Electric vehicles (depending on the electricity generation mix) can be another example of energy-efficient future mobility solutions [9].

2. INTEGRATING ENERGY EFFICIENCY THROUGHOUT THE ENERGY VALUE CHAIN

Whether energy or environment, energy efficiency is always mentioned as something that can be easily implemented. For most it seems to offer immediate and quick success. But because of the hurdles we face, it doesn't support this claim. There is considerable technical potential for improving energy efficiency throughout the energy value chain, from oil, gas, coal, uranium, etc. to the end consumer. Few research projects or studies have been able to estimate the potential with the necessary level of technical detail. Few have been able to estimate energy efficiency savings and communicate these findings in a way that makes them easy to understand.

Examining product productivity and cost can provide useful information about the efficiency of the whole process. It helps to assess the impact of energy efficiency improvements and to develop an easier understanding of the "motric factors", the evolutionary factors that acts these improvements.

It also helps reduce fuel consumption and increase availability and profitability in the sector.

Over the years, a number of questions have been raised about measuring and recording the impact of energy-efficient technologies and the savings that can be achieved by deciding to use a particular technology, whether practical or available [1].

The energy value chain is a sequence of productive activities that starts with the exploration and production of raw materials (primary energy) for further processing, transportation (liquefied natural gas - LPG, gas to liquid - GTL, liquid thermal fuel - LTF), distribution and use (Fig.2).

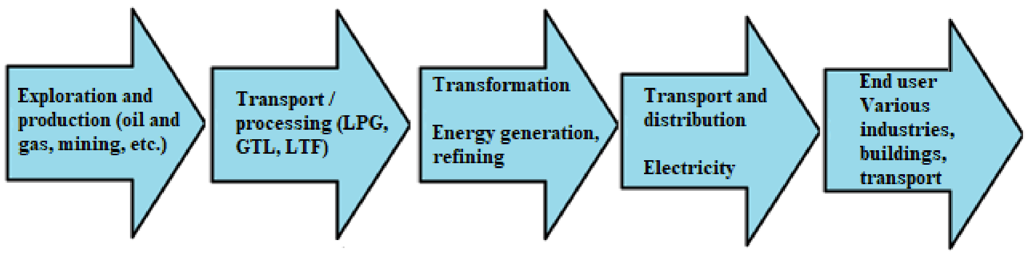

Fig. 2. The energy value chain.

The more developed the value chain, the greater the benefits that can be achieved through improved energy efficiency [9.]

A sustainable energy system, based on the energy efficiency approach, requires the optimal integration of all resulting components into an integrated energy system.

In order to set up an integrated energy system, the following must be completed:

- identification and specification of energy requirements;

- reviewing possible options for increasing efficiency throughout the energy conversion chain and selecting the most appropriate option tailored to the performance requirements;

- system optimisation using tools such as information and communication technologies, e.g. control, real-time optimisation and smart grid technologies, in all sectors and infrastructures throughout the energy chain and in all regions.

It is important to carry out assessment projects without delay, taking into account the key benefits provided by energy efficiency improvements, from reduced CO_2 emissions to billions of dollars in potential savings from lower energy bills [2].

To achieve faster progress in energy efficiency, guidance, communication and information should be a priority, even more important than incentives.

This is where governments can and should take a more proactive approach. All energy investments and energy efficiency measures should be based on cost-benefit analysis that includes environmental costs.

3. EFFICIENCY IN INDUSTRIAL ENERGY USE

Industry uses a large amount of energy to power various manufacturing and resource extraction processes. Many industrial processes require large amounts of thermal and mechanical energy, much of which is provided by natural gas, petroleum fuels and electricity.

Some industries generate waste streams that can be recovered to provide additional energy [4].

Because industrial processes are so diverse, from processes that need cold or low temperatures to processes that require high temperatures, it is difficult to describe the myriad opportunities for energy efficiency improvements in industry.

There are several processes and energy services that are widely used in many industries (Fig.3). Many depend on the specific technologies and processes in each industrial facility. However, efficient energy management in industry, regardless of size, technology or process will increase energy efficiency by at least 5%.

Implementing cogeneration, reducing the level or amount of industrial heat or recovering waste heat offers important energy efficiency opportunities in many countries. Various industries cogenerate steam and electricity for further use in their own plant [9].

When electricity is generated, the heat, as a by-product, can be captured and used for process steam, heating or other industrial purposes. Cogeneration converts up to 90% of fuel into usable energy.

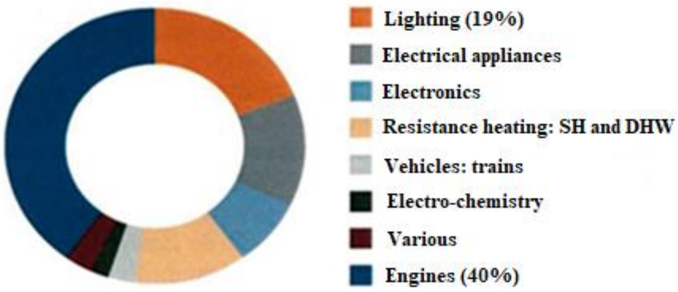

Fig. 3. Global electricity demand.

Advanced boilers and furnaces can operate at higher temperatures while consuming less fuel. These plants are more efficient and produce fewer pollutants.

Electric motors are by far the most important type of electrical load in the industry using about 70% of the electricity in the process. In the tertiary sector, electric motor systems use almost a third of the electricity processed.

Electric motors usually run at a constant speed, but the variable speed drive allows the energy at the motor terminals to match the load required. This results in energy conservation of between 3 and 60% depending on how the motor is used. Electric motor coils made of super-conducting materials can also reduce energy losses. In addition, motors can also benefit from voltage optimisation [3].

The industry uses a large number of pumps and compressors of all shapes, sizes and applications. The efficiency of pumps and compressors depends on many factors, but improvements can often be made by implementing better process control and maintenance practices. According to the US Department of Energy, optimizing compressed air systems by installing variable speed drives, along with preventive maintenance to detect and eliminate air leaks can improve energy efficiency by 20 - 50% [7].

Energy efficiency is sometimes seen as an easy way to achieve immediate energy savings. Technically efficient solutions are available today for most applications and uses. Technological developments offer and will in the future offer various technical solutions to improve energy efficiency, but there are barriers: organisational, financial and behavioural that need to be addressed holistically.

4. CONCLUSIONS

Implementing the concept of sustainable development requires the development of the following appropriate policies for the energy sector:

- stimulating the production of electricity from renewable energy sources as a solution to reduce greenhouse gas (GHG) emissions;

- encouraging energy efficiency, linked to the introduction of new technologies, but also with important financial symbols, which is one of the most difficult problems facing the energy sector;

- ensuring energy security, operational reliability and energy quality;

- the accessibility of electricity to users, a major requirement for this sector in order to improve society's standard of living;

- appropriate reforms of the energy market, a complex market economy issue;
- the problem of energy resources, the choice of electricity production structure, the use of high-performance technological means;
- ensuring minimum environmental impact.

Ambitious energy efficiency targets go beyond technical solutions and go further in terms of cost-effectiveness, financing, acceptance, innovation and environmental impact assessment.

The profitability of investing in energy efficient technologies is often unknown or questioned. Government agencies should promote comprehensive cost-effectiveness studies, including cost/benefit assessments.

Funding energy efficiency requires a long-term commitment and the funding framework should take this into account. The duration of loans should cover the whole lifetime of the solution.

REFERENCES

[1]. Handra A.D., Păsculescu D., Uțu I., Marcu M.D, Popescu F.G., Rada A.C., *Tehnici de optimizare în energetică*, Editura UNIVERSITAS, Petroșani 2022

[2]. Leca A., *Managementul energiei* , Editura Agir, Bucuresti, 2007.

[3]. Rada A.C., Irimie S., Irimie S.I, *Economic, Energetic, and Environmental Impact Evaluation of the Water Discharge Networks from Mining Works.* Sustainability, Basel, Switzerland, 2018.

[4]. Suciu C., Handra A.D., Rada A.C., Marcu M.D., *Improving the operational strategy of industrial enterprises,* Annals of Constantin Brâncuși University of Târgu-Jiu - Engineering Series, 2021.

[5]. * * * Baza de date privind eficienţa energetică a Consiliului Mondial al Energiei – CME, 2010.

[6]. * * * Best Available Techniques for Energy Efficiency, Sevilla, Spain, February 2009.

[7]. * * * Department of Energy USA, https://www.energy.gov/.

[8]. * * * Agenția Internațională a Energiei, *World Energy Outlook* (Perspective energetice mondiale, AIE), 2011.

[9]. * * * *Perspectivele energetice mondiale. Tehnologiile eficiente din punct de vedere energetic.* (Raport recapitulativ preluat de la Consiliul Mondial al Energiei), EMERG 1, an 1, Editura AGIR, București, 2015.

HEALTH AND SAFETY RISK ASSESSMENT FOR THREE REPRESENTATIVE WORKSTATIONS FROM PAROSENI THERMO-ELECTRIC POWER PLANT

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Abstract: The results obtained regarding the assessment of occupational injury and illness risks for three representative workplaces within a thermo-electric power plant are presented, following the application of a nationally recognized method. Based on the description of the investigated workplaces, the identification of specific risks, the allocation of severity and probability classes, the calculation of partial and global risk levels, the ranking of risks and the establishment of intervention priorities were carried out. On this basis, prevention and protection measures intended to be implemented in order to minimize occupational risks in a pragmatic, feasible and realistic manner were proposed.

Key words: thermo-electric power plant, risk of injury and occupational disease, probability, severity, prevention and protection measures.

1. INTRODUCTION

In specialized terminology, human safety in the work process is considered as that state of the work system in which the possibility of occupational injury and illness is excluded. In common language, safety is defined as the fact of being safe from any hazard, and risk - the possibility of getting into hazard [1], [13]. If we consider the usual meanings of these terms, we can define safety as the state of the work system in which the risk of injury and illness is zero. Therefore, safety and risk are two abstract, opposite concepts that are mutually exclusive [2], [14].

In reality, due to the features of any work system, such absolute states cannot be achieved [3], [16]. There is no system in which the potential risk of injury or illness is completely excluded; there is always a "*residual*" risk, if only due to the unpredictability of human action. If corrective interventions are not made along the way, this residual risk increases as elements of the work system degrade through "*aging*". Consequently, the systems can be characterized by "safety levels", respectively "risk levels", as quantitative indicators of the safety and risk states respectively [4], [5].

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In this context, in practice a minimum risk limit must be admitted, i.e. a risk level different from zero, but small enough to consider that the system is safe, as well as a maximum risk limit, which is equivalent to a such a low level of safety that the operation of the system is no longer allowed [6], [7], [23]. Risk has been defined in the specialized literature in the field of work safety by the probability with which, in a work process, an accident or a professional illness occurs, with a certain frequency and severity of the consequences [8], [17].

Indeed, if we admit a certain risk, we can represent it, depending on the severity and the probability of the consequences, through the surface of a rectangle, developed vertically; it follows that the same surface can also be expressed by a square or by a rectangle extended horizontally. In all three cases the risk is equally high. Consequently, we can assign different gravity - probability couples, the same level of risk.

If we join the three rectangles through a line drawn through the vertices that are not on the coordinate axes, we obtain a curve with the appearance of a hyperbola, which describes the connection between the two variables: gravity - probability. In order to represent the risk as a function of severity and probability, such a curve is defined as a "*risk acceptability curve*" [9], [15].

This curve allows the differentiation between acceptable and unacceptable risk. Thus, the risk of occurrence of an event A, with serious consequences, but very low frequency, located below the acceptability curve, is considered acceptable, and the risk of event B, with less serious consequences, but with a higher probability of occurrence, of whose coordinates lie above the curve, is unacceptable. For example, in the case of a nuclear power plant, such measures are taken that the risk of a nuclear event - be it the risk of event A - is characterized by an extreme seriousness of the consequences, but an extremely low probability of occurrence [18], [20].

Due to the very low frequency of occurrence, the activity is considered safe and the risk accepted by society. Conversely, if for the risk of event B we take as an example the road accident caused by the activity of a driver, although this type of event causes less serious consequences than a nuclear accident, the probability of occurrence is so high (very high frequency) that the place of the driver's work is considered unsafe (unacceptable risk) [19], [22]. Any safety study aims to establish acceptable risks. Such a treatment of risk raises two problems:

- how to establish the coordinates of the risk: the gravity-probability couple;
- which risk coordinates will be chosen to delimit the areas of acceptability from those of unacceptability.

In order to solve them, the premise from which the development of the applied evaluation method started was the risk - risk factor relationship. The existence of risk in a work system is due to the presence of occupational injury and disease risk factors [21]. Therefore, the elements with which the risk can be characterized, so its coordinates can be determined, are actually the probability with which the action of a risk factor can lead to an accident and the severity of the consequence of the action of the risk factor on the victim. Risk assessment for the safety and health of workers is a legal obligation for any organization [10-12].

2. MATERIAL AND METHOD

2.1. General presentation of the Paroșeni Electrocentrale Branch

The activity profile of the organization is the production and emission in the National Energy System of electricity, installed power 150 MWh. The Paroşeni Electrocentrale branch was built at the beginning of the 50s, starting from a project of Russian origin, being the first coal-fired power plant in our country. The electricity and thermal energy production plant in the municipality of Vulcan was designed to supply the entire Valea Jiului region with electricity and thermal energy, as well as the mining industry in the six localities of the area. The modernization of the Paroşeni Power Plant was carried out by a consortium formed by the Japanese companies Itochu, Hitachi and Toshiba. The project included the refurbishment of a group of 150 megawatts and 150 gigacalories/hour.

Generically named "*Group IV*" of S.E Paroseni, it was put into operation in 2007 and represents the largest investment in the thermal energy system since 1989 and until now. The Paroseni power plant is located in the central part of Romania, in the so-called "*Jiu river valley*", which connects the south (Oltenia region) with the center of Romania (Transylvania). The Paroseni power plant is located on the lower terrace on the right bank of the West Jiului, "*at the mouth of the mine*" in the center of the Petroşani depression, between the towns of Vulcan and Lupeni. The road access to the plant site is made from DN 66 A Petrosani-Lupeni, and the railway connection is made from Vulcan Station via the independent railway line of the plant (Fig.1).

Fig.1. Location of the Paroşeni Power Plant

Access to S.E. Paroşeni is reached from the national road "*DN - 66A*", practicable all year round. The access of intervention vehicles to the objective is achieved through the main gate and a secondary entrance (gate no. 2). The internal access roads are 90% paved and the rest are paved and are accessible to emergency vehicles all year round. During bad weather, the roads leading to the coal stacks and coal unloading stations no. 1 and 2 are more difficult to access for emergency vehicles. The coal is brought to the plant by normal railway on the route "Vulcan station - Paroşeni sorting - coal stacks S.E. parishioners".

Coal is provided by a number of mines located approx. 5-15 km away from the plant. Its transport is done by rail. Coal unloading is done from wagons either in the coal stacks or directly in the bunkers of the coal unloading station (Fig.2).

Fig. 2. The coal unloading station

The solid fuel storage consists of two equal coal stacks with a total capacity of 60,000 tons. The coal stacks are slightly elevated above the level of the surrounding land and have been provided with water drains. BAT technologies (the best available techniques) are applied to the entire fuel flow of the plant: unloading, sorting-crushing, storage-retrieval, transport and supply of bunkers arranged on two distinct circuits (reserve in machinery 100%) so that corroborated with the nominal flow rate and the reserve stock, it is possible to ensure the coal supply continuously and at the parameters required for the boilers in operation.

With the help of the belt circuit, the coal reaches the bunkers of the mills. In coal mills, coal dust is obtained which reaches the coal burners through the air-dust pipes. Physico-chemical characteristics of the type of coal used (project data):

- total humidity: 11.2 - 6.0 % (10.7 % guarantee value);
- ash: 46-33.7 % (38.0 % guarantee value);
- lower calorific value: 3300-4510 kcal/kg (3916 % guarantee value).

The natural gas is taken from the national methane gas distribution network (SNGN ROMGAZ SA Mediaş), by means of a regulation and measurement station, located in the vicinity, through a pipe with nominal diameter Dn 500 mm.

The measurement regulation station has the role of filtration, pressure regulation and measurement of the gas used in the plant (Fig.3).

Fig.3. The measurement regulation station

- maximum pressure after SRM: 0.5 bar;
- nominal pressure after SRM: 0.35 bar;
- minimum breakdown pressure: 0.2 bar.

Physico-chemical characteristics of natural gas for starting and sustaining, Pci = 8050 ÷ 9500 kcal /Nmc.

The amount of gas consumed annually is 5,500 thousand m3, at an average calorific value of 8330 l/m3. Cooling water (technological water): the cooling water supply source (on the hydrotechnical circuit) is the Jiul de Vest river through a mobile dam equipped with 5 weirs, located 1.5 km upstream from the plant. About 200 m downstream from the water intake there is a decanter with a flow rate of 54,000 mc/h, provided with 2 settling chambers (Fig.4).

Fig.4. Baleia dam

The water is passed through a sanitiser and is transported by gravity to the plant through a reinforced concrete channel with two compartments. The plant can operate in open, mixed and closed circuit. The indoor cooling circuit is composed of hot and cold water channels and pipes, cooling water pump station and cooling towers, respectively:

- 5 cooling towers with countercurrent natural draft, Hyperbolic type, of which 3 in operation and 2 withdrawn from operation, capacity 10,000 m^3/h each (Fig.5);

Fig.5. Cooling towers

- 6 recirculation pumps for mixed or closed circuit;
- 2 pcs (1 and 2) P=250 Kw and Q= 4,000 m^3/h;
- 4 pcs (3-6) P= 1100 KW and Q = 12,000 m^3/h.

The evacuation of the water from the cooling circuit is done in the Jiul de Vest river, through an open channel. The water requirement for the plant is:

- open circuit – 29,920 m^3/h;

- mixed circuit – 13,160 m^3/h;
- closed circuit – 1,160 m^3/h.

Water consumption in West Jiu in 2013 was 19,981 thousand cubic meters. The water flow is necessary for the following installations:

- turbine condensate installation;
- cooling installation;
- slag and ash evacuation system.

2.2. The applied method for assessing the accidents and occupational diseases risks

The method developed within the I.N.C.D.P.M. Bucharest aims to quantitatively determine the level of risk for a workplace, sector, section or enterprise, based on the systemic analysis and assessment of occupational injury and disease risks. The essence of the method consists in the identification of all risk factors in the analyzed system (workplace) based on predetermined checklists and the quantification of the size of the risk based on the combination of severity and frequency of the maximum foreseeable consequence. The method can be used both in the conception and design phase of jobs, as well as in the exploitation phase. However, its application requires complex teams made up of people specialized both in work safety and in the analyzed technology (evaluators + technologists). In the first situation, the method is a useful and necessary tool for designers in order to integrate the principles and measures of work safety in the conception and design of work systems. In the exploitation phase, the method is useful to the personnel from the labor protection departments of enterprises for the fulfillment of the following attributions:

- the analysis on a scientific basis of the state of labor security at each workplace;
- rigorous substantiation of prevention programs.

The method includes the following ***mandatory steps***:

1. *defining the system to be analyzed (job);*
2. *identification of risk factors in the system;*
3. *assessment of occupational injury and illness risks;*
4. *the ranking of risks and the establishment of prevention priorities;*
5. *proposing preventive measures*.

The steps necessary for the assessment of work security in a system, described previously, are carried out using the following ***work tools***:

a. *List of identification of risk factors;*
b. *List of possible consequences of the action of risk factors on the human body;*
c. *Rating scale of severity and probability of consequences;*
d. *The risk assessment grid;*
e. *The classification scale of the risk levels, respectively of the security levels;*
f. *Job sheet - centralized document;*

g. *List of proposed measures.*

The global risk level (N_r) at the workplace is calculated as a weighted average of the risk levels established for the identified risk factors. In order for the obtained result to reflect reality as accurately as possible, the rank of the risk factor is used as a weighting element, which is equal to the risk level.

In this way, the factor with the highest level of risk will also have the highest rank. This eliminates the possibility that the compensation effect between extremes, which any statistical average implies, masks the presence of the factor with the maximum level of risk. The formula for calculating the global risk level is as follows:

$$N_r = \frac{\sum_{i=1}^{n} r_i \cdot R_i}{\sum_{i=1}^{n} r_i} \qquad (1)$$

where:

N_r is the overall level of risk in the workplace;

r_i - "i" risk factor rank;

R_i - risk level for risk factor "i";

n - the number of risk factors identified at the workplace.

The application of the method ends with the drafting of the analysis report. This is an informal instrument that must contain, clearly and succinctly, the following:

- the manner of carrying out the analysis;
- the persons involved;
- the results of the assessment, respectively job sheets with risk levels;
- interpretation of the evaluation results;
- prevention measures sheets.

In order for the application of the method to lead to the most relevant results, the first condition is that the system to be analyzed is a workplace, well defined in terms of its purpose and elements. In this way, the number and type of potential interrelationships to be investigated and implicitly the risk factors to be considered are limited.

A particularly important condition is the existence of a complex and multidisciplinary evaluation team, which includes occupational safety specialists, designers, technologists, ergonomists, physicians specialized in occupational medicine, etc., corresponding to the varied nature of the elements of work systems, but also to risk factors. The team leader must be the occupational safety specialist, whose main role will be to harmonize the points of view of the other evaluators, in the sense of subordinating and integrating the criteria used by each of them to the goal pursued by the analysis: the evaluation of occupational safety.

3. ASSESSMENT OF RISKS FOR THE SAFETY AND HEALTH OF WORKERS WITHIN THE FRAMEWORK OF C.E.T. PAROSENI: EARTH – COAL MOVER MACHINIST

3.1. The work process/task

The MCB bucket wheel combined machine is intended for operation in the coal depot at S.E. Paroşeni, being able to perform the following distinct operations:

- heap stacking of the coal taken from the stationary belt on the ground;
- taking the coal from the dump and depositing it on the stationary belt from the ground (and from here, to the energy boilers for steam production);
- passing the entire flow of material from the stationary conveyor belt from the ground through the machine (by-passing the machine);
- picking up the material from the dump and additionally depositing it on the material flow of the stationary conveyor belt on the ground that passes through the machine (by-passing + additional depositing).

For taking or depositing (stacking) the coal, the combined machine can work from a fixed point or by translating the machine (on its track). For the safety of the attendants and the machine, to avoid accidents, the component equipment are connected in an interlocking system that ensures the stopping of the upstream or downstream equipment, as the case may be, when one of the equipment stops. For example, in stacking mode, if the reversible arm conveyor is stopped, then the intermediate conveyor, ground belt 11B and all upstream belt flow will be stopped by interlocking. Another example: in pick-up mode, if the reversible conveyor stops, then the bucket rotor will also stop.

3.2. The means/equipments of production

The combined machine with bucket wheel serves:

- in the stacking cycle - for depositing the material in the above-ground storage of the thermal power plant;
- in the pick-up cycle - for removing the material from storage.

The pick-up and stacking arm can perform a rotation movement relative to the track axis as well as a lifting-lowering movement. The coal stacking and taking operations are performed on one side of the track, along the warehouse. The power supply of the control and power devices is made by cables which, during the translational movement of the machine, are wound on the cable drums. The control cabin is located as reasonably as possible at the top of the boom, ensuring optimal visibility during operation. The operation of the machine is done in accordance with the work safety instructions of the respective work sector and the internal instructions developed by the Fuel Exploitation Section.

3.3. Working task

The earthmoving machine drivers work in 3 shifts, according to the monthly schedule, based on the schedule (shift I, II or III). They, depending on the level of authorization (ISCIR and internal), work on the various earthmoving machines in the warehouse. The combined machine is operated by at least two drivers:

- machinist handling the machine (driver of the machine);
- machinist supervision and current maintenance of the machine.

During the service, the two machinists collaborate and support each other, they can replace each other, rotate in the execution of the tasks and therefore work in approximately the same conditions. For this reason, they are exposed to the same risks of accidents and occupational diseases. During the operation of the combined machine, if necessary, the intervention of the operation, maintenance or PRAM - AMC electricians is ensured.

3.4. Work environment

The combined machine serves the external coal storage, located in the western part of the thermal power plant premises. The activity of the drivers on the combined machine takes place both in the cabin of the machine and in the open air, on the work platforms and its circulation paths. The work platforms and circulation lanes are made of corrugated sheet metal or metal gratings, to ensure a good grip when the workers who use them move or stand. However, in winter there is the possibility of snow deposition and the formation of portions of ice, and therefore there is a risk of slipping. There is work lighting and backup lighting for continuing work or evacuation. The lighting is natural during the day and artificial at night, from the headlights and projectors of the car and from the projectors on the perimeter of the warehouse. The climate in Vulcan - Paroşeni is normal temperate. The temperatures usually fall between the values "- 20 ˚C" and "+ 30 °C" and the relative humidity is a maximum of 65%.

The cab of the combined machine is heated, but in winter the operator for supervision and current maintenance (who works outdoors on the outside platforms) is exposed to low temperatures, precipitation and drafts. During hot periods, both machinists who service the machine are exposed to high temperatures. At wind speeds greater than 25 m/s, the wind protection operates and the machine disengages and stops working. Due to the motors on the machine, the carbon belts, the bucket rotor, the production of vibrations is inherent during its operation and these are transmitted to the limbs and throughout the body, from the seat, levers, floors, platforms, etc.

During operation, the swing of the machine arm, on which the bucket wheel and control cab are mounted, may occur. The noise produced during the operation of the machine does not exceed the permitted limit of 87 dB, neither in the cabin nor in the outside spaces. Because masses of coal are handled, drivers are exposed to respirable pneumoconiogenic dusts, especially when the coal is dry. To a lesser extent, because they work outdoors, they are exposed to toxic gases, vapors, aerosols from the operation of engines. It can be concluded that the outdoor coal storage is a rather aggressive workplace, which presents risks of injury and illness for the workers. Types of accidents / diseases related to the profession: mechanical trauma, cutting, slipping, penetration of foreign bodies into the eyes, burns, intoxications, electrocutions, sunstrokes, colds, rheumatic diseases, dorsolumbar diseases, etc.

A relevant extract from the risk assessment sheet is represented in table 1.

Table 1. ***The evaluation form of the analyzed workplace***

Unit: SC Hunedoara Energy Complex		**THE EVALUATION FORM OF THE ANALYZED WORKPLACE**	**Workers exposed:** 15			
Section: C.E.T Paroșeni			**Exposure length**: 8 h/shift			
Workplace: Earth-coal mover machinist			**Evaluation team**: Risk assessor, department head, occupational medicine doctor, machine operator			
Work system component	**Identified risk factors**	**The concrete form of manifestation of the risk factors (description, parameters)**	**Max. severity**	**Severity class**	**Likelihood class**	**Risk level**
a. <u>Work equipment</u>	***a1.Mechanical risk factors***	1. Functional movements of technical equipment and machine parts in motion: translating (moving) the entire machine on the CF rail, turning / raising / lowering the arm, raising / lowering the belt rider, turning bucket wheel, running belts, rollers and tape drums , strippers and plows, discharge funnels and valves, servomechanisms (hydraulic cylinders), drums for electrical cables, etc.	Death	7	3	5
		4. The overturning of the machine due to the appearance of additional loads that lead to the imbalance of the access due to improper operation in winter (additional loads due to snow, frost), operation during strong wind (with a speed greater than 25 m/sec.), the production of sudden movements, shocks in the event of malfunctions (e.g. the failure of the arm tilting servomechanism with bucket) or the appearance of additional resistances (e.g. frozen portions in the coal stack, in winter), obstacles on the machine's path, etc.	Death	7	2	4
		7. The uncontrollable swing of the machine arm and the driver's cab or sudden movement (shock), due to some obstacles in the work front (e.g. bolts, metals, wooden material), difficult working conditions in winter due to frost, non-compliance with the prescriptions in the machine's technical book.	Death	7	2	4

		13. Containers under pressure: hydraulic cylinders, hoses, solenoid valves, etc. from the arm tilting servomechanisms and the rider conveyor (30 - 160 bar).	Death	7	1	3
	a2. Thermal risk factors	15. High temperature of accidentally touched surfaces (eg: ungreased, seized bearing boxes and transmission boxes; terminal boxes and motor casings with electrical or mechanical defects).	ITM 3 - 45 days	2	3	2
	a3. Electrical risk factors	17. Electrocution by direct contact with live components of equipment or installations (e.g. accidental damage to housings or insulation).	Death	7	1	3
	a4. Chemical risk factors	19. Risk of fire due to the presence of combustible and flammable materials: coal, coal dust, rubber tape, cable insulation, oils, greases.	Invalidity degree 3	4	3	4
b. Work environment	***b1. Physical risk factors***	20. High air temperature in the summer, during hot periods, when it is possible to go beyond the normal limits of comfort.	ITM 3 - 45 days	2	3	2
		21. Low air temperature in winter, when working outdoors, when starting work when the cabin is not heated, when carrying out revisions or repairs.	ITM 45 - 180 days	3	4	3
		22. Drafts when working outdoors or due to leaks in the cabin.	ITM 3 - 45 days	2	4	2
		26. Insufficient exterior lighting level of the warehouse at night in some parts.	Death	7	2	4
		27. Natural calamities: lightning, strong wind, blizzard, hail, frost, earthquake.	Death	7	1	3
	b2. Chemical risk factors	28. Pneumoconiogenic dusts in suspension in the breathed air (respirable quartz dusts that can exceed the maximum permissible limit of 2 mg/m3) due to the handling of coal masses - dust released in the area of the bucket rotor, coal discharge points and due to oscillations during the movement of the belt over the rollers and the vibrations induced by the rotating aggregates .	Disability degree 3	4	3	4
	b3.	29. Dangerous animals (stray dogs) or insects (wasps, bees).	Death	7	1	3

	Biological risk factors					
c. <u>Working task</u>	***c2. Oversized / undersized task in relation to the ability of the performer***	30. Static effort exerted by the driver in the cab, for handling the machine controls.	Negligible ITM < 3 days	1	5	1
		31. Dynamic effort (high physical effort) performed by the supervising machinist for cleaning the color, platforms (dust and fallen material), cleaning stuck material on rollers, drums, beams, etc., unclogging hoppers, movements to carry out maneuvers, adjustments and supervision, maintenance works, liquidation of accidents, incidents, snow removal in winter, etc.	ITM 3 - 45 days	2	5	3
		35. Stress due to some (possible) problems at department and/or company level (e.g. relationships with colleagues and superiors, tasks and workload, work climate, job uncertainty, etc.) and own problems (health, financial problems, family problems, etc.).	ITM 45 - 180 zile	3	3	3
d. <u>Human factor</u>	***d1. Wrong actions***	36. Working under the influence of alcoholic beverages, in an advanced stage of fatigue or after taking certain medications.	Death	7	1	3
		37. Working under the influence of inappropriate conditions at the moment (stress, emotions, nervousness, depression, family or professional conflicts, voluntary effort at the moment).	Death	7	2	4
		43. Leaving the cab by the driver while the machine is operating, without stopping it, putting the controls in the zero position, engaging the brakes, cutting off the electric current and securing the machine against any possibility of movement or accidental start-up during rest.	Death	7	1	3
		44. Parking in dangerous areas (within the range of action of the bucket wheel, on the CF when moving (translating) the machine, at coal dumping points, in areas with a danger of tripping over coal stacks, etc.).	Death	7	1	3
		45. Running the machine's power cord by hand - risk of unbalancing, bumping, catching and crushing or breaking hands.	Disability degree 3	4	2	3

		46. Falling from the same level by tripping, slipping, unbalancing when moving on the circulation paths from the external coal storage but also on the circulation paths from the machine.	ITM 3 - 45 zile	2	4	2
		47. Falling from a height (from a car) by slipping, tripping, unbalancing, leaning over railings, climbing on equipment without taking safety measures.	Death	7	3	5
		48. Faulty communication, non-synchronization between the two drivers of a work formation on the machine (e.g. performing rotation maneuvers, raising / lowering the arm, moving the machine, starting lanes, etc. without announcing and informing each other).	Death	7	1	3
		49. Sleeping in the cabin or in other areas of the machine.	Death	7	1	3
	d2. Omissions	50. Failure to use the protective equipment provided (individual protective equipment and protective devices).	Death	7	3	5
		52. Omission of some operations, for example: - failure to check the condition of machinery, brakes, lubrication mechanisms, electrical installations, etc. at the start and then periodically during the work; - starting the machine without giving the start sound signal, to warn the other workers; - cleaning, greasing or repairing machine parts in motion without stopping the respective equipment.	Death	7	1	3
		57. Failure to release the manual clamps for blocking the machine's translation, when it is put back into motion.	Death	7	1	3
		58. Failure to ensure the necessary visibility from the control cabin, due to the windows being dirty, blocked or frozen or due to the non-functioning of the lighting installations at night .	Death	7	1	3
		59. Omitting some preparatory operations for fixing faults: correct positioning, with the security devices and equipment that must be activated, disconnecting the electricity, bringing all controls to the zero position, etc..	Death	7	1	3

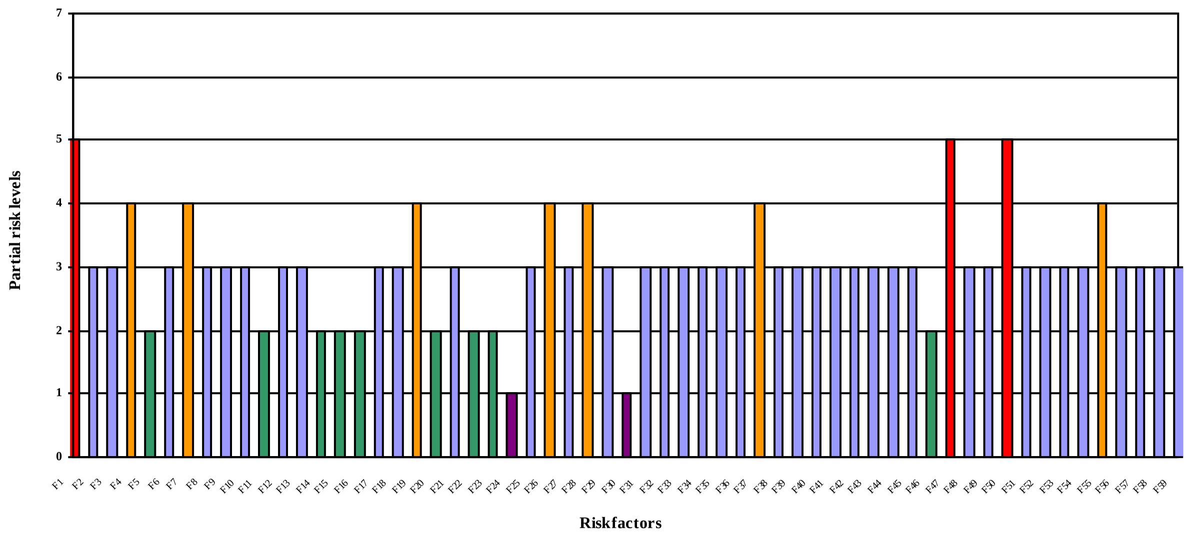

Fig.6. Partial risk levels of the identified risk factors for the job „Earth-coal mover machinist"

Calculation of the global risk level

$$\mathbf{N_{rgl}} = \frac{\sum_{i=1}^{n} r_i R_i}{\sum_{i=1}^{n} r_i} = \frac{\sum_{i=1}^{59} r_i R_i}{\sum_{i=1}^{59} r_i} = \frac{2(1x1) + 9(2x2) + 38(3x3) + 7(4x4) + 3(5x5) + 0(6x6) + 0(7x7)}{(2x1) + (9x2) + (38x3) + (7x4) + (3x5) + (0x6) + (0x7)} = \frac{567}{177} = \mathbf{3,20}$$

Table 2 centralizes the prevention and protection measures proposed based on the evaluation, measures that will form the basis of the prevention and protection plan drawn up in accordance with the requirements imposed by the legislation in force.

Table 2. ***Extract Sheet of proposed measures for the workplace: Earth-coal mover machinist***

Crt. no	Factori de risc identificaţi	Partial risk level	Measures proposed for rosk mitigation
1.	1. Functional movements of technical equipment and machine parts in motion: translating (moving) the entire machine on the CF rail, turning / raising / lowering the arm, raising / lowering the belt rider, turning bucket wheel, running belts, rollers and tape drums , strippers and plows, discharge funnels and valves, servomechanisms (hydraulic cylinders), drums for electrical cables, etc.	5	***Technical measures*** - Maintaining in good condition the protectors and security casings of moving machine bodies; Their painting and inscription according to the norms of s.s.m.; - Keeping the blockages, interlocks, signals and devices for safety shutdown of the equipment in good working order; - Keeping the traffic lanes in good condition: railings, not to slide, not to be obstructed by the storage of materials, etc.; - During operation, only the presence of its attendants (2 people) is allowed on the machine; - Before putting the machine and the equipment on it into operation (e.g. conveyor belts), the sound signals established in the internal technical instructions will be given; ***Organizational measures*** - Review and permanent update of the s.s.m. documentation. (risk assessments, instructions, OSH plans, training topics, etc.); - Providing the appropriate personal protective equipment: non-slip shoes, tight overalls, helmet equipped with a chin strap, protective gloves, etc.
2.	47. Falling from a height (from a car) by slipping, tripping, unbalancing, leaning over railings, climbing on equipment without taking safety measures.	5	***Technical measures*** - Keeping traffic overpasses, stairs, work platforms in good technical condition; - Prohibition of storing materials, parts, tools on the combined machine in order not to block the circulation paths and work platforms; - Keeping the railings in good condition; - Erasing oil or vaseline stains from the roads; - Intervention in certain areas of the car, not protected by railings, will only be done using the seat belt. ***Organizational measures*** - Training of service personnel as well as repair personnel on the dangers and measures for safe movement at high heights (over 2 m) of the combined machine: only on arranged and maintained circulation paths, ensuring lighting, etc.); - Equipping personnel with protective equipment for working at height (safety belt, rope, mobile ladders).

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Crt. no	Factori de risc identificaţi	Partial risk level	Measures proposed for rosk mitigation
3.	50. Failure to use the protective equipment provided (individual protective equipment and protective devices).	5	***Organizational measures*** - Training workers regarding the consequences of non-use or incomplete use or the use of inadequate personal protective equipment; - Verification of the wearing of protective equipment by workers, daily, carried out by the shift leader and/or, by survey, by hierarchical superiors. Prohibition of working without full protective equipment. Penalty for not wearing protective equipment.
4.	19. Risk of fire due to the presence of combustible and flammable materials: coal, coal dust, rubber tape, cable insulation, oils, greases.	4	***Technical measures*** - Casing according to the degree of risk presented by the dusty environment of electrical equipment (panels, panels, switches, terminal boxes, etc.); - Maintenance of electrical installations in good condition; Avoiding improvisations; Correct laying of cables; Grounding or grounding; - Thermal insulation of sources that release heat (bearings) by casing, shielding; - Permanent cleaning to eliminate possible sources of ignition: material (coal) fallen from the belts, dust deposits, oil leaks; - Prohibition of storing combustible / flammable materials under or on the combined machine; ***Organizational measures*** - Periodic training and testing of workers in the PSI field for the activity performed; - Review and permanent update of the specific internal PSI instruction for the combined machine; - Organization of fire protection at workplaces, according to the PSI legislation in force; - Establishing and setting up smoking areas according to the rules. Hygienic-sanitary measures - Equipping first aid kits with ointments and special medicines for burns; - Equipment of the Expl. Section Fuel with personal protection and rescue equipment and devices (gas and smoke masks, anti-caloric suits, PSI storms, stretchers, rescue ropes, etc.);

4. RESULTS INTERPRETATION

The global risk level calculated for the job ***Earth-coal mover machinist*** is equal to 3.20 - a value that falls into the category of jobs with medium risk level / medium security level. The result was obtained by drawing up the ***Job Evaluation Form***, from which it can be seen that out of the total of 59 identified risk factors:

- 0 falls into the category of *maximum risk factors* (level 7);
- 0 falls into the category of *very high risk factors* (level 6);
- 3 fall into the category of *high risk factors* (level 5);
- 7 fall into the category of *medium risk factors* (level 4);
- 38 fall into the *low risk class* (level 3);
- 9 fall into the *very low risk class* (level 2);
- 2 fall into the *minimum risk class* (level 1).

From a statistical point of view, regarding the distribution (weight, frequency) and level (value) of risk factors by types of generating sources, the situation is presented in fig.7:

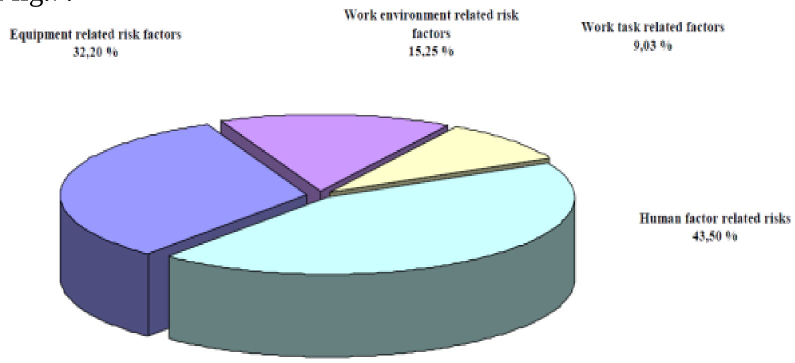

Fig.7. The share of the number of risk factors identified by the elements of the work system

It is noted that the main risk factors are the combined machine and the workers, so great importance will be given to the technical condition, working technology with the combined machine and the training and discipline of the workers. For a better interpretation and awareness, the distribution of risk factors is represented in the form of diagrams in fig.2 and fig.3. From the analysis of the Evaluation Form, it is found that out of the 59 identified risk factors, 40 can have irreversible consequences on the performer (35 death and 5 disability grade 3), i.e. 67.79%.

5. CONCLUSIONS

The research aimed at risk assessment and the development of the prevention and protection plan for the Paroşeni Power Plant Branch, in accordance with the legislation in force at national level in the field of safety and health at work. The study was developed based on the data provided by S.C. Complexul Energetic Hunedoara

S.A. – Paroşeni Power Plant Branch; through the job descriptions, lists of technical equipment, their technical books, the regulations for granting individual protective equipment, information about technological processes and the development of the work process for each job, received from the company's management and technical staff, as well as and the own observations made on the occasion of the documentation visits and follow-up of the activity for each workplace. The completion of the work consisted of the following stages:

- analysis of the activities carried out within the company;
- establishing the workplaces for which the risk assessment for safety and health at work was carried out;
- identification of risk factors for each workplace;
- establishing the maximum foreseeable consequence of the action of the risk factors onto the human body, for each individual risk factor;
- classification in gravity classes;
- classification in probability classes (frequency);
- determination of the partial risk level for each identified risk factor;
- calculation of the global risk level for each job;
- interpretation of the results of the risk assessment for safety and health at work for each workplace, through the lens of current legislation;
- preparation of measures sheets for each workplace, for risk factors that exceed the acceptable level.

The ranking of analysed workplaces, depending on the global level of risk, is shown in table 3.

Table 3. ***Ranking of investigated workplaces according to the global level of risk***

Nr. crt	**Workplace**	**Overall risk level**
1	Earth-coal mover machinist	3.20
2	Machinist at the drive head of the coal conveyor belts	3.085
3	Coal unloading operator	3.01

The overall risk level on company is:

$$N_{gS} = \frac{\sum_{i=1}^{14} r_i \cdot N_{gi}}{\sum_{i=1}^{14} r_i} = 3{,}098 \qquad (2)$$

According to the ranking, it is found that all jobs have a global risk level below the allowed limit (3.5), they fall into the category of those with a low to medium risk level. The value of the aggregate global risk level per company N_{gS} = 3.098, determines its inclusion in the category of those with a low to medium risk level.

This situation, good from the point of view of compliance with the legislation in the field of safety and health at work, is due both to the concerns of the designated worker (or the internal/external prevention and protection service) and to the efforts made by the management of the company, which integrates aspects of efficiency economic with those of safety and health at work.

Risk assessment must be carried out in a systematic way based on a defined and logical methodology. The starting point must be a general examination (analysis of the current situation) that reveals the situation of the enterprise from the point of view of safety and health at work.

The assessment of risks in an enterprise must be comprehensive enough to offer alternative solutions for combating occupational risks (preferably at the source) and to establish the ranking and priority of preventive measures. The scope and level of detail of a risk assessment must always respect the severity and probability of occupational risks. For this, it must be shown that the generally recognized dangers of an industrial branch are taken into account, but it must be demonstrated that concrete findings from the field, at a given time, were also taken into account. The risk assessment must be appropriate, in the sense that the depth of analysis and the level of measures must be different for major and minor hazards.

REFERENCES

[1]. Azadeh-Fard N., Schuh A., Rashedi E., Camelio J.A., *Risk assessment of occupational injuries using accident severity grade*. Saf Sci **76**:160–167, 2015.

[2]. Băbuţ G.B., Moraru R.I., Cioca L.I., *Kinney methods": useful or harmful tools in risk assessment and management process?*, Proc. of the 5th Int. Conf. on Manufacturing Science and Educations - MSE 2011, Sibiu, Romania, 02-05 June, vol. II, 315-318, 2011.

[3]. Băbuţ G.B., Moraru R.I., *Critical analysis and ways to improve the I.N.C.D.P.M. Bucharest for the assessment of the risks of accidents and occupational diseases*, "Quality - access to success", **14** (137), 55-66, 2013.

[4]. Carter D.A., Hirst I..L., Maddison T.E., Porter S.R., *Appropriate risk assessment methods for major accident establishments*, Trans IChemE, **81**B, pp 12–18, 2003.

[5]. Cioca, L.I., Moraru, R.I., *Explosion and/or fire risk assessment methodology: a common approach structured for underground coalmine environments,* Arch. Mining Sciences, **57** (1), 53-60, 2012.

[6]. Fîţă N.D., Lazăr T., Popescu F.G., Pasculescu D., Pupăză C., Grigorie E., *400 kV power substation fire and explosion hazard assessment to prevent a power black-out*, International Conference on Electrical, Computer Communications and Mecatronics Engineering - ICECCME, 16 – 18 November, Maldives, 2022.

[7]. Fîţă N.D., Obretenova M.I., Pasculescu D., Tatar A., Popescu F.G., Lazar T., *Structure and analysis of the power subsector within the national energy sector on ensuring and stability of energy security*, Annals of the Constantin Brancusi University of Targu-Jiu, Engineering series, Issue 2 / 2022, pp.177-186, 2022.

[8]. Fîţă N.D., Radu S.M., Păsculescu D., Popescu F.G., *Using the primary energetic resources or electrical energy as a possible energetical tool or pressure tool,* Proceedings of Sciendo International Conference Knowledge based organisation – "Nicolae Balcescu" Land Forced Academy Sibiu, Vol. XXVII, No. 3, pp. 21-26, 2021.

[9]. Handra A.D., Popescu F.G., Păsculescu D., *Utilizarea energiei electrice - lucrări de laborator*, Editura Universitas, Petroşani, 167 pag., 2020.

[10]. Ivaşcu, L., Cioca, L.I., *Occupational Accidents Assessment by Field of Activity and Investigation Model for Prevention and Control*, Safety Journal, **5**, pp. 12, 2019.

[11]. Kokangül, A.„ Polat, U., Dağsuyu, C., *A new approximation for risk assessment using the AHP and Fine Kinney methodologies.* Saf Sci 91:24–32, 2017.

[12]. Lazăr T., Marcu M.D., Uțu I., Popescu F.G., Păsculescu D., *Mașini electrice - culegere de probleme*, Editura UNIVERSITAS, Petroșani, pp.197, 2023.

[13]. Moraru, R.I., Băbuţ, G.B., *A Romanian occupational health and safety risk assessment tool: premises, development and case study*. In: *Risk assessment and management*, Zhang, Z. (Ed.), Academypublish.org (Publishing Services LLC), Cheyenne, WY, USA, pp. 292-311, 2012.

[14]. Niculescu T., Pasculescu D., Pana L., *Study of the operating states of intrinsic safety barriers of the electric equipment intended for use in atmospheres with explosion hazard*, WSEAS Transactions on Circuits and Systems, Volume 9, pp.430-439, 2010.

[15]. Pasculescu D., Romanescu A., Pasculescu V., Tatar A., Fotau I., Vajai Ghe., *Presentation and simulation of a modern distance protection from national energy system*, Proceedings of the 10 th International Conference on Environment and Electrical Engineering – EEEIC 2011, Rome, Italy, pp. 646-650, 2011.

[16]. Pasculescu D., Slusariuc R., Popescu F.G., Fîță N.D., Tatar A., Lazar T., *Modeling and simulation of lighting of a road with 2 strips per direction to en 13201: 2015 Standard*, Annals of the University of Petrosani, Electrical Engineering, Vol.24, pp.65-74, Petrosani, 2022.

[17]. Pasculescu, V. M., Radu, S. M., Pasculescu, D., Niculescu T., *Dimensioning the intrinsic safety barriers of electrical equipment intended to be used in potentially explosive atmospheres using the simpowersystems software package*, Papers SGEM2013/Conference Proceedings, 417- 422 pp, Vol. Science and technologies in geology, exploration and mining, Bulgaria, 2013.

[18]. Pece, Ş., *Risk assessment in the work system*, Publishing House Rubin, Galaţi, 2010.

[19]. Popescu F.G., Pasculescu D., Marcu M., Pasculescu V.M., Fîță N.D., Tatar A., Lazar T., *Principles of effective energy management and power control system*, Annals of the University of Petrosani, Electrical Engineering, , Vol.24, pp.111-118, Petrosani, 2022.

[20]. Popescu F.G., Păsculescu D., Păsculescu V.M., *Modern methods for analysis and reduction of current and voltage harmonics,* LAP LAMBERT Academic Publishing, ISBN 978-620-0-56941-7, pp. 233, 2020.

[21]. Romanian Parliament, *The 319/2006 Act on Occupational Health and Safety*, Oficial Journal of Romania, Part I, No 646/26.07.2006

[22]. Romanian Government, *H.G. no. 1425/2006 for the approval of the Methodological Norms for the application of the provisions of the Law on safety and health at work no. 319/2006*, Official Gazette of Romania, Part I, no. 882 / 30.10.2006.

[23]. Romanian Government, *H.G. no. 955/2010 for the modification and completion of the Methodological Norms for the application of the provisions of the Law on safety and health at work no. 319/2006, approved by H.G. no. 1425/2006,* Official Gazette of Romania, Part I, no. 661 / 27.09.2010.

ELECTRICAL RESONANCE ANALYSIS ON RLC SERIES CIRCUIT

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Abstract: In a series RLC circuit, resonance occurs when the inductive reactance (XL) and capacitive reactance (XC) are equal in magnitude but opposite in phase.

It's important to note that in a series RLC circuit, the total impedance is the vector sum of the resistance (R), inductive reactance (XL), and capacitive reactance (XC). The resonant frequency is the frequency at which XL and XC are equal, resulting in the cancellation of these two reactances, leaving only the resistance.

In summary, the resonant frequency in a series RLC circuit is the frequency at which the inductive and capacitive reactances cancel each other out, leading to a minimum impedance and maximum current flow.

Key words: circuit, current, frequency, power, resonance, voltage.

1. INTRODUCTION

Alternating current electrical circuits are those circuits supplied with alternating electromotive voltages, usually sinusoidal in time. These circuits are of particular importance in engineering because of their many advantages in the generation, transmission, distribution and use of electricity [1], [3], [5].

In a series RLC circuit a frequency point occurs when the inductive reactance of the inductor becomes equal in value to the capacitive reactance of the capacitor. In other words, $X_L = X_C$. The point at which this occurs is called the **resonant frequency** point of the circuit, and as we analyze a series RLC circuit, this resonant frequency produces a **series resonance** [4], [7], [9].

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Series resonant circuits are some of the most important circuits used in electrical and electronic circuits [22]. They can be found in various forms such as AC mains filters, noise filters and also in radio and television circuits producing a highly selective tuning circuit for the reception of different frequency channels [2], [11], [17].

Resonance is a very valuable property of AC reactive circuits used in a variety of applications.

2. CASE STUDY

It is well known that passive AC electrical circuits of the Resistor-Coil-Capacitor (RLC) type achieve resonance (and therefore dissipate maximum energy on the resistor in the form of heat) at the resonant frequency, where the electrical impedance is minimum [8], [16], [18].

An experiment organized on an experimental stand formally described in Fig.1 can confirm this finding.

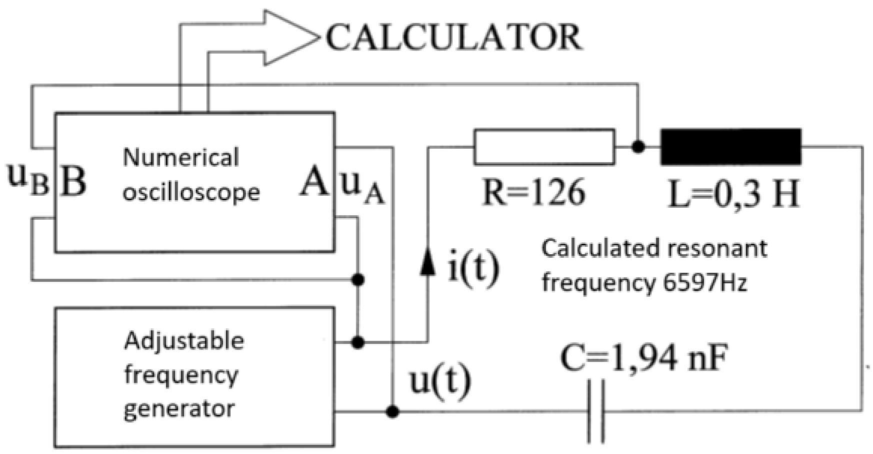

Fig.1. Schematic for electrical resonance analysis on the RLC series circuit

A frequency-tunable harmonic signal generator feeds a series circuit consisting of a resistor with resistance $R = 126\ \Omega$, a coil with inductance $L = 0.3\ H$ and a capacitor with capacitance $C = 1.94\ nF$. The resonance of this circuit is at pulse $\omega = 2\cdot\pi\cdot f$ (here f is the frequency) for which the electrical impedance modulus Z is minimum:

$$Z = \sqrt{R^2 + \left(X_L - X_C\right)^2} = \sqrt{R^2 + \left(\omega \cdot L - \frac{1}{\omega \cdot C}\right)^2} \qquad (0.1)$$

In this case the moduli of the inductive X_L and capacitive X_C reactances are equal. This condition is achieved for the excitation pulse $\omega = \frac{1}{\sqrt{L \cdot C}}$, i.e. the frequency: $f = \frac{1}{2 \cdot \pi \cdot \sqrt{LC}}$.

One can further investigate the evolution of the active power absorbed by this circuit for different values of the excitation frequency (at and near resonance) [6], [10], [23].

The active electrical power absorbed by the RLC circuit from the signal generator can be described with the relation:

$$P = \frac{1}{T} \cdot \int_{t=0}^{T} u(t) \cdot i(t) \cdot dt \qquad (0.2)$$

The active electrical power appears as the average value of the instantaneous power *p(t) = u(t)·i(t)* (product of instantaneous voltage - instantaneous current) calculated by integrating over a period *T=1/f* the instantaneous excitation voltage *u(t).* Instantaneous voltage and instantaneous current can be described as harmonic quantities with the relations [13], [19]:

$$\begin{aligned} u(t) &= U\sqrt{2}\sin(\omega t) \\ i(t) &= I\sqrt{2}\sin(\omega t - \varphi) \end{aligned} \qquad (0.3)$$

Here *U* and *I* are called rms values of voltage and current respectively (sometimes also called *rms* values, abbreviation of *root mean square*), the products $U\sqrt{2}$ and $I\sqrt{2}$ are the amplitudes of the harmonic developments, φ is the phase shift between current and voltage which can be positive or negative, depending on the character of the reactance, inductive ($X_L > X_C$) or capacitive ($X_C > X_L$ *)* [12], [15], [20].

With relations (1.3) the evolution of the active power in relation (1.2) can be written:

$$P = \frac{2}{T} \cdot \int_{t=0}^{T} U\sin(\omega t) \cdot I\sin(\omega t - \varphi) \cdot dt \qquad (0.4)$$

respectively

$$P = \frac{2 \cdot U \cdot I}{T} \cdot \int_{t=0}^{T} \sin(\omega t) \cdot [\sin(\omega t) \cdot \cos(\varphi) - \cos(\omega t) \cdot \sin(\varphi)] \cdot dt =$$
$$= 2 \cdot U \cdot I \cdot \cos(\varphi) \cdot \frac{1}{T} \int_{t=0}^{T} \sin(\omega t) \cdot \sin(\omega t) \cdot dt -$$
$$-2 \cdot U \cdot I \cdot \sin(\varphi) \cdot \frac{1}{T} \int_{t=0}^{T} \sin(\omega t) \cdot \cos(\omega t) \cdot dt$$

I mean:

$$P = 2 \cdot U \cdot I \cdot \cos(\varphi) \cdot F_1 - 2 \cdot U \cdot I \cdot \sin(\varphi) \cdot F_2 \qquad (0.5)$$

With:

$$F_1 = \frac{1}{T} \int_{t=0}^{T} \sin(\omega t) \cdot \sin(\omega t) \cdot dt$$
$$F_2 = \frac{1}{T} \int_{t=0}^{T} \sin(\omega t) \cdot \cos(\omega t) \cdot dt \qquad (0.6)$$

Although there are mathematical reasons on the basis of which the factors F_1 and F_2 can be calculated, a simple numerical calculation method is presented here [14], [21]. Assuming a discretization of the expression of the time variable of the form: $t \approx k \cdot \Delta t$, one can consider $\Delta t \approx dt$, one can write $T \approx n \cdot \Delta t$, and the factor F_1 can be given as:

$$F_1 \approx \frac{1}{n \cdot \Delta t} \sum_{t=0}^{t=n \cdot \Delta t} \sin(\omega t) \cdot \sin(\omega t) \cdot \Delta t = \frac{1}{n} \sum_{t=0}^{t=n \cdot \Delta t} \sin(\omega t) \cdot \sin(\omega t) \qquad (0.7)$$

Plot the evolution of the function *sin(ωt)·sin(ωt)* over a period *T = 1s* and calculate according to (1.7) the value of F_1 as the arithmetic mean (of *n* values) of this function over the period *T* .

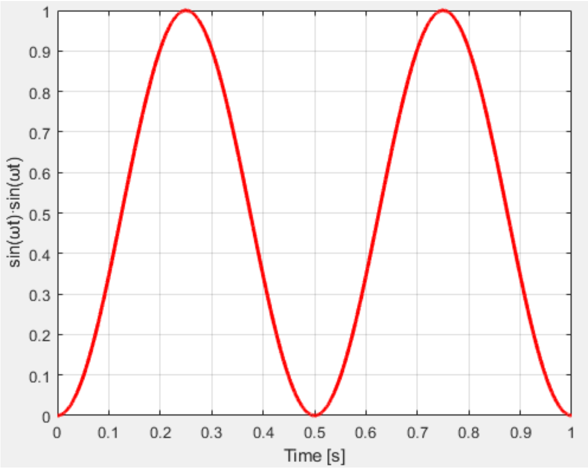

Fig.2. Graphical representation of the function sin(ω·t)· sin(ω·t) on an interval equal to period T=1 s. F1=1/2

According to the representation in Fig.2, it is first observed that the *sin(ωt)·sin(ωt)* function has double the frequency of the instantaneous current and voltage. It is also observed that the mean value of this function is 1/2, so $F_1 = \frac{1}{2}$.

Absolutely identical considerations allow writing the factor F_2 according to:

$$F_2 \approx \frac{1}{n\cdot\Delta t}\sum_{t=0}^{t=n\cdot\Delta t}\sin(\omega t)\cdot\cos(\omega t)\cdot\Delta t = \frac{1}{n}\sum_{t=0}^{t=n\cdot\Delta t}\sin(\omega t)\cdot\cos(\omega t) \qquad (0.8)$$

The evolution of the function *sin(ωt)·cos(ωt)* over a period *T = 1s* will also be plotted.

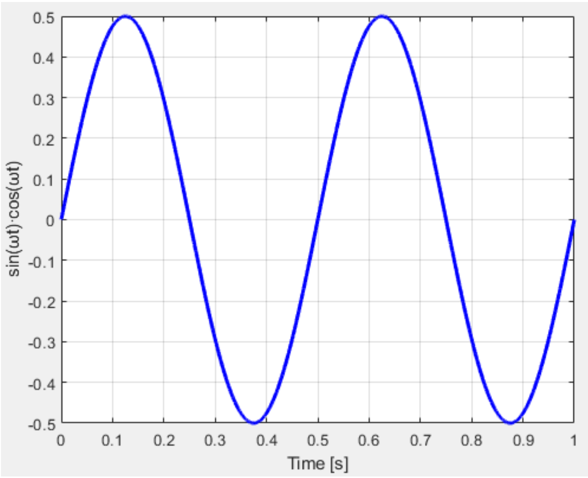

Fig.3. Graphical representation of the function sin(ω·t)· cos(ω·t) on an interval equal to period T=1 s. F2 = 0

In this case, according to the representation in Fig.3, it is also observed that the function *sin(ω·t)· cos(ω·t)* has double the frequency of the instantaneous voltage and a zero value of the factor F_2 is obtained.

With $F_1 = \frac{1}{2}$ and $F_2 = 0$, the relation (1.5) becomes:

$$P = U \cdot I \cdot \cos(\varphi) \tag{0.9}$$

The active power is in fact the product of the rms values of the instantaneous voltage and current and the so-called power factor *cos(φ)*.

Let's take this approach again from relation (1.2). According to Fig.1, using a digital oscilloscope, two voltages are sampled and transmitted to a computer: u_A and u_B. The two voltages describe in this order the instantaneous voltage *u(t)* and the instantaneous current *i(t)* (deduced on the basis of the relation $i(t) = u_B(t)/R$ applying Ohm's law) applied to the RLC circuit, and used in relation (1.2). Based on these considerations relation (1.2) can be rewritten as:

$$P = \frac{1}{T \cdot R} \cdot \int_{t=0}^{t=T} u_A(t) \cdot u_B(t) \cdot dt \tag{0.10}$$

The voltage values taken by the computer via the oscilloscope are sampled and converted into numerical format. Let Δt be the sampling interval of the two voltages (considered sufficiently small). Let the period T be expressed as: $T \approx n \cdot \Delta t$, with n an integer (as number of samples). Let the numerical expression of the voltages involved in (1.10) be of the form: $u_A(t) = u_A(k \cdot \Delta t)$, respectively $u_B(t) = u_B(k \cdot \Delta t)$, assuming a discrete (sampled) time representation of the form $t = k \cdot \Delta t$.

To perform the calculations, the relation (1.10) is approximated by finite summation, (assuming that $dt \approx \Delta t$, for sufficiently small Δt) according to:

$$P \approx \frac{1}{n \cdot \Delta t} \cdot \frac{1}{R} \sum_{k=1}^{n} \left[u_A(k \cdot \Delta t) \cdot u_B(k \cdot \Delta t) \cdot \Delta t \right] \tag{0.11}$$

In relation (1.11) the constant Δt is removed from the sum and simplified so that it becomes:

$$P \approx \frac{1}{n} \cdot \frac{1}{R} \sum_{k=1}^{n} \left[u_A(k \cdot \Delta t) \cdot u_B(k \cdot \Delta t) \right] \tag{0.12}$$

Based on relation (1.12), the power absorbed by the RLC series circuit can be measured. Let there be three distinct situations of supplying the RLC circuit with voltage u_A *(t)* of constant amplitude but for three different values of frequency in the resonance region.

Fig.4 shows the evolution of the voltages u_A and u_B for a supply signal frequency of 6122 Hz (sub-resonant).

For a sampling interval of $\Delta t = 100$ *ns*, applying the formula (1.12) -where $n = 1633$- leads to the determination of the active electrical power $P = 50.3\ \mu W$.

Also marked on the figure is the current-voltage phase shift, $\varphi = 80.50$ (the current is phase-shifted following the voltage, according to (1.3) it later passes through zero).

If the phase shift is positive, the reactance of the circuit is said to be inductive. The active electrical power absorbed is very low, mainly because of the very low power factor. According to (1.9), $cos(\varphi) = 0.165$.

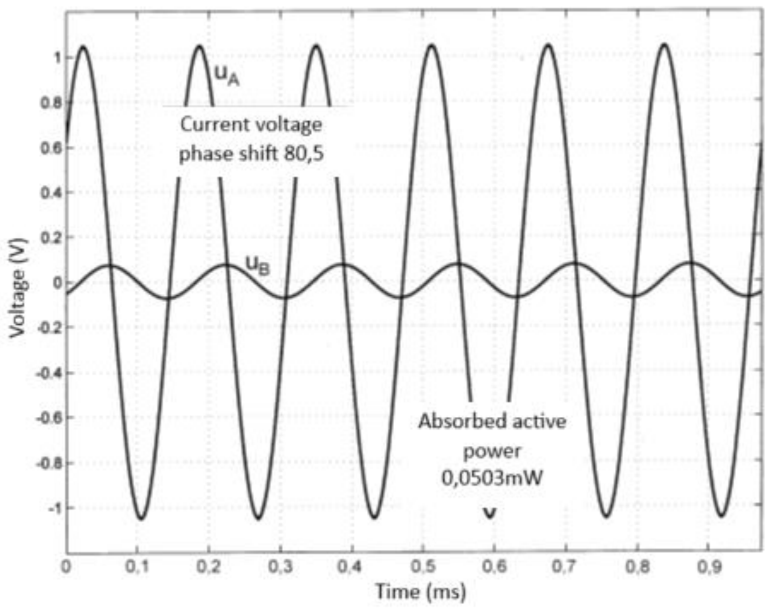

Fig.4. Relationship between the voltages u_A and u_B for a sub-resonant frequency (6122 Hz) supplying the circuit; P = 50.3 μW

Fig.4 shows the evolution of the voltages u_A and u_B for a supply signal frequency of 6364 Hz (near resonance).

Two aspects are worth noting here in comparison with Fig.4. The first is the increase in the amplitude of the voltage u_B , hence the current in the circuit. The second is related to the drastic reduction of the current-voltage phase shift to the value $\varphi = 11.91^o$ (the reactance of the circuit is still inductive).

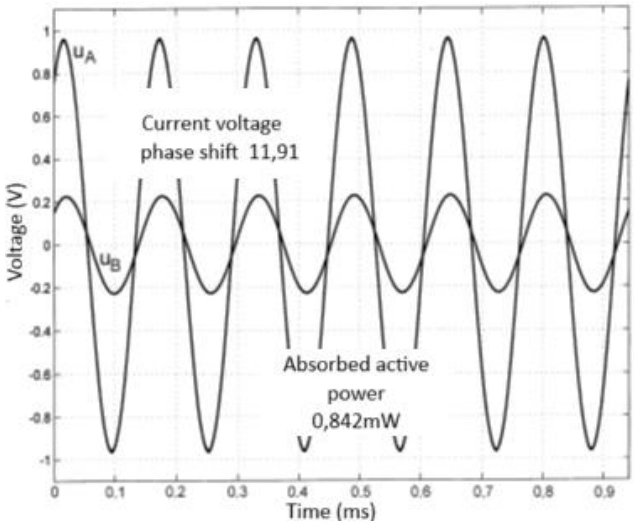

Fig.5. Relationship between voltages u_A and u_B for a circuit supply frequency near resonance (6364 Hz); P = 842 μW

Both aspects contribute to the increase of the absorbed active power which here has the value $P = 842\ \mu W$. It is obvious that when the circuit is excited at resonance the current-voltage phase shift will be zero, the power factor is maximum $cos(\varphi) = 1$, *the* reactance is zero ($X_L = X_C$), the character of the load is purely resistive, the effects induced in the circuit by the coil and capacitor disappear. Obviously, the active power absorbed by the circuit will be maximum. Practically here resonance is difficult to achieve because of the difficulties of frequency tuning.

Fig.6 shows the evolution of the voltages u_A and u_B for a supply signal frequency of 7212 Hz (over-resonant).

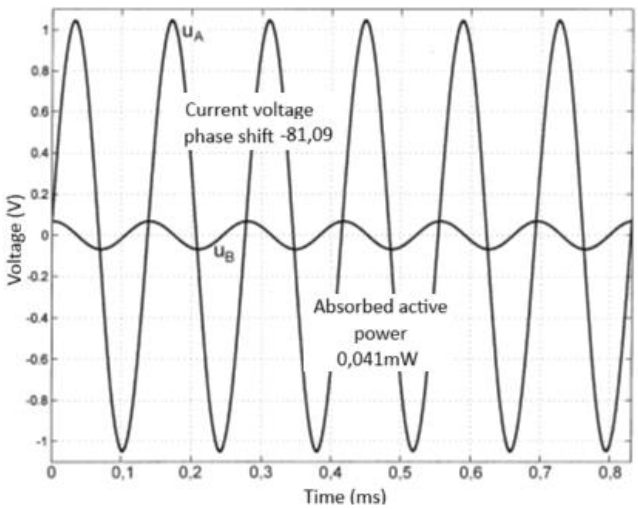

Fig.6. Relationship between the voltages u_A and u_B for an over-seasonal supply voltage frequency (7212 Hz). P = 41 μW

Two points are worth noting here. The value of the voltage u_B (hence the current in the circuit) drops again, apparently similar to the value in figure 3 and the current-voltage phase shift changes radically, this time $\varphi = -81.09^o$ is negative which means a purely capacitive character of the inductive reactance ($X_C > X_L$), the current passes through null values before the voltage. Both aspects contribute to the definition of a low value of absorbed active power: $P = 41\ \mu W$.

3. CONCLUSIONS

Simulink comes with a comprehensive set of pre-built blocks that represent various electrical components and mathematical operations. This includes blocks specific to RLC circuits, such as resistors, inductors, capacitors, and more. These pre-built blocks simplify the process of building complex circuit models.

From the three examples described in Fig.4, 5 and 6, an important conclusion is that the active power absorbed by the RLC series circuit is maximum at resonance and tends asymptotically to zero for sub- and super-resonant excitation frequency values. In all three cases the absorbed active power is dissipated as heat by the resistor due to the Joule effect.

REFERENCES

[1]. Fîță N.D., Lazăr T., Popescu F.G., Pasculescu D., Pupăză C., Grigorie E., *400 kV power substation fire and explosion hazard assessment to prevent a power black-out*, International Conference on Electrical, Computer Communications and Mecatronics Engineering - ICECCME, 16 – 18 November, Maldives, 2022.

[2]. Fita N.D., Obretenova M.I., Pasculescu D., Tatar A., Popescu F.G., Lazar T., *Structure and analysis of the power subsector within the national energy sector on ensuring and stability of energy security*, Annals of "Constantin Brâncuși" University of Târgu Jiu, Engineering series, Issue 2/2022, Pages 177-186, 2022.

[3]. Fîță N.D., Radu S.M., Păsculescu D., Popescu F.G., *Using the primary energetic resources or electrical energy as a possible energetical tool or pressure tool*, Proceedings of Sciendo International Conference Knowledge based organisation – "Nicolae Balcescu" Land Forced Academy Sibiu, Vol. XXVII, No. 3, pp. 21-26, 2021.

[4]. Handra A.D., Popescu F.G., Păsculescu D., *Utilizarea energiei electrice - lucrări de laborator*, Editura Universitas, Petroșani, 167 pag., 2020.

[5]. Horodinca, M., Seghedin, N., Carata, E., Filipoaia, C., Boca, M. Chitariu, D., *Experimental Investigations of the Power Absorbed at Mechanical Resonance*, Experimental Techniques, vol. 30, issue 7, pp.21-31, September 2013**.**

[6]. Horodincă M., *Mechanical resonance: control and correction*, Performantica Publishing House, pp.356, 2014.

[7]. Kuphaldt T.R., *Lessons In Electric Circuits, Volume II - AC,* Sixth Edition, last update July 25, 2007.

[8]. Lazăr T., Marcu M.D., Uțu I., Popescu F.G., Păsculescu D., *Mașini electrice - culegere de probleme*, Editura UNIVERSITAS, Petroșani, pp.197, 2023.

[9]. Marcu M.D., Popescu F.G., Pana L., *Modeling and simulation of power active filter for reducing harmonic pollution using the instantaneous reactive power theory*. Environmental Engineering and Management Journal, June, Vol.13, No. 6, Pages: 1377-1382, DOI:10.30638/eemj.2014.148, 2014.

[10]. Niculescu T., Arad V., Marcu M., Arad S., Popescu F.G., *Safety barrier of electrical equipment for environments with a potential explosion in underground coal mines*. MINING OF MINERAL DEPOSITS. Volume: 14 Issue: 3 Pages: 78-86, DOI: 10.33271/mining14.03.078, 2020.

[11]. Niculescu T., Păsculescu D., *Use of numerical simulation to study capacitive loads which is connecting to an AC power source*, 15th SGEM GeoConference on Informatics, Geoinformatics and Remote Sensing, SGEM2015 Conference Proceedings, Albena, Bulgaria, June 18-24, Vol. 1, pp. 391-398, 2015.

[12]. Niculescu T., Pasculescu D., Pana L., *Study of the operating states of intrinsic safety barriers of the electrical equipment intended for use in atmospheres with explosion hazard*, WSEAS Transactions on Circuits and Systems, Volume 9, pp.430-439, 2010.

[13]. Pasculescu D., Dobra R., Ahmad M.A., *Dosimetric Quantity System for Electromagnetic Fields Bio-effects*, International Journal of Scientific Research (IJSR) 5, no. 2, pp. 28-32, 2016.

[14]. Pasculescu D., Romanescu A., Pasculescu V., Tatar A., Fotau I., Vajai Ghe., *Presentation and simulation of a modern distance protection from national energy system*, Proceedings of the 10 th International Conference on Environment and Electrical Engineering – EEEIC 2011, Rome, Italy, pp. 646-650, 2011.

[15]. Pasculescu D., Slusariuc R., Popescu F.G., Fîță N.D., Tatar A., Lazar T., *Modeling and simulation of lighting of a road with 2 strips per direction to en 13201: 2015 Standard*, Annals of the University of Petrosani, Electrical Engineering, Vol.24, pp.65-74, Petrosani, 2022.

[16]. Pasculescu V. M., Radu, S. M. Pasculescu D., Niculescu T., *Dimensioning the intrinsic safety barriers of electrical equipment intended to be used in potentially explosive atmospheres using the simpowersystems software package*, Papers SGEM2013/Conference Proceedings, 417- 422 pp, Vol. Science and technologies in geology, exploration and mining, Bulgaria, 2013.

[17]. Popescu F.G., Pasculescu D., Marcu M., Niculescu T., Handra A.D., *The technical and economic advantages of power factor correction*, Annals of University of Petrosani, Electrical Engineering, Vol. 21, pp.35-42, Petrosani, 2019.

[18]. Popescu F.G., Pasculescu D., Marcu M., Pasculescu V.M., Fîță N.D., Tatar A., Lazar T., *Principles of effective energy management and power control system*, Annals of the University of Petrosani, Electrical Engineering, , Vol.24, pp.111-118, Petrosani, 2022.

[19]. Popescu F.G., Pasculescu D., Marcu M., Slusariuc R., Buica G., Lazar T., *Analysis of filtering and correction of the power factor in distorted balance*, Annals of University of Petrosani, Electrical Engineering, Vol. 23, pp. 77-82, Petroşani, 2021.

[20]. Popescu F.G., Păsculescu D., Păsculescu V.M., *Modern methods for analysis and reduction of current and voltage harmonics*, LAP LAMBERT Academic Publishing, ISBN 978-620-0-56941-7, pp. 233, 2020.

[21]. Tătar A., *Energy consumption management of basic condensate pumps, related to TA 330 MW, for C.T.E ROVINARI*, Annals of the „Constantin Brancusi” University of Targu Jiu, Engineering Series, No. 3/2019, pp. 111-114, 2019.

[22]. Tătar A., *Alternative power supply solutions to reduce air pollution with substances emitted by thermal power plants*, Fiabilitate si Durabilitate - Reliability & Durability, No 1/2019, "Academica Brâncuși" Publishing House, Târgu Jiu, ISSN 1844 - 640X, pp. 240-243, 2019.

[23]. Uțu I., Păsculescu D., *Power Quality Study in Order to Comply with European Norms*. Publicat in Revista Calitatea, Supplement of “Quality - Access to Success” Journal, Vol.18, S1, January, pp. 366-371, 2017.

STUDY OF STIRLING ENGINE FOR INDUSTRIAL APPLICATIONS

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Abstract: In this paper is studied the possibility of using the Stirling engine in order to reduce environmental pollution. Constructive types, operating principle, main advantages and disadvantages are presented. Finally, the stages of the practical realization of such an engine are presented.

Key words: stirling machine, mechatronics of stirling engines, stirling thermodynamic cycle.

1. INTRODUCTION

The Stirling engine defines a regenerative closed-cycle hot-air heat engine. In this context, "closed cycle" means that the working fluid is in a closed space called a thermodynamic system; "regenerative" refers to the use of an internal heat exchanger which significantly increases the potential output of the Stirling engine.

Usually, the Stirling engine is classified as an external combustion engine, although the source of thermal energy can be not only the combustion of a fuel, but also solar energy or nuclear energy. A Stirling engine operates by using an external heat source and a heat sink, each of which is maintained within predetermined temperature limits and a sufficiently large temperature difference between them [1], [7], [9].

The Stirling engine achieves the highest efficiency in the process of converting thermal energy into mechanical work, theoretically up to the maximum efficiency of the Carnot cycle, although in practice this is reduced by the properties of the gas and materials used.

As an external combustion engine, it can be adapted to use various fuels, such as biofuels, alcohols, hydrogen, vegetable oils (from seeds, from soybeans, from peanuts, or extracted from various plants), or biofuels extracted from seaweed and oceanic, etc. [8], [10]

These thermal engines are strong, robust, dynamic, compact, noxious, oil-free, smoke-free, working with high efficiencies (not only mechanical but also thermal) [2].

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2. STIRLING ENGINE USES

2.1. Cogeneration applications (CHP - Combined Heat and Power)

Through cogeneration, from a pre-existing energy source, usually an industrial process, with the help of an installation, in addition to the delivered mechanical or electrical power, heat necessary for heating is provided. Normally the primary heat source is the input to the Stirling engine heater and as such will be at a higher temperature than the heat source for the heating application which is the exhaust energy from the engine [3], [11].

Fig.1. Stirling engine at the Hochhut Technical Collection in Frankfurt am Main

The power produced by the Stirling engine is often used in agriculture in various processes, resulting in biomass waste that can in turn be used as engine fuel, thus avoiding the costs of transporting and storage the waste. The process in general is plentiful in energy resources being in its entirety advantageous from an economic point of view (figure1).

2.2. Solar electricity generators

Placed in the focus of a parabolic mirror, a Stirling engine can be used as an electric current generator with an efficiency higher than simple solar panels with photovoltaic cells and comparable to that solar panels with concentrator photovoltaic cells.

2.3. Refrigeration installations Stirling - Cryocooler

Any Stirling machine can work in reverse as a heat pump: if the mechanical work is introduced by driving the machine, a temperature difference appears between the cylinders [12]. One of the modern uses is in the cold industry as refrigeration and cryogenic installations (cryocooler).

The main components of a cryocooler are identical to those of the Stirling machine. The rotation of the motor shaft will compress the gas, increasing its temperature. By pushing the gas into an exchanger, heat will be delivered. In the next phase, the gas will be subjected to expansion, after which it will cool down and will be circulated to the other exchanger where it will take heat. This exchanger is located in a thermally insulated space such as a refrigerator [13], [15].

2.4. Heat pumps

A Stirling heat pump is very similar to a Stirling cryocooler, the difference being that the heat pump works at room temperature and its main role is to pump heat from outside the building inside to provide cheap heating. As with other Stirling machines and in this case the heat passes from the expansion zone to the compression zone, however, unlike the Stirling engine, the expansion zone is at a lower temperature than the compression zone, so instead of producing work mechanically, it is necessary to provide it by the system to satisfy the requirements of the second law of thermodynamics.

2.5. Nuclear energy

In nuclear power plants, there is the possibility of using Stirling machines for the production of electricity. By replacing steam turbines with Stirling engines, construction complexity can be reduced, efficiency can be achieved, and radioactive waste can be reduced. Certain uranium enrichment reactors use liquid sodium as a coolant by design. If the thermal energy is still used in a steam plant, water/sodium heat exchangers are needed, which increases the degree of danger due to the possibility of a violent reaction of sodium with water in case of direct contact. The use of the Stirling engine means that water can be removed from the cycle [14].

2.6. Automobile engines

In the automotive industry, the non-use of Stirling engines for driving vehicles is often argued by the power-to-weight ratio being too low and the start-up time being too long. The biggest problems appear in the long start-up time, slow acceleration, stopping and load response for which no immediately applicable solutions have been found. Some researchers believe that the hybrid drives would eliminate these shortcomings, but so far, no vehicle has been built on this basis.

3. PRESENTATION OF THE STIRLING ENGINE

3.1. The advantages and disadvantages of the Stirling engine

The main advantages of the Stirling engine are [3]:

- waste heat is easily usable so Stirling engine can be used in combined systems such as WhisperGen;
- it can use any heat source without modification, not only those based on a combustion process, such as solar, geothermal, biological or nuclear energy;
- the combustion process can be continuous, significantly reducing the level of polluting emissions, in the case of the fuel-based source;
- most Stirling engines have their drives and seals on the cold side, so its require less lubricant and have longer service intervals than other types of machines;
- actuation mechanisms are simpler than in other types of reciprocating machines, valves are not required and the combustion system can be simpler.
- Stirling engine uses a non-changing working fluid that is under close to nominal pressure, so there is no danger of explosion in normal use.
- in some cases, the low pressure may allow using very light weight cylinders.
- it can be built for very quiet operation without air supply, for propulsion without air consumption in submarines or in space technology.

- it start easily (yet slowly after a warm-up period) and run more efficiently in cold weather, compared to internal combustion engines that start quickly in hot weather and hard in cold weather.

- it are very flexible and can operates as cogeneration plants (CHP - Combined Heat and Power) in the winter and as a refrigeration plant in the summer.

The main disadvantages of the Stirling engine are:

- by construction, the Stirling engine is equipped with heat exchangers both for absorption and for its release, exchangers that must withstand the pressure of the working fluid, which in turn is proportional to the engine power. In addition, the heat exchanger on the expansion side is subject to very high temperatures, which is why the material must resist strong corrosive effects and have reduced deformations. Usually these requirements increase the cost of the material.

- thermodynamic cycles require large temperature differences in order to function efficiently. This means that high strength materials are required.

- the removal of waste heat is quite complicated because the cooler must be kept at a temperature as low as possible to increase efficiency.

Because of this, large radiators are needed that increase the volume. Along with the cost of the material, this was one of the reasons that prevented the use of Stirling engines for motor vehicles. Other applications, however, such as ship propulsion and stationary micro-power plants using cogeneration (CHP), do not require a large liter power.

3.2. Motor cycle

Since the cycle of the Stirling engine is closed, it contains a certain amount of gas called "working fluid", usually air, hydrogen or helium. During normal operation, the engine is sealed and there is no gas exchange with its interior. Unlike other types of engines, valves are not required.

The gas in the Stirling engine, similar to other heat engines, goes through a cycle consisting of 4 transformations (times): heating, expansion, cooling and compression.

The cycle occurs by moving gas back and forth between the hot and cold heat exchangers. The hot heat exchanger is in contact with an external heat source, for example a fuel burner, and the cold heat exchanger is in contact with an external radiator, for example an air radiator.

A change in the temperature of the gas causes a change in pressure, while the movement of the piston contributes to the alternate compression and expansion of the gas [4], [5].

In conclusion, the Stirling engine uses the temperature difference between the two zones, the hot and the cold, to create an expansion-contraction cycle of a given mass of gas inside a machine to convert thermal energy into mechanical work. The greater the difference between the temperatures of the two zones, the greater the efficiency of its cycle.

3.3. The theoretical reversible cycle of the Stirling engine

The theoretical cycle of a Stirling engine is the same regardless of whether the engine has one or two cylinders and consists of two isotherms and two isochores (fig.2.).

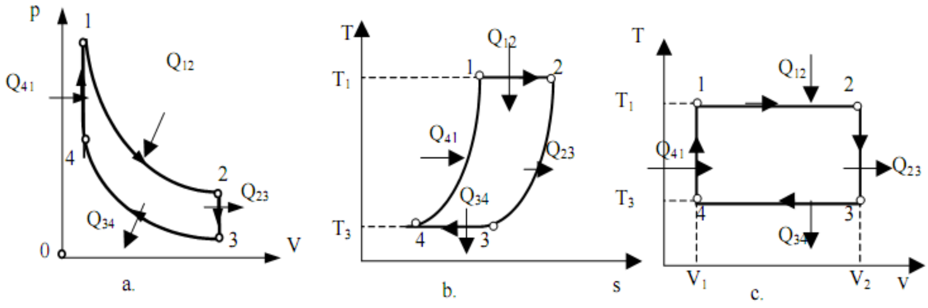

Fig.2. The theoretical reversible cycle of the Stirling engine
a - in P-V coordinates; b - in T-s coordinates; c - in coordinates T-V

For the description of the reversible Stirling cycle, it is assumed that the engine has two cylinders (figure 3).

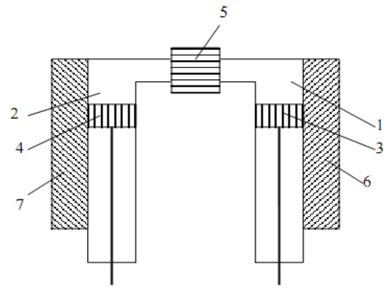

Fig.3. Scheme of the two-cylinder Stirling engine:
1,2 - the hot, respectively cold cylinder; 3,4 - hot and cold piston;
5 - heat regenerator; 6.7 - the source of hot, respectively cold heat

When the hot piston 3 moves down, the isothermal expansion 1-2 of the working agent takes place. In this transformation, the system receives heat from the hot source:

$$Q_{SC} = Q_{12} = mRT_1 LN \frac{V_2}{V_1} = mT_1(s_2 - s_1)\ [kJ] \qquad (1)$$

Where: m - is the mass of the working agent [kg]; R- perfect gas constant of the working agent [kJ/kgK].

Simultaneously with the up movement of the piston 3 on the first portion, the cold piston 4 moves down. In this way, the passage of the working agent takes place through the heat regenerator 5 which receives the heat Q_{23} by heating the copper wires that compose it. Due to the synchronization of the movement of the two pistons, the transformation to which the working agent is subjected is isochore 2-3. As a result, the evolved gas decreases its temperature and pressure at T_3, respectively p_3. Next, the cold piston 4 performs the isothermal compression 3-4, being in contact with the cold source, it gives up its heat:

$$|Q_{sr}| = |Q_{34}| = mRT_3 ln\frac{V_3}{V_4} = mT_3(s_3 - s_4) \quad [kJ] \tag{2}$$

By reversing the direction of movement of the two pistons, the 4-1 isochore transformation is achieved during which the evolutionary medium absorbs the heat from the regenerator Q_{41}, and the active elements of the regenerator cool down. It is easy to see that, under the conditions that $T_1 = T_2$ and $T_3 = T_4$, and points 2,3 and 4,1 are found on two isochores:

$$|Q_{23}| = |Q_{41}| = mc_v(T_2 - T_3) = mc_v(T_1 - T_4) \quad [kJ] \tag{3}$$

The mechanical work produced is:

$$L = Q_{sc} - |Q_{sr}| = mR\left(T_1 ln\frac{V_2}{V_1} - T_3 ln\frac{V_3}{V_4}\right) = m\,(T_1 - T_3)(s_2 - s_1) \quad [kJ] \tag{4}$$

The thermal efficiency of the reversible Stirling cycle will be:

$$\eta = \frac{L}{Q_{sc}} = 1 - \frac{T_3}{T_4} \tag{5}$$

4. CASE STUDY – BUILDING A STIRLING ENGINE MODEL

4.1. Introduction

The two-piston Stirling engine is a heat engine that operates through compression and decompression cycles of a working fluid, based on temperature differences, and which, in the end, directly transforms thermal energy into mechanical energy (figure 4).

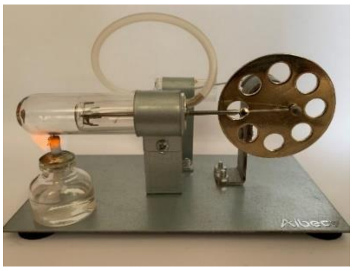

Fig.4. The two-piston Stirling

This engine can operate on the basis of a heat source regardless of its quality, be it solar, chemical or nuclear energy. Stirling engines are quieter and more economical than internal combustion engines, can be safer to operate, and do not have high maintenance requirements.

4.2. The practical realization of the Stirling Engine (with two pistons)

The two-piston Stirling engine has a very simple construction, being built almost entirely of galvanized sheet iron and glass. It can have a speed of up to 200 rpm. The base is a galvanized iron plate, which has a rectangular shape placed on four rubber feet to have a well-defined stability (fig.5).

Fig.5. Stirling Engine base and piston

In each of the racks, one by one, carefully fix the cylinders of the pistons and at the same time insert the pistons into them (fig.6). After mounting the cylinders in the racks, connect each piston with the connecting rod, respectively the engine crank. Rotate the connecting rod to ensure that there is not a large frictional force between the pistons and cylinders and adjust a 90^0 offset between the connecting rod and the engine crank. After adjustment it is noticed that a smoother rotation occurs [6].

Fig. 6. Fixing the cylinders in the racks and connecting the pistons to the engine

Now the engine is ready, carefully assembled all the details. The lighter is ignited and clamped under the end of the hot piston (fig.7).

Fig.7. The two-piston Stirling engine

It is allowed to burn and heat the piston air for about 60 s. After this time interval we give a small impulse to the crank, the hot steam from the hot cylinder being pushed by the piston travels through the silicone tube to the piston the cold cylinder pushing the piston, thus the engine ours is in constant motion as long as the heat source exists [4].

5. CONCLUSIONS

Stirling engines have a simpler construction than internal combustion engines and are quite efficient. They can only be put into operation by the presence of a heat source. Any type of raw material that has the property of burning and releasing heat can be used as a heat source for the Stirling engine. An ecological example would be the straw left on grain fields after they are harvested. The energy capacity of straw has a ratio of approximately 1/3 of the energy capacity of average quality coal that is used to heat houses in winter.

Stirling engines are considered "external combustion" engines with relatively high efficiency. These observations represent decisive arguments in favor of the use of Stirling engines in industrial applications, since they present a very low percentage of pollution compared to internal combustion engines.

REFERENCES

[1]. Hargreaves C. M., *The Philips Stirling Engine*, Elsevier Publishers, 1991.

[2]. Homuțescu C.A., ș.a., *Introducere în mașini stirling*, Editura CERMI, Iași, 2003.

[3]. Lazăr T., Marcu M.D., Uțu I., Popescu F.G., Păsculescu D., *Mașini electrice - culegere de probleme*, Editura UNIVERSITAS, Petroșani, pp.197, 2023.

[4]. Martini W., *Stirling Engine Design Manual*, NASA-CR-135382. NASA, 1978.

[5]. Păsculescu D., Uțu I., *Increasing the quality of protections for high-voltage power lines*. Publicat in Revista Calitatea, Supplement of "Quality - Access to Success" Journal, Vol.18, S1, January, pp. 234-239, 2017.

[6]. Pătrăşcoiu N., *Senzori şi traductoare,* Editura Universitas, Petroşani, 2000.

[7]. Petrescu F.I., Petrescu R.V., Motoare *termice,* Create Space publisher, USA, October 2012.

[8]. Popescu F.G., Slusariuc R., Utu I., Cucaila S., Stochitoiu M. D., *Study of the dependence of bending resistance in correlation to temperature of a conductive material*, International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM 18(4.1), pp. 643-650, 2018.

[9]. Slusariuc R., Samoila L., Utu I., Popescu F.G., Handra A. D., *SCADA systems analysis for industrial processes,* Annals of University of Petrosani, Electrical Engineering, Vol. 21, Petroşani, pp.17-22, 2019.

[10]. Stochitoiu M.D., Marcu M., Utu I., Niculescu T., Popescu F.G., *Modern concepts and its application for energetically security requirement at different connected sources*. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM Volume 18, Issue 2.1, pp. 591 – 596, 2018.

[11]. Tăbăcaru T., Uțu I., *Maşini electrice şi acţionări: culegere de probleme*. Universitas, Publishing House, Petroșani, 2012.

[12]. Utu I., Marcu M., Niculescu T., Popescu F.G., Slusariuc R., *The use of semiconductor materials in the construction of modern equipment for adjustable drive of power equipment from a lignite open pit,* SGEM Volume 18, Issue 2.1, pp.805 – 812, 2018.

[13]. Utu I., Marcu M., Popescu F.G., Stochitoiu M. D., Rada A.C., *Determination of the optimum operating regime for two power transformers 35 / 6,3 kV*, Annals of University of Petrosani, Electrical Engineering, Vol. 22, pp.71-76, Petroșani, 2020.

[14]. Uțu I., Păsculescu D., *Power Quality Study in Order to Comply with European Norms*. Publicat in Revista Calitatea, Supplement of "Quality - Access to Success" Journal, Vol.18, S1, January, pp. 366-371, 2017.

[15]. Uţu I., Stochiţoiu M. D., *Applications of power electronics in electromechanical drives from mining plants.* Annals of University of Petrosani, Petrosani, 2011.

DETERMINATION BASED ON EXPERIMENTAL MEASUREMENTS OF THE EQUATIONS GOVERNING OPERATION OF THE NETWORK - CENTRIFUGAL PUMP IN ORDER TO SIMULATE OPERATING CONDITIONS FOUND IN PRACTICE

ANDREI CRISTIAN RADA[1], ILIE UȚU[2]

Abstract: The paper aligns current global concerns regarding energy sustainability, focusing on issues of operational sustainability of water pumping system. After an overview of the current situation sectoral regulations and international, national and local issues of concern highlighted in this background is developed in an approach multidisciplinary research that integrates conceptual approaches, methodological and basic tools of the machines and networks hydraulics, energetics industrial installations in the spirit of ISO 50001 energetics management and sustainable development.

The energetics system for the installation of a pumping groundwater mining, identification and analysis of major components, energy flows and performance of this system is the core of the article.

Key words: turbo pumps, electric pumps, pump systems, hydraulic network, energy efficiency, sustainable use of water pumping systems.

1. INTRODUCTION

Methodological instruments used mainly include operational tools in sustainable water pumping systems and methods for quantifying the performance of energetics systems (energetics analysis methods/exergetic, economic and quantify the environmental impact). On these bases diagnoses the current state of the system are simulated operating conditions and establish areas of operation corresponding to a performance indicator aggregate energy cost, economic cost and the environmental cost, identifying measures/solutions to improve ahead, compatible with sustainable development [1, 6].

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2. THEORETICAL CONSIDERATION

The pumping station, pumping aggregates ensures the circulation of water in the basin volume suction consumers who are connected to the network.

Figure 1 is the general case of a pump operating in a facility. The circulation of the fluid between the suction tank R_A and the discharge R_R is provided by the pump P through the suction tube draws C_A and discharges through the discharge pipe C_R. Additional gauges of pressure were positioned in the suction nozzle (1) and the discharge (2) [2, 5].

The flow rate of the fluid that is circulated by a pump units can be expressed by: the volumetric flow rate discharged, Q_1 (m^3/s, m^3/h, l/s), the volumetric flow rate sucked Q_2 (m^3/s, m^3/h, l/s), volume flow nominal Q_n (m^3/s, m^3/h, l/s), volume flow optimally Q_{opt} (m^3/s, m^3/h, l/s), maximum flow and minimum Q_{max}, Q_{min}.

The load of pump or pumping the total height H (m) is useful mechanical work submitted by the impeller to fluid or increase energy pumped fluid passage through paragraphs (1) and (2) fig.1.

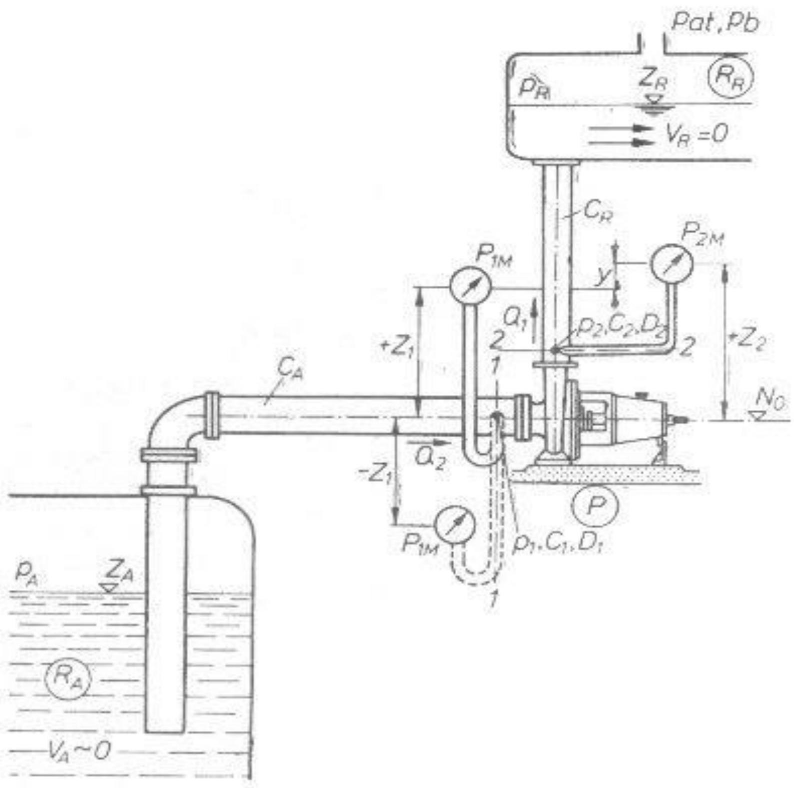

Fig.1. The operation of a pump in an installation

The unit of time, due to losses occurring in pumps ($\Delta P=\gamma\Delta Q\cdot\Delta H$) to achieve output power P_u, the pump must obtain a higher input power $P_p=\gamma\cdot Q\cdot H/\eta_p$, η_p – at the shaft - is the overall efficiency of the pump.

Speed and direction of rotation of the pumps. They are driven by electric motors in general, resulting from the relationship speed:

$$n = k\frac{60\cdot f}{p} \quad (1)$$

where *f* is frequency of the current in the network; k - the coefficient of sliding depending on the type of the motor (synchronous motors k = 1, and asynchronous motors 1 < k); p - number of pole pairs of the motor [3].

3. EXPERIMENTAL RESULTS

Based on experimental measurements correlated with the performance specified in the leaflets pumps were established significant parameters summarized in Tables 1 and 2. I built with the utility EXCEL graphs of variation of significant parameters and I determined the equations of the curves corresponding results (Figures 2, 3 and 4) [1, 4].

Based on experimental measurements, correlated with information from literature and the available documentation, using the model previously described for analysis of electro LOTRU 100 yielded significant results regarding:

- The variation of pump parameters analzyed depending on time (fig.5);
- Operating point network movement depending on the variable speed shown in (figure 6);
- Percentage change of characteristic parameters for varying speed (fig.7);
- Percentage change in specific energy consumption depending on the method of adjustment (fig.8);

Table 1. ***Characteristics experimentally determined***

Pump flow rate - Q [m^3/h]	0	5	10	15	20	25	30	35	40
Load of pump - Hp [m]	47.5	49	47.5	45	42.5	39	35	29	22.5
Load of Network - Hr [m] speed control	10	12	14	17	21	28	35	42	
Pump efficiency- etaP [%]	0	25	42	55	61	64	62.8	60	53
Pump efficiency+motor - etaP+M [%]	0	20	37	47	52	56	55.6	52	46
Power pump - Pp [kW]	2	2.5	2.8	3.1	3.8	4.1	4.22	4.5	4.8
Motor power - Pm [kW]	2.9	3.4	3.7	4	4.7	5	5.12	5.3	5.6
Load of Network - Hr + Hv [m] adjustament tub	20.4	22.5	24.2	26.5	30.1	34.5	42.7		

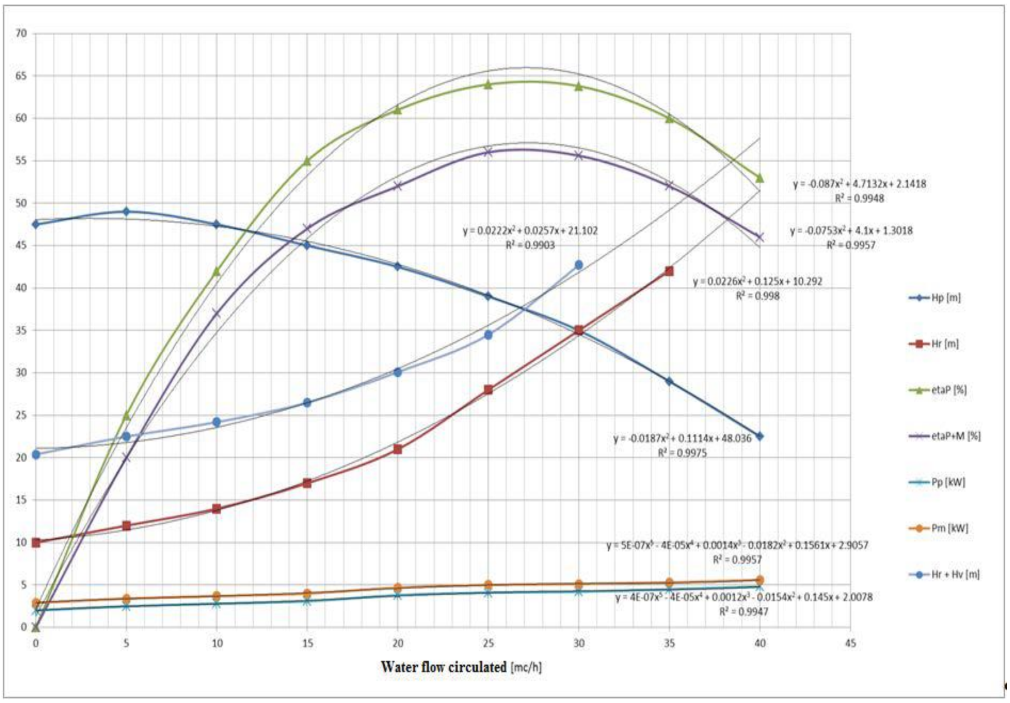

Fig.2. Trendline equation for pump and network characteristics

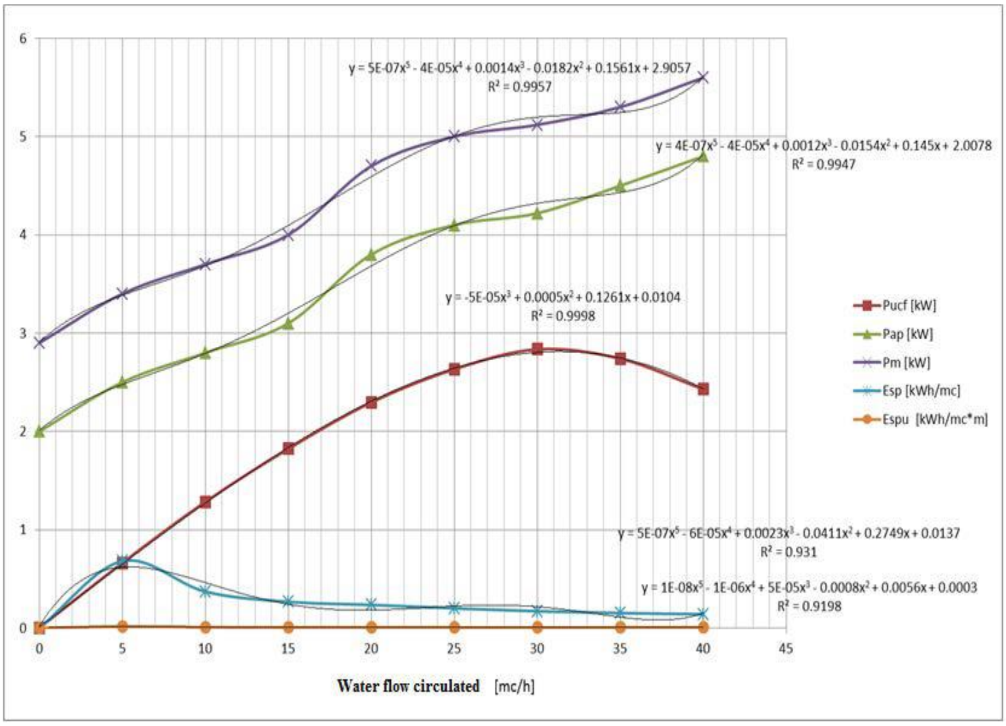

Fig.3. Trendline equations for energetics characteristics of the pump

Table 2. ***Characteristics energetics experimentally determined***

Pump flow rate - Q [m^3/h]	0	5	10	15	20	25	30	35	40
Load of Network - Hp [m]	47.5	49	47.5	45	42.5	39	35	29	22.5
The power output of stream water – Pucf [kW]	0	0.661 5	1.282	1.822	2.295	2.632	2.835	2.740	2.43
Power at the pump shaft - Pap [kW]	2	2.5	2.8	3.1	3.8	4.1	4.22	4.5	4.8
Electrical motor power - Pm [kW]	2.9	3.4	3.7	4	4.7	5	5.12	5.3	5.6
Specific energy – Esp [kWh/m^3]	0	0.68	0.37	0.266 667	0.235	0.2	0.170 667	0.151 429	0.14
Specific energy util- Espu [kWh/mc*m]	0	0.013 878	0.007 789	0.005 926	0.005 529	0.005 128	0.004 876	0.005 222	0.00 622

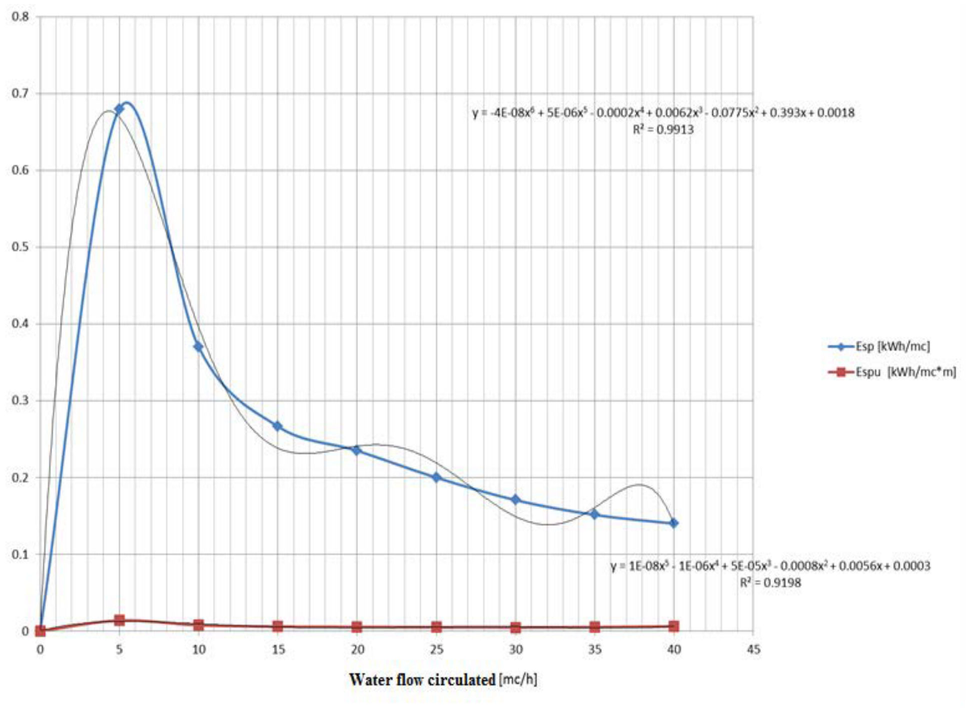

Fig.4. Trendline equations to specific energies, using a refined model regression

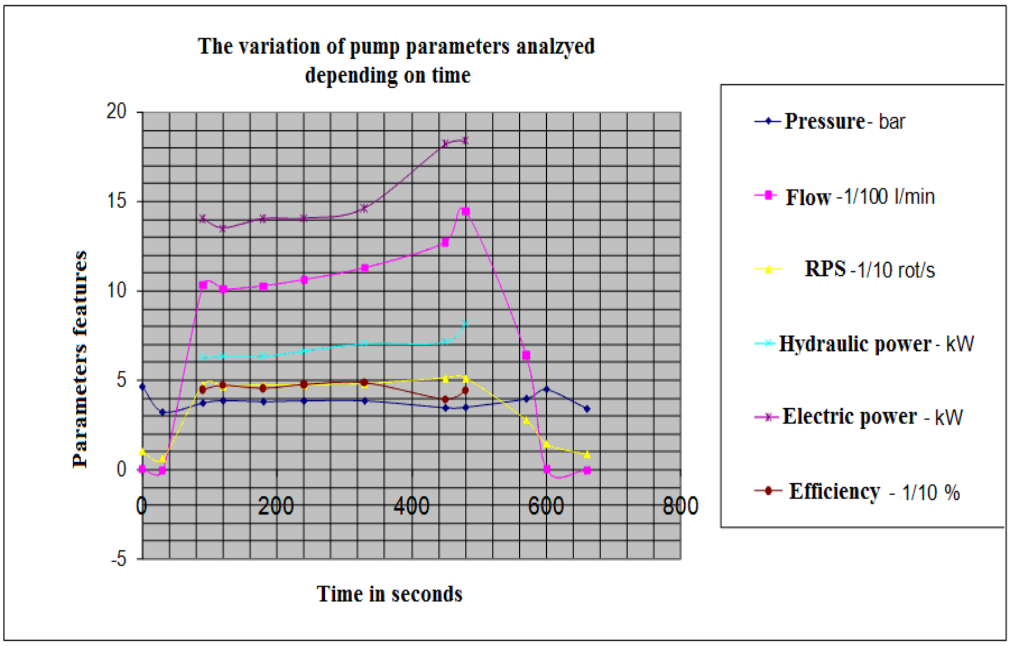

Fig.5. The variation of pump parameters analzyed depending on time

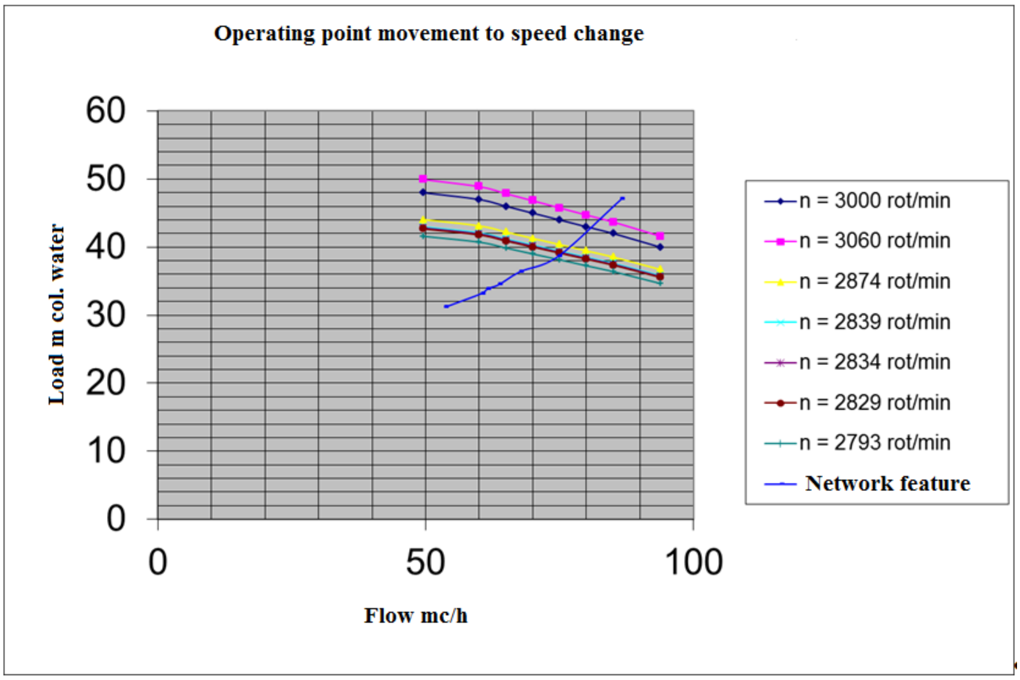

Fig.6. Operating point network movement depending on the variable speed

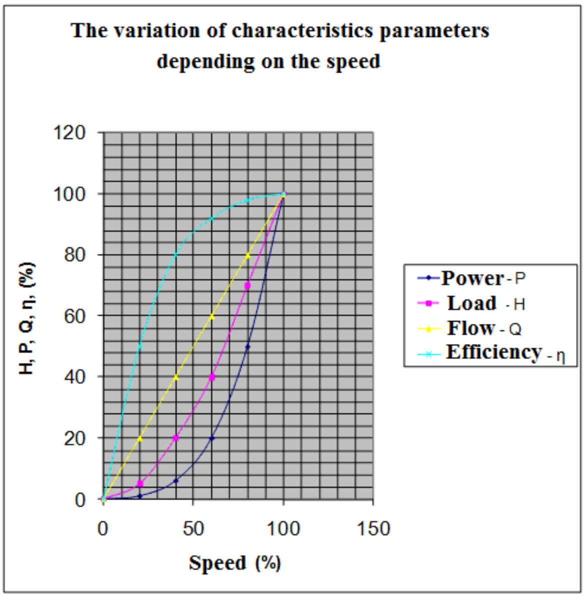

Fig.7. Percentage change of characteristic parameters for varying in specific energy consumption

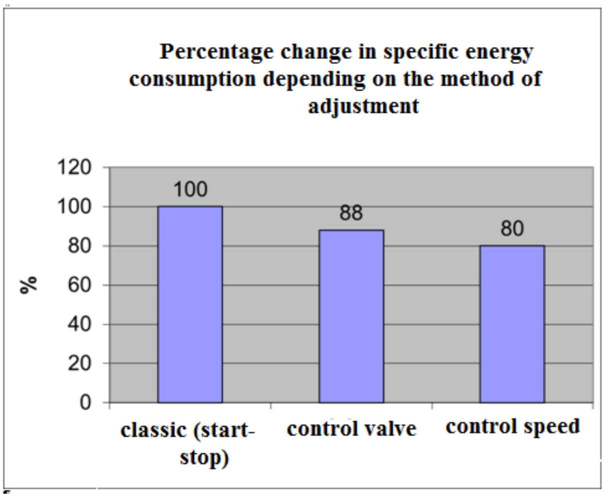

Fig.8. Percentage change speeddepending on the method of adjustment

4. CONCLUSIONS

It analyzed aggregate flow adjustment in pump systems with the following methods described in detail:

- changing pump performance curves (internal control);
- changing characteristics of installations (external adjustment);

adaptation of different working groups pumps (in series or parallel operation working pumps).

It drew charts variations versus time of characteristic parameters electropump, moving the operating point to the network for varying speed, the percentage change in the characteristic parameters for varying speed and the percentage change in specific energy consumption depending on the method of adjustment.

REFERENCES

[1]. Handra A.D., Păsculescu D., Uțu, I., Marcu M.D, Popescu F.G., Rada A.C., *Tehnici de optimizare în energetică*, Editura UNIVERSITAS, Petroșani, 2022.

[2]. Ionel I., *Adjustable pumping plants*, Editura Technică, București, 1976.

[3]. Leca A., *Managementul energiei*, Editura Agir, București, 2007.

[4]. Rada A.C., Irimie S., Irimie S.I, *Economic, Energetic, and Environmental Impact Evaluation of the Water Discharge Networks from Mining Works.* Sustainability, Basel, Switzerland, 2018.

[5]. Sârbu I., *Optimizarea energetică a sistemelor de distribuţie a apei.* Editura Academiei Române, Bucureşti, 1997.

[6]. Suciu C., Handra A.D., Rada A.C., Marcu M.D., *Improving the operational strategy of industrial enterprises,* Annals of Constantin Brâncuşi University of Târgu-Jiu, Engineering Series, 2021.

Annals of the University of Petrosani, Electrical Engineering, 25 (2023)

COMPREHESIVE ASPECTS VIEWING EFFICIENCY OF MONITORING BATTERY SYSTEM AS PART OF ENERGY STORAGE

MARIA DANIELA STOCHITOIU [1]

Abstract: The electricity systems evolve and widespread industry understanding of the needs to implement further adaptable storage technologies as power systems are developing. These adaptable solutions are necessary to fulfill the rising demand for a variety of services, including transportation, to reliably integrate intermittent renewable energy sources, and to make it easier and more affordable to transition between supply and storage. A battery management system is a part of energy storage system for preventing the damaging the battery.

Key words: energy storage, efficiency, battery management.

1 INTRODUCTION

As the global electricity systems are shaped by decentralization, digitalization and decarbonization, the worldwide explores the new frontiers with challenges and energy transitions for keeping equilibrium with fast moving developments.

Energy storage systems can be found in industrial as using energy storage systems to relieve congestion instead of constructing extra power lines (it consists of batteries placed at either end of a transmission line to absorb excess renewable production and discharge during peak demand, controlled by a proprietary algorithm), commercial or domestic applications that contain a large number of rechargeable batteries, thus incurring high operating and maintenance costs [1],[2].

Nowadays major decarbonizing efforts are orientated to remove thermal electric power generation and scale up renewable energies, the adoption of energy storage continues to be described as the key changer for electricity systems. Energy storage provides advantages due to flexibility and due to the possibility of closer linking of different energy and economic sectors.

Energy storage is in a deep tie with widespread needs such as relieving congestion or smoothing out the variations in power that occur independently of renewable-energy generation.

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Energy storage can contribute to a better energy transition, often is reduced to battery technologies. In the below diagram (fig.1) is showing the sample of storage technologies.

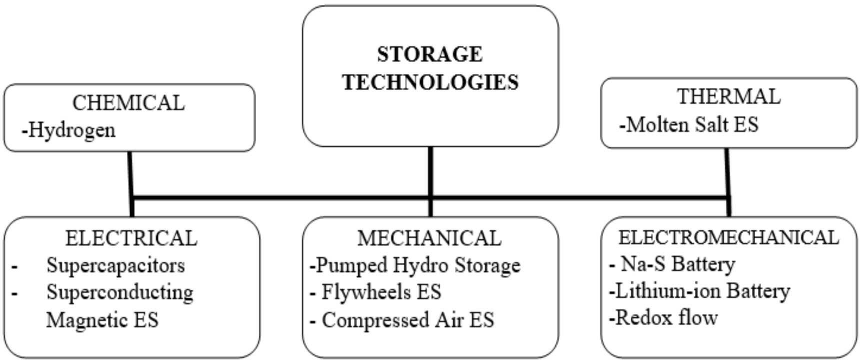


Fig.1. Overview diagram of energy storage

Storage technologies as fuel cells, supercapacitors, were developing and monitoring or controlling systems are recommended. Appear two questions which are taking into account as the place where the energy sector decides to push forward a wide range of technologies or continues to limit energy storage to battery storage and energy policies are enabling regulatory market. The figure below is showing the key between the parties concerned [3].

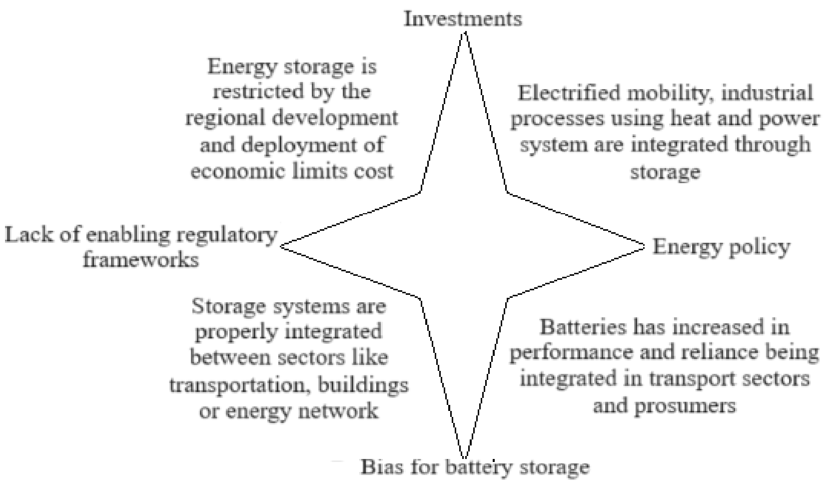


Fig.2. Dependence of the development of innovative technologies and applications

The World Energy Council considers that a wide range of energy storage technologies will be address to the challenges of the energy transition based on battery innovation, in particular lithium-ion. However, lithium-ion batteries may not be fit for a series of requirements of future energy systems, in particular fast charging and long duration storage integration [4].

2 THE FEATURES OF BATTERY MANAGEMENT SYSTEM

A battery management system (BMS) has the role to protect the battery for damage, ensuring the safety and life`s prediction in the same time to maintain the battery operation for a high efficiency.

Battery management system (BMS) is technology dedicated to the oversight of a battery pack, which is an assembly of battery cells, electrically organized in a row, column matrix configuration to enable delivery of targeted range of voltage and current for a duration of time against expected load scenarios.

The oversight that a BMS provides usually includes: monitoring the battery, providing battery protection, estimating the battery's operational state, continually optimizing battery performance and reporting operational status to external devices.

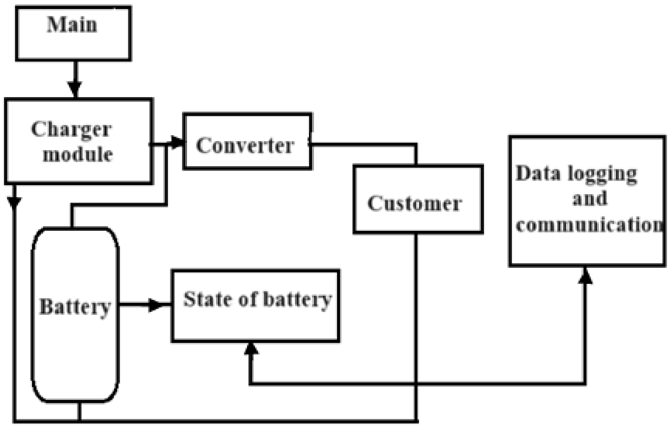


Fig.3. Block diagram of a BMS

The BMS has an important role above energy storage due to three characteristics as: efficiency, safe and dependable [1],[4].

To increase the efficiency of the system is possible through: to select the appropriate charging current for maintain the current density limit at the electrode surfaces; to control and compensate the state of charge range for charging and discharging over the operating range in order to maintain coulombic efficiency; to compensate the cut-off voltage with temperature variations; to keep al cell voltage and state of charge in balance for increasing the operating range; to maintain the optimum temperature range by thermal controlling.

To increase the dependable life time is possible through: maintain the current density for preventing the damage of electrode surfaces; to achieve the balance between capacities in and out at various operating conditions; to increase the overall age of the pack by preventing under charging of good cells and over charging of weak cells; to prevent the deep discharging by limit the discharge at the end of the discharge cut-off voltage; save the battery from abuses of overcharging (that causes heating and out-gassing).

3. THE FUNCTIONS OF BATTERY MANAGEMENT SYSTEM

To provide safety and reliability through: to maintain and control the operations in safety limits; to show the safety alarms beyond the function condition; to prevent the thermal runaway conditions by implement the thermal conditions systems; to indicate the remaining life of battery.

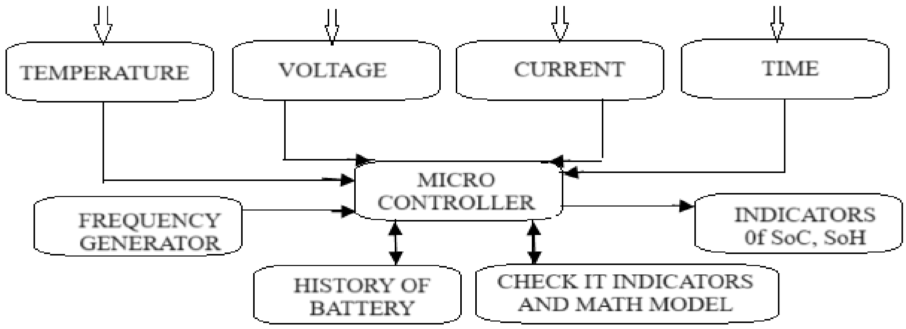


Fig.4. The main functions of a battery management system

Battery management system includes the following functions [5]:

- **monitoring of parameters as temperature** (multiple temperature parameters), **battery current, battery voltage**;

Monitoring the temperature, voltage battery and current battery represent the most basic function of a battery management system in the same time with allowing and foundation of other functions. So, what we want to notice is the fact that the battery state of charge, state of health evaluations is in dependence on accurate of voltage, current and temperature pursuing.

- **battery state estimation** as state of charge (SoC), state of health (SoH), state of function (SoF) and also state of power (SoP), state of life (SoL), state of range (SoR), state of energy (SoE);

The more common features of battery state estimation functions are SoC, SoH, SoF evaluation. The SoC evaluation is an important function of battery management system due to the its role in implementation of the control strategies, efficiency and robustness. The definition of most important factor SoC is expressed below, where the numerator and denominator are in Coulombs (C) or ampere-hour (Ah, 1Ah = 3600C).

$$\text{SoC} = \frac{\textit{remaining dischargeable}}{\textit{battery capacity}} \text{ x } 100\% \qquad (1)$$

The power battery management system has a high tolerance of the temperature monitoring error. Taking into account the SoC evaluation, the effective capacity of the battery varies with the temperature at the same discharge rate.

- **safety management** is contenting common protections as: over temperature protection, over current protection and over charge or discharge protection;

Over temperature protection is taking into account like a protective measurement for power battery when the temperature exceeds a certain limit value. That means that environment temperature, battery pack temperature and battery cell temperature should be take into account.

Over current protection refers if the working current overtakes the safe value in the process of charging or discharging.

Over charge protection as a disconnection of the charging circuit of the battery should be taken to prevent damage to the battery if is charging after 100% SoC. Over discharge protection refers if the battery is continuously discharged in 0% SoC.

- **energy control management** is based on charging control management, discharging control management and balancing control management,

Energy control management function of BMS provides in real time optimal control for the charging voltage, charging current and charging time, charging efficiency. Also, discharging control management refers to the control of the discharging current based on the battery state during discharging.

By balancing control management, it is possible to reduce the negative effects of cell inconsistency and improve the discharge efficiency of the battery pack.

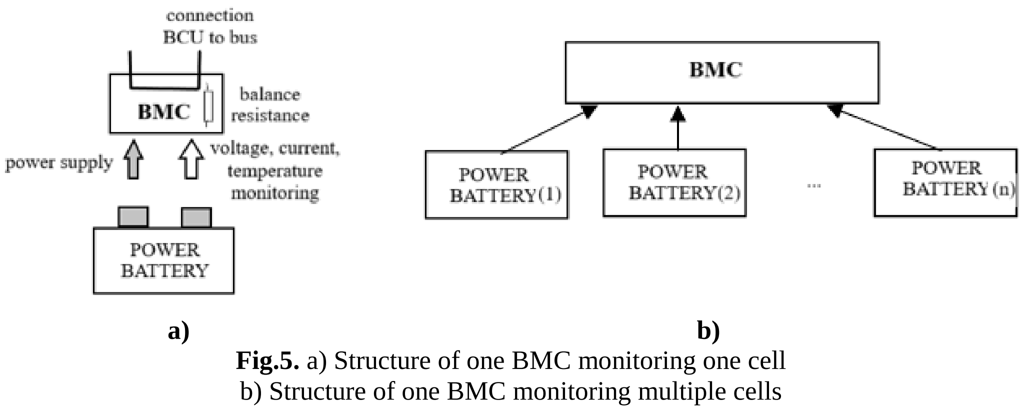
- **information management** is focus on storage battery`s history information, internal and external information interaction and battery information display.

Due to complexity of arrange of cells in the battery pack, a lot of data are generated instantaneous, some of that are provided or are sent to the components other than the battery management system. The historical storage of the battery is similar with a black box of an aircraft, helping in analyzing and identifying data for remove the failure [6].

3. THE STRUCTURE OF A BATTERY MANAGEMENT SYSTEM

The structure of system can be defined taking into account two base structures: a battery monitoring circuit (BMC) and a battery control unit (BCU). Relationship between its and cells are important, too.

There are two characteristic structures as shown in the below figure. The first structure is for each cell corresponds one BMC and the second structure means one BMC corresponding to multiple cells (fig.5). In the first case, the advantage consists in shorter distance between the BMC and the cell but the disadvantage is the higher cost of acquisition.

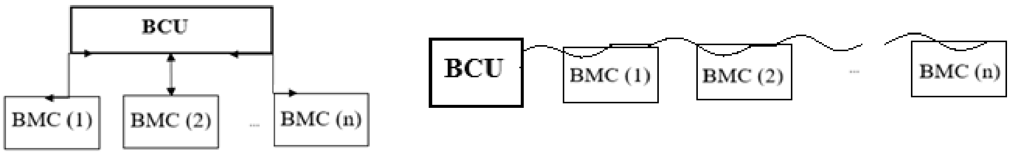


a) **b)**

Fig.5. a) Structure of one BMC monitoring one cell
b) Structure of one BMC monitoring multiple cells

In the second case, compared with the one -to- one structure, the structure is cheaper but there appears a ham of wirings and the acquisition line is longer. Relationship between a BCU and BMC can be achieved in different structures as a star connection or serial type connection (fig.6). The first one has the advantage of suitable access control and lackness of communication impact with another BMC when certain BMC stop working. Besides advantages there are some disadvantages as the difficulty of maintenance of longer line of communication and poor expandability [7],[1].

The second one has the advantage of lower cost of ham of wires, more flexibility connection and strong expandability.



a) **b)**

Fig.6. a) Star connection of BCU and BMS
b) Serial connection of a BCU and BMC

4. CONCLUSIONS

The energy systems are continuously developed, as the storage system becomes essential, especially for automotive and stationary applications. With an efficient control over optimum charge or discharge ranges, the management of battery system can extend the life of energy storage through preventing the risk of damage or failure.

REFERENCES

[1]. **Andrea Vezinni, s.a.,** *Battery management system and its applications*, Ed. Willey, 2023.

[2]. **Stochitoiu M.D, Utu I**., *The necessity of storage technology development for unpredictable energy sources*, SIMPRO 2021, University of Petrosani, 2021.

[3]. **Stochitoiu M.D., Utu I.,** *Challenges of the European energy transition,* Annals of Electrical Engineering, vol.24, University of Petrosani, 2022.

[4]. *** Report of Council of European Union *Assessment of the potential for energy efficiency in electricity generation, transmission and storage* 5180/23

[5]. www.worldenergy.org , Report *Five steps tot energy storage*

[6]. www.theodoresbooks.com

[7]. www.energynomics.ro

TOKEN-BASED AUTHENTICATION: NAVIGATING ACCESS SCENARIOS FOR SECURE USER VERIFICATION

MATEI-VASILE CĂPÎLNAȘ[1], TRAIAN SIMEDRU[2]

Abstract: The concepts of digitization and automation are becoming increasingly common nowadays. The development of web applications or the migration of different softwares to the web make the appearance of security breaches more and more frequent. This paper aims to provide a solution to secure the authentication process in order to reduce the risks of cyber-attacks.

Key words: web, cyberattacks, cybersecurity.

1. INTRODUCTION

The number of web applications is constantly growing. Although there is no exact statistic of the number of web applications, at the beginning of 2022 there were approximately 351.5 million domain names purchased. We can thus say that this is also the approximate number of web applications, regardless of their type (static or dynamic). This study's emphasis on web applications is driven by the rising prevalence of vulnerabilities and attacks within this domain, coupled with the limited number of research studies that provide visual insights into this issue. Fig.1 illustrates the evolving trends in the Open Web Application Security Project (OWASP) top ten vulnerabilities from 2017 to 2021.

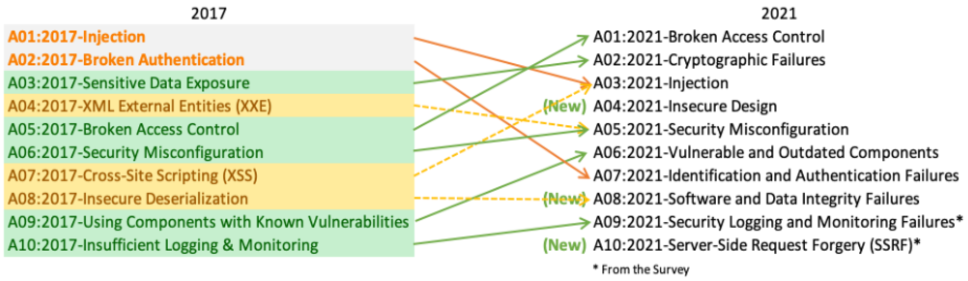


Fig.1. OWASP top ten vulnerabilities

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Security vulnerabilities often creep into software during its creation. To catch and fix these issues within the software development cycle, organizations adopt various methods like security audits and static analysis. A wide array of commercial tools and numerous research endeavors are focused on aiding the discovery of these security flaws. Responsibility for application security commonly resides with a specialized team within organizations, known as the 'Software Security Group' or SSG [1]. This team consists of application security experts charged with performing both static and dynamic analyses to pinpoint security vulnerabilities lurking in application source code.

2. METHODOLOGY DESCRIPTION

TypeScript Remote Procedure Call (RPC) is a concept and approach that involves using TypeScript, a statically-typed superset of JavaScript, to facilitate communication between different parts of a software system or between different systems [2]. RPC is a mechanism that allows one piece of code to invoke functions or methods on a remote server or module as if they were local, abstracting away the complexities of network communication and data serialization [3].

Here's how TypeScript RPC typically works:

- Defining Remote Services: You define a set of services, along with their methods, that you want to expose for remote access. These services are typically written in TypeScript and represent the business logic or functionality you want to access remotely.
- Generating TypeScript Interfaces: You create TypeScript interfaces that define the structure of these remote services. These interfaces serve as a contract between the client and the server for the available methods and their parameters.
- Client-Server Communication: TypeScript RPC frameworks or libraries handle the communication between the client and server. When a client wants to invoke a method on a remote service, the framework takes care of serializing the data, sending it over a network (e.g., HTTP, WebSocket, or other transport protocols), and deserializing the response on the server side.
- Type Safety: One of the key advantages of using TypeScript for RPC is that it provides type safety. TypeScript checks the types of function parameters and return values, which can help catch errors at compile-time rather than runtime.
- Code Generation: Some TypeScript RPC frameworks or tools may also provide code generation capabilities. They can generate TypeScript code for client-side and server-side components, which ensures that the client and server both understand the service contracts.

Node.js is an open-source, cross-platform JavaScript runtime environment that allows you to execute JavaScript code on the server-side. It is built on the V8 JavaScript engine developed by Google for use in their Chrome web browser. Node.js extends the capabilities of JavaScript beyond just being a client-side scripting language, enabling it to be used for server-side scripting and building network applications [4].

Key features and characteristics of Node.js include:

- Asynchronous and Non-blocking: Node.js is designed to be non-blocking and event-driven. This means it can handle many concurrent connections and I/O operations without getting blocked, making it highly efficient for building scalable and high-performance applications.
- Event Loop: Node.js uses an event-driven, single-threaded architecture, which allows it to efficiently manage asynchronous operations through an event loop.
- NPM (Node Package Manager): Node.js comes with a package manager called NPM that simplifies the installation and management of third-party libraries and modules, making it easy for developers to reuse code and share their own libraries.
- Server-Side Applications: Node.js is often used for developing server-side applications, such as web servers, API servers, and real-time applications like chat applications and online games.
- JavaScript: Node.js uses JavaScript as its primary programming language, which allows for code reuse between the client and server, making it easier for full-stack developers.
- Large Ecosystem: There is a vast ecosystem of open-source libraries and frameworks available through NPM, which can significantly speed up the development process and provide solutions for various use cases.

3. THE FUNCTIONALITIES OF THE APPLICATION

The primary aim of this application was centered around developing a robust authentication system that prioritized security. This was achieved by leveraging several key components such as Remote Procedure Calls (RPC), Cookies, Access Tokens, and Refresh Tokens. These elements were strategically employed to ensure a secure and reliable authentication process within the application.

When overseeing the authorization of a login attempt, the system considered three distinct scenarios or cases. In each of these cases, the system executed checks to verify the legitimacy and validity of two essential components: the Access Token and the Refresh Token.

The Access Token, which remained valid for a duration of one hour, was scrutinized by the system to ensure its current and legitimate status. Similarly, the Refresh Token, designed to remain valid for a span of one day, underwent examination by the system to confirm its authenticity and appropriateness for the login attempt.This dual verification process aimed to guarantee the security and integrity of the authentication procedure by evaluating the validity of these tokens within specified timeframes.

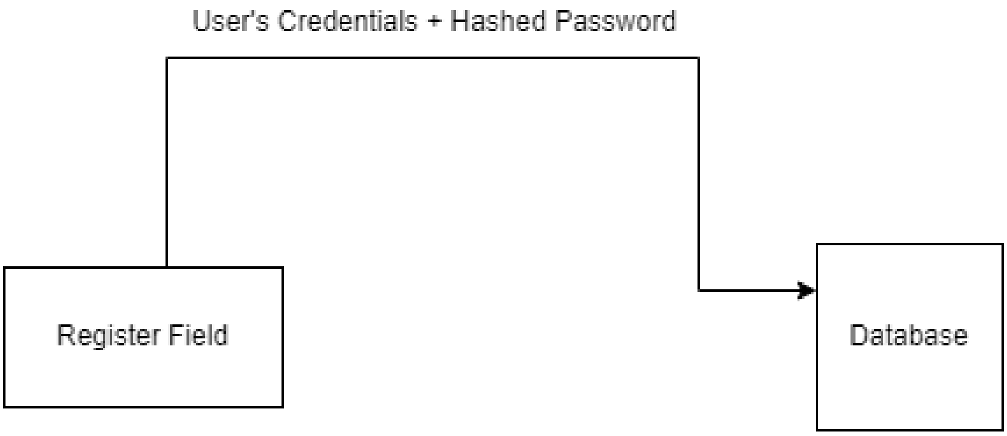

Fig.2. Registration flow

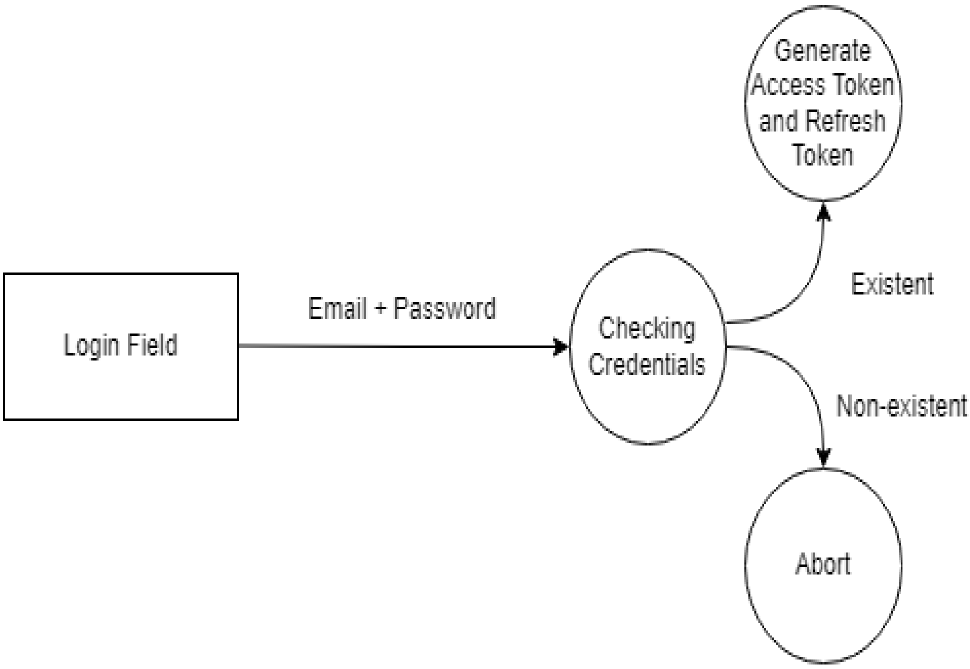

Fig.3. Login Flow

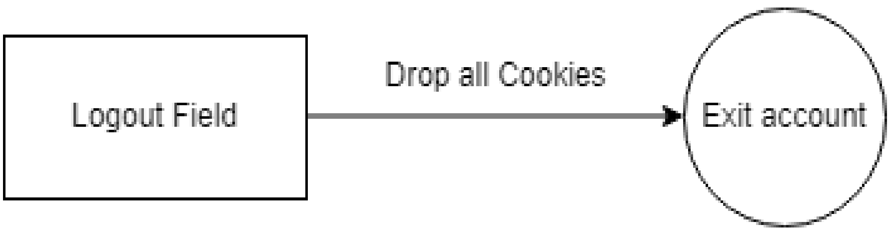

Fig.4. Logout Flow

Case 1

In this particular scenario where both the Access Token and the Refresh Token are confirmed as valid, a process called deserialization takes place specifically on the Access Token. Deserialization involves interpreting or converting the Access Token from its encoded or encrypted form into a readable format that contains information about the user and their access privileges.

Once the Access Token is deserialized, the user's provided credentials undergo validation. This step involves checking whether the user-provided credentials, such as a username and password, match the stored or expected credentials associated with the Access Token.

If the provided credentials are validated and deemed accurate, the user is granted access to the platform or system. Conversely, if the credentials fail to match or are found to be invalid during this validation process, access to the platform is denied, and the user's entry is rejected as a security measure. This method ensures that only users with authenticated and legitimate credentials are allowed access, while unauthorized or incorrect attempts are prevented from entering the platform.

Case 2

In this specific scenario, the Access Token has reached its expiration, rendering it invalid for further authentication purposes. However, it's important to note that while the Access Token has expired, the Refresh Token remains valid.

Given this situation, the system utilizes the Refresh Token as a mechanism to renew or regenerate the Access Token. This process involves using the Refresh Token to request a new Access Token from the authentication server without requiring the user to re-enter their credentials (such as username and password). The Refresh Token serves as a secure means to extend the user's authentication session without compromising security by sharing sensitive information repeatedly.

Once the system uses the Refresh Token to acquire a new Access Token, the authentication flow essentially mirrors the process from the previous scenario where both tokens were initially valid. The newly generated Access Token is then subjected to the same authentication flow: deserialization to extract user information and validation of credentials associated with the refreshed token.

Case 3

In this scenario, the Refresh Token has reached its expiration, making it invalid for generating new Access Tokens. However, despite the expiration of the Refresh Token, the Access Token remains valid and usable.

When the system encounters this situation, where the Refresh Token has expired but the Access Token is still valid, it continues the authentication flow without encountering any errors or disruptions. This is because the Access Token, which is the immediate credential used for authentication purposes, is still within its valid timeframe.

In essence, the authentication process replicates the flow observed in the first case. The system proceeds by deserializing the Access Token to extract user information and then validates the provided user credentials against this Access Token.

4. CONCLUSIONS

The authentication process within a system is a critical aspect ensuring security and user access. Understanding the various scenarios involving Access Tokens and Refresh Tokens provides a comprehensive view of how authentication flows can be managed in different situations.

Understanding these scenarios underscores the importance of a robust authentication system that leverages tokens effectively to ensure uninterrupted access for users while safeguarding against unauthorized entry. Implementing such practices enhances system security, user experience, and overall reliability

REFERENCES

[1]. Parth G., *Typescript microservices: build, deploy, and secure microservices using typescript combined with node*. Packt Publishing Ltd, 2018.

[2]. Thomas T.W., Tabassum M., Chu B., Lipford H., *Security during application development: an application security expert perspective*. Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18). Association for Computing Machinery, New York, USA, pp.262, 1–12, 2018.

[3]. https://auth0.com/docs/secure/tokens/access-tokens

[4]. https://www.loginradius.com/blog/engineering/guest-post/what-are-refresh-tokens-and-when-to-use-them/

DESIGNING SOFTWARE-BASED TOOLS FOR MONITORING, CONTROL AND TRAINING MICROGRID IMPLEMENTATIONS FOR ELECTRIC POWER NETWORKS

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Abstract: The current paper is the result of research program dedicated to designing new tools and instruments in designing and optimizing electric power networks management, and training for creating interaction between energy utilities providers and user behavior. We implemented a SCADA system for energy management and control, then we integrated a micro grid system with user interaction specific tools. On the current implementation we measured the training skills delivery results according with Scottish Credit and Qualifications Framework for creating the frame of acceptance and interaction for an efficient energy management.

Key words: Smart grid development, micro-grid, Quality of energy, training, user-interaction, smart living.

1. ELECTRICAL ENERGY MANAGEMENT IS PART OF OUR LIFE-HOW TO APPROACH IT?

The electrical energy is mostly the central part of our life, not only because it is supporting the other domestic utilities, but is strongly influencing the social life of everyone. So, in order to make steps forward into the progress tendencies in terms of modernization, it has to be accepted and favorized during implementation and updates of its added management techniques and methods. The positive point is that fact that

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“basic layer “in most of implementations starts from known, and stable implementations. For instance, the communication setup is implemented using RS485 with MODBUS protocol, then for communicating with software (through RS485), the devices are interconnected with serial cable with male-female connectors. The software is usually designed to allow and to support the students and professors in most of the training activities: control, and measurement interfaces, installation support, devices, and instruments individual control, debugging tools (devices supervision, Modbus control, reset). As an object-oriented representation technique [1], the global representation of electric power systems (for control and training) is shown in next figure.

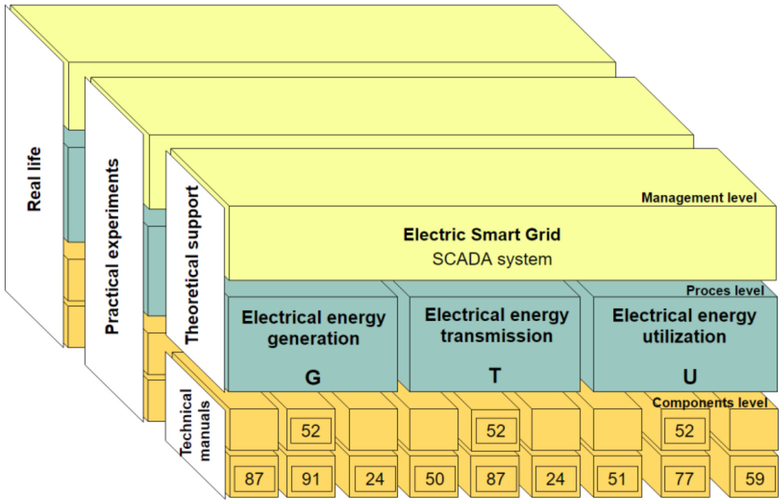


Fig.1. The multi-layer and object- oriented representation of the Smart Grid system that coordinates the involved electrical energy production processes

1.1 Service- oriented approach for training context- process levels trainers in system architecture design

Under the same branch name- GTU- there is a significant number of trainers dedicated to the energy production (Generation- G), transportation/ distribution (Transportation-T), and utilization (Utilization-U). The designed objectives of these trainer are intended to cover the most of the training topics from an electric power distribution network. In the next figure, there is represented a screen hoot that is taken from an electrical distribution software simulator, figuring generators, busbars, transmission lines with different load ratio, and demands from consumers, accompanied by some cost’s considerations [1-3]. In a simplified representation, we can identify components like in next figure.

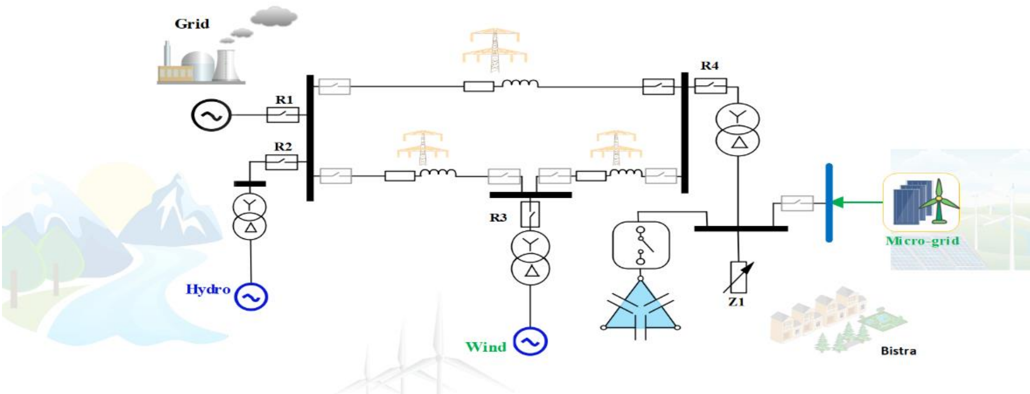


Fig.2. The one wire representation of the power grid entities involved in the energy management, according with [1], [3]

One wire representation of an electric power network composed by two generators, a loop transmission line, different power supplies, and a complex and big load, monitored and controlled by adequate protection devices and power switches.

1.2 The monitoring and control structure "planes" analysis approach

The associated documentation with the equipment and controlling software is grouped by three layers. It is organized from bottom-to-top, from simple-to-complex notions in progressive training approach, according with IEC TC 57.

1. Naturally, we must understand the role of the power network components, including measuring and protective devices. The main "language" of the study is using one wire representation with ANSI Standard Device Numbers (ANSI /IEEE Standard C37.2).

2. Then, because the trainer is approaching topics from electric power networks, the training continues with processes approach (generation of electrical energy, transportation and distribution of electrical energy, and use of it). At level process, we are studying and making experiments with devices through them application, not from the fundamental study point of view. All GTU groups of experiments are situated at this level.

3. In the actual context of the ICT and automation, the top level is the management level, with highly integrated intelligence. Smart-Grid trainer is our most representative trainer in this 3D representation.

1.3 The documentation "planes" approach analysis

On the different "planes" of the representation we have organized the analyzed documentation in the same similar progressive way.

I. First, we are using technical manuals support because the trainers are composed mostly by industrial devices used in electric power systems. Protection devices have own technical documentation and control software- they are invoked and used in our trainers.

II. Using reach and with high level of variety of theoretical sources, we added a comprised theoretical support (in many cases, organized like a state-of-arts of the used topics). The intention was to select theoretical literature cross- culture, and standard restrictions- free symbolizations.

III. The experiments are comprised in a specific chapter and they are organized in the way that they can be selected, and eventually printed as bundles. Optimally, they should be color printed in high resolution, but diagrams/ graphs are designed in the way that they allow also black and white printing.

IV. We have added also the forth section which suggests that all documentation is strongly linked with real life- we are inviting you in most of the cases to expand experiments, and scenarios according with available time and local specificities.

2. DESIGNING APPROACH FOR INTEGRATING LOCAL ALTERNATIVE ENERGY RESOURCES IN THE CONTEXT DESCRIBED REPRESENTATION

2.1 Service- oriented approach for integrating solar systems as ON-GRID implementation

In a simplified representation [1], [4], the approach intends to create suggestive representation of the place of solar system- as micro grid implementation- and the role of the user- as a beneficiary, like in next figure.

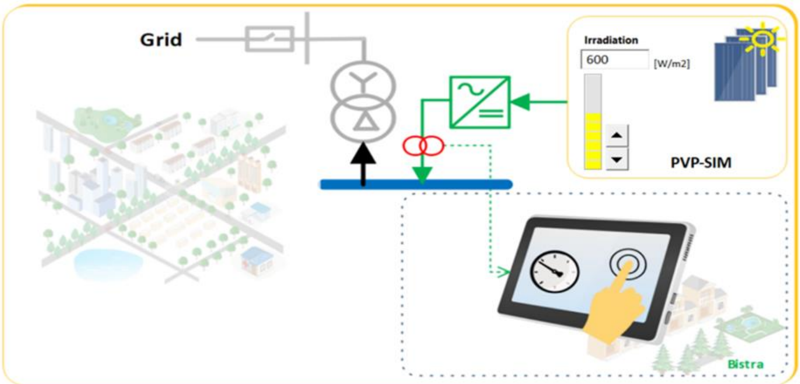


Fig.3. The integration of user/ grid entities in dedicated SCADA system

We have created a simulator of the solar panel (PVP-SIM) that replicates the entire behavior of the solar module, independent by the environment conditions, in a way that provide knowledge for the energy management at local level. The tablet symbol is representing the interactivity of the user.

2.2 Expanding the design analysis for integrating hybrid generators

For the study purpose, the hybrid inverter is integrated like in next figure (taken from inverter's user manual).

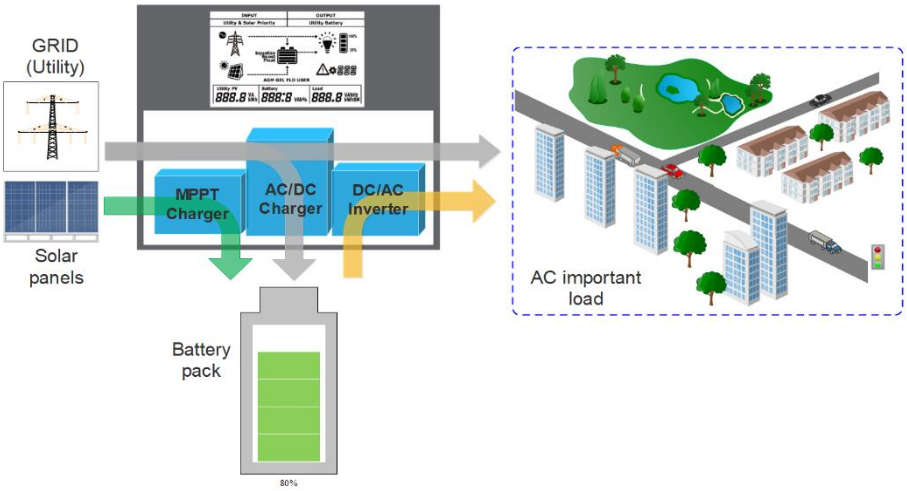


Fig.4. The symbolistic representation of the hybrid inverter integration in its management

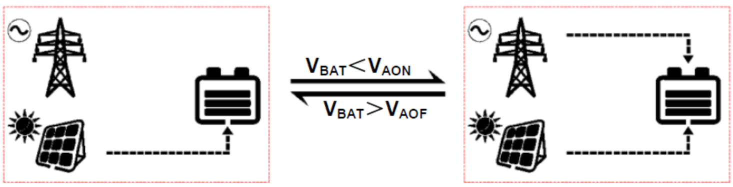
The main indicated flows show the inverter's components with them role: MPPT charger store regulated energy from the solar system into the battery pack; the charger add additional energy from the grid (utility) to the battery pack; then, the DC/AC inverter convert the DC stored energy into AC energy to be used by the important load.

The analysis of inverter's integration must be done from two point of views:

- Inputs point of view
  - PV priority
  - Grid priority
  - PV & Grid
  - PV
- Output point of view
  - Grid
  - Battery

2.3. Defining working mode for solar priority

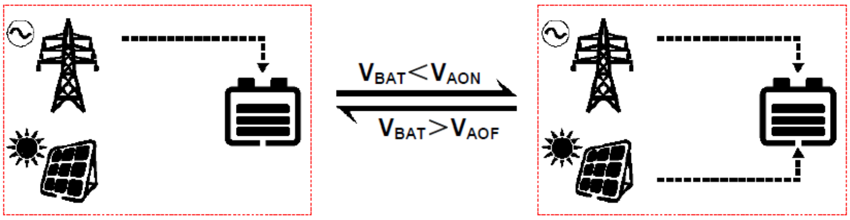
For the study, the representation model is shown next.



The software for monitoring allows setting up like in next procedure: the battery is charged in solar priority mode and when the battery voltage is lower than "Auxiliary Module ON Voltage (VAON)", the utility starts charging. When the battery voltage reaches to "Auxiliary Module OFF Voltage (VAOF)", the utility stops charging.

2.4 Defining working mode for utility priority

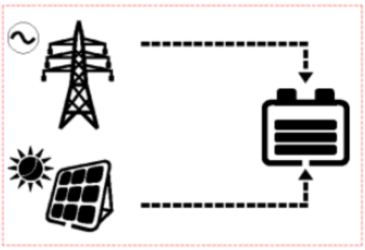
For the study, the representation model is shown next.



The battery is charged in utility priority mode and when the battery voltage is lower than “Auxiliary Module ON Voltage (VAON)”, the solar starts charging. When the battery voltage reaches to “Auxiliary Module OFF Voltage (VAOF)”, the solar stops charging.

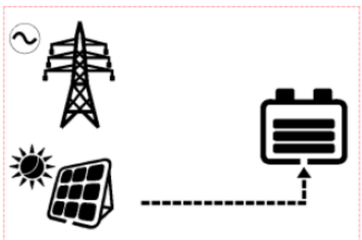
2.5 Defining working mode for utility and solar

In this representation, both, utility and solar are charging the battery.



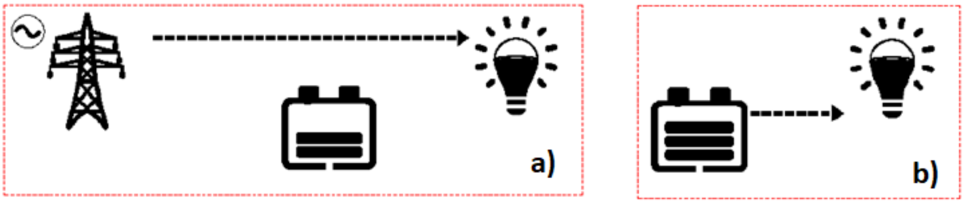
2.6 Defining working mode for solar input

In this representation we have next figure.



2.6 Defining working mode for the output priorities

When utility priority is configured/ desired, the representation is next (a). When battery priority is configured/ desired, the representation is next (b).



In any case of working mode, at control/ monitoring or training level, the role of the hybrid system must be understood with its main role.

3. TESTS ON THE INTERRACTION OF THE HYBRID SYSTEM INTO THE CONTEXT OF THE MICRO GRID INTEGRATION

For the testing purpose, but as a basic approach in training and understanding the role of the system, we have tested two major configurations [1], [5].

3.1 Working mode: Input- Grid (Utility) priority; Output: Grid (Utility)

The response of the SCADA environment shows intuitive icons and interfaces:

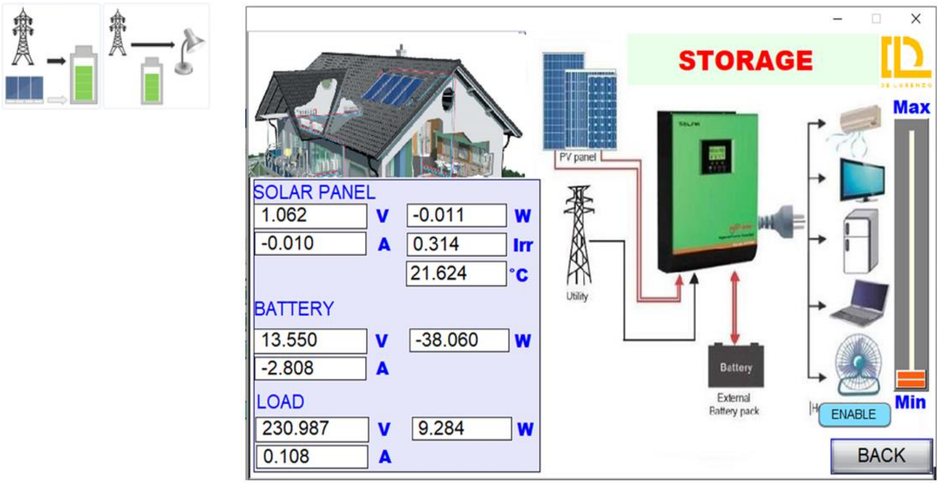


Fig.5. The "user" emulator interface showing the accessible data in one scenario of working

From the above figure, we understand the displayed data: 38.060 W used to charge the battery, 9.284 W consumed internally. No solar power available. Then, 38.909 W are consumed to charge the battery, and 37.302W is composed by the internal consumption 9.284 W and load consumption (37.302-9.284).

3.2 Working mode: Input- Solar and Grid (Utility); Output: Grid (Utility)

The response of the SCADA environment shows intuitive icons and a similar interface:

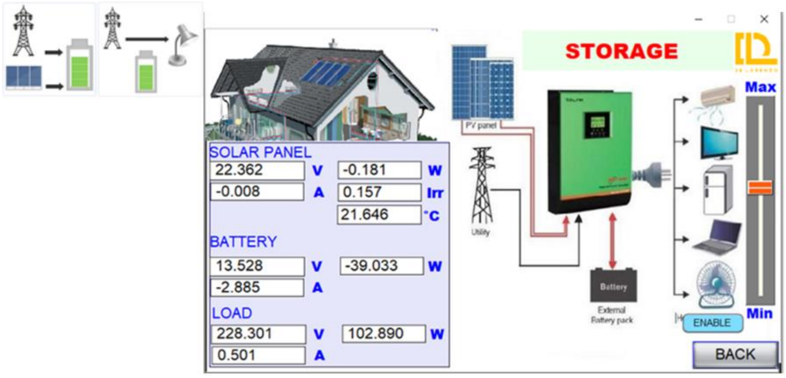


Fig.6. The "user" emulator interface showing the accessible data in another scenario of working

Where the read the data on the HMI application: at the moment of taking the screenshot, produced power from sun: 1.382 W; injected power into the battery 21.638 W, consumed power (internal loses and load) 103.251W. The total demanded power (21.638 W+103.251 W = 124.889 W) is covered by 1.382 W from sun and the rest from the grid (123.507 W. Then if we decrease the value of the load, the data should be changed in the corresponding text fields.

4. DESIGNING THE MODEL-BASED INTEGRATION OF THE MICRO-GRID SECTION INTO THE MAIN POWER GRID

A typical grid configuration could be represented like in next figure.

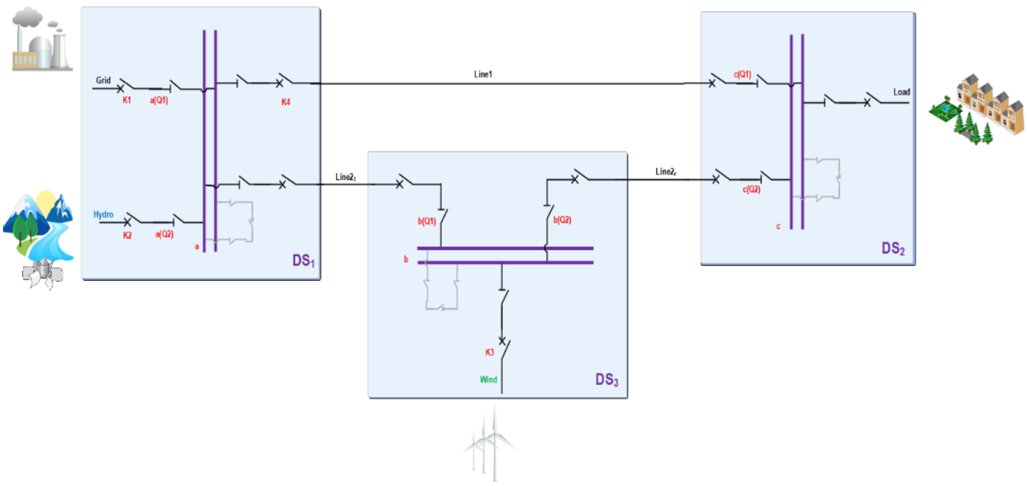


Fig.7. The "user" emulator interface in located and integrated in an electric power system scene, according with [1], [5], [6]

This mesh configuration allows supplying the load from the grid, with the possibility to add other power supplies, through the three distribution stations (DS1, DS2, DS3, also marked by letters a, b, c). Each distribution station is managed by insulation switches (labeled by Q) and power breakers (labeled with K); for instance, aQ1 is the first section of the insulation switch from the DS1; cQ2 is second section of the insulation switch from the DS2. The parallel line adds outcomes in terms of safety and reliability. At DS3 level the microgrid is intended to be integrated. The experiment is designed by separating the electrical energy production and the grid system, by the user, or human operator. The sense of this approach is to underline the two independent layers, with two different governing laws (energy management layer and user's behavior layer). The users/human operators are seeing the electrical energy production by the sun, and operate on some load according with own needs. So, the SCADA and the equipment are working according with designing principles of them (in grid), and the users have own way of approaching the trainer (in micro grid). The user actor in this experiment is represented by an HMI device (Human Machine Interface entity) that is connected to the SCADA for information exchanging with user's behavior, via a TCP/IP interface. The HMI has implemented an application that allows interaction between user and some trainer's component- specific to a user, without interfering into the grid SCADA management- see next figure (where PV-SIM is photovoltaic array simulator).

There is implemented a SCADA software for managing the grid operations (in current experiment we simulate the sun energy radiation for energy production), and on the HMI, there is implemented a software that manages the microgrid system. Where, as a user in the lab/dispatching system, in next figure we show you how to interact with the system (having in the mind that always, the user will act for simulating SCADA operations, and in the same time will be an energy consumer- as typical user).

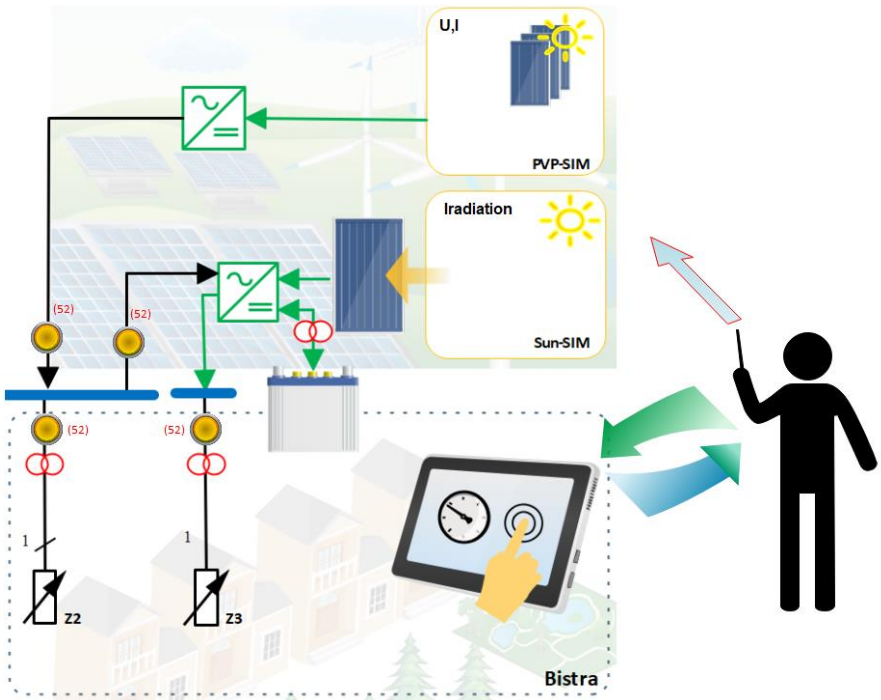


Fig.8. The "user" emulator interaction with the management level implementation

5. CONCLSIONS. METRICS FOR EVALUATING THE IMPLEMENTED SYSTEM

A proposed system is fully developed and it is working without no interruption for 4 months. The interface is developed and independent platform, providing data in local area network, and through a virtual private network in any web- accessible location. Next, the conclusions are provided as a tabular representation.

5.1 Descriptor: General architectures. Concepts

C1- Knowledge and understanding	**C2- Practice; applied skills**	**C3- Generic cognitive skills**	**C4- Comm., ICT skills**	**C5- Autonomy and working in teams**
critical understanding of the principal theories, concepts and principles of functions-based management in smart grid; extensive knowledge in cost-based management in smart grid	Apply knowledge, skills and understanding in smart grid architecture design; in planning and executing an extensive project of smart grid; designing particular project according with local particularities.	Critically identify, define, conceptualize and analyses complex/professional problems and issues in designing smart grid architectures. Offer professional insights, interpretations and solutions to problems and issues in smart grid applications.	Communicate, using appropriate methods, to a range of audiences with different levels of knowledge/ expertise.	Take responsibility for own work and/or significant responsibility for the work of others. Take significant responsibility for a range of resources.

5.2 Descriptor: Communication support for Smart grid. Reliability issues

C1- Knowledge and understanding	**C2- Practice; applied skills**	**C3- Generic cognitive skills**	**C4- Comm., ICT skills**	**C5- Autonomy and working in teams**
critical understanding of the principal theories, concepts and principles of communication systems for SCADA	Apply knowledge, skills and understanding in running specialized skills for reliability tests in smart grid communication	Deal with complex issues and make informed judgements in situations in the absence of complete or consistent data/information.	Communicate with peers, senior colleagues and specialists on a professional level.	Manage complex ethical and professional issues and make informed judgements on issues not addressed by current professional and/or ethical codes or practices.

5.3 Descriptor: SCADA support for smart grid. Software installation and configuration issues

C1- Knowledge and understanding	C2- Practice; applied skills	C3- Generic cognitive skills	C4- Comm., ICT skills	C5- Autonomy and working in teams
Knowledge and understanding of the ways in which the SCADA system is developed. Knowledge of programming environments for SCADA. Extensive knowledge in software engineering for SCADA	Apply knowledge, skills and understanding in executing a defined project of research, development or investigation and in identifying and implementing relevant outcomes for every particular case of software configuration and security.	Critically identify, define, conceptualize and analyses complex/professional problems and issues in SCADA systems as support for Smart Grid.	Communicate with peers, senior colleagues and specialists on a professional level.	Exercise autonomy and initiative in professional/equivalent activities. Practice in ways that show awareness of own and others’ roles and responsibilities. Recognize the limits of these codes and seek guidance where appropriate.

5.4 Descriptor: Demonstration experiments

C1- Knowledge and understanding	C2- Practice; applied skills	C3- Generic cognitive skills	C4- Comm., ICT skills	C5- Autonomy and working in teams
critical understanding of a range of specialized theories, concepts and principles for smart grid major topic.	Apply knowledge, skills and understanding in demonstrating originality and/or creativity, including in practices when running processes experiments in Smart Grid.	Develop original and creative responses to problems and issues. Make judgements where data/information is limited or comes from a range of sources.	Communicate at an appropriate level to a range of audiences and adapt communication to the context and purpose.	Take significant responsibility for a range of resources. Work in a peer relationship with specialist practitioners.

5.5 Future development

After identifying the metrics parameters, and proving then consistency in the current development, next proposed research is to create quantitative weights of these parameters, according with SCOF [7]. The major reason of creating quantitative map of them is to create definite tools for controlling the skills delivery in the field.

REFERENCES

[1]. Clarke L., Edmonds J., Jacoby H., Pitcher H., Reilly J., Richels R., *Scenarios of greenhouse gas emissions and atmospheric concentrations*, US Department of Energy Publications, 6, 2017.

[2]. *,** GE: *GE Wind Turbine Technology Selected for New Wind Power Station in Japan,* http://site.geenergy.com/about/press/en/2003_press/100103.htm

[3]. *,** *Japan Wind Development Company: world's First Commercial Application of CaFrESS,* http://www.cir-strategy.com/uploads/Kuhrt.pdf

[4]. *,** *Network Protection and Automation Guide*, Alstom Grid, 2018.

[5]. *,** *Renewable Energy World: Storage Boosts the Power of Renewable Energy*, http://www.renewableenergyworld.com/rea/news/article/2008/06/storage-boosts-thepower- of-renewable-energy-52716

[6]. *,** *SCQF LEVEL DESCRIPTORS TOOL*, https://scqf.org.uk/about-the-framework/scqf-level-descriptors-tool/, last visited in December, 2023.

[7]. *,** *Yogogawa: STARDOM and FA-M3 Ensure Smooth Supply of Power to Grid by Wind Farm,* http://www.yokogawa.com/iab/suc/power/iab-suc-jwd-en.htm

ARTIFICIAL INTELLIGENCE APPLIED IN NETWORK SECURITY

MATEI-VASILE CĂPÎLNAȘ[1]

Abstract: The purpose of this paper is to analyze methods for the development of a system capable of recognizing potential attacks and/or preventing cyberattacks, which have become increasingly prominent in recent years. The overall objective of the system is to assist qualified individuals in the field, optimizing their analysis processes and providing as precise reports as possible to combat cybercrimes. To achieve this goal, artificial intelligence techniques will be used, particularly focusing on deep learning techniques due to their success in addressing similar problems in recent years.

Key words: artificial intelligence, cyberattacks, cybersecurity.

1. INTRODUCTION

According to [1], starting from the 19th century, researchers have studied anomaly detection and produced numerous works using various techniques, from statistical models to evolutionary computation approaches. However, it is not easy to identify and classify all existing anomaly detection techniques because various factors must be considered, such as the type of anomaly, the system, the techniques and algorithms used, as well as technical dilemmas like processing costs and network complexity. Consequently, the available literature today is fragmented, and many works attempt to summarize everything but fail to present the complete picture of the anomaly detection spectrum.

Network anomalies can be caused by a variety of factors, including network attacks, infections with malware programs, improperly configured network devices, or even legitimate user behavior that falls within normal activity limits. Detecting and identifying network anomalies is an important aspect of network security because it can help organizations identify and respond to potential threats promptly. Various tools and techniques, such as Intrusion Detection Systems (IDS), network monitoring software, and machine learning algorithms, can be used to detect and analyze network anomalies.

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2. INTRUSION DETECTION IN IOT NETWORKS USING DEEP LEARNING ALGORITHM

In the study by [2], researchers utilized a dataset to classify attacks. They employed machine learning techniques (specifically Random Forest: RF) as well as deep learning methods, including Convolutional Neural Network (CNN) and Multi-Layer Perceptron (MLP). The anticipated outcome of this research is the implementation of results into a Network Intrusion Detection System (NIDS), enabling anomaly detection in an IoT network.

Their study investigated various machine learning and deep learning algorithms within an IoT network. Specifically evaluating RF, CNN, and MLP algorithms, they found that RF and CNN provided the highest accuracy and Area Under the Curve (AUC) for multiclass classification. Experiments were conducted with different batch sizes, noting that including epochs in trials with 32 and 64 batches slightly decreased accuracy, while trials with 128 batches slightly increased accuracy.

Moreover, it was discovered that increasing batch size could expedite the computation process. Doubling the batch size in MLP resulted in computation 1.4-2.6 times faster, while CNN led to a process 1.8-2.4 times faster.

3. NETWORK ANOMALY DETECTION: A MACHINE LEARNING PERSPECTIVE

Bayesian networks are often used in conjunction with statistical methods, offering several advantages for data analysis. They can handle missing data, represent causal relationships, and merge prior knowledge with data. In the article by [3] a system based on this network is proposed. In the field of anomaly detection in networks, several variations of the basic Bayesian network technique have been suggested. These techniques can capture conditional dependencies between different attributes using complex Bayesian networks. Bayesian techniques have been commonly used for classification and false alarm suppression.

A multisensor fusion approach has been proposed where outputs from different IDS sensors are aggregated to produce a single alarm. This approach assumes that no anomaly detection technique can classify a set of events as an intrusion with enough confidence.

The advantages of using Bayesian networks for anomaly detection in networks are numerous. They allow the representation of interrelationships among dataset attributes, are easily understood by human experts, and can be easily modified as needed. Bayesian networks permit explicit characterization of uncertainty, quick and efficient computation, and fast training. Their high adaptability, ease of construction, and ability to explicitly represent domain-specific knowledge make Bayesian networks attractive for anomaly detection in networks. However, it's essential to consider the method's limitations.

The accuracy of the method relies on certain assumptions based on the behavioral model of the target system, and deviation from these assumptions will decrease its precision.

4. THE ANALYSIS OF FIREWALL POLICY THROUGH MACHINE LEARNING AND DATA MINING

An interesting approach can be observed in the study by [4]. To conduct this study, researchers extracted data from a firewall. However, they encountered an issue - a single log file containing a large amount of data would have used up the entire firewall memory. To overcome this problem, the researchers decided to save the data in smaller chunks using the firewall's own interface. Specifically, they saved the data in 48 pieces, each of which could be used as training data for the study.

By using smaller data chunks, the researchers managed to avoid overwhelming the firewall's memory and conduct the study more efficiently. This approach also allowed them to gain a better understanding of the firewall's behavior as they could analyze each data chunk in detail. Overall, the decision to save the data in 48 pieces proved to be a smart move and helped the researchers achieve their research objectives.

12 training data chunks were analyzed using 6 different classifiers (Naive Bayes, kNN, DecisionTable, HyperPipes, OneR, and ZeroR) to identify the most efficient machine learning algorithms.

Despite the availability of a large number of algorithms, only 6 were selected for further analysis based on their performance in preliminary tests. These 6 algorithms were chosen for their ability to produce the best results and employed different approaches in machine learning.

5. ANALYSIS OF TRAFFIC FROM A SOCIAL MEDIA PLATFORM NETWORK

The study [5] serves as a good starting point in approaching network traffic analysis. With the onset of the COVID-19 pandemic in 2020 and last year in 2022, coinciding with the outbreak of the conflict in Ukraine, there has been a noticeable increase in user activity on social networks. For many, this virtual environment serves as a refuge during challenging times, a space where they can express their feelings through images or comments. Building on this aspect, in 2022, within a research project, we decided to develop a web application to collect comments in Romanian regarding specific images with different emotional impacts.

Starting from the developed application, I believe that improving it to transform it into a social media platform (where users can upload their own photos and interact with each other) could lead to creating an optimal environment for network traffic analysis. Gathering logs generated when a user performs a normal action (e.g., uploading a photo) or when someone attempts an attack on an account or the entire application could yield a dataset usable in developing an intrusion detection and prevention system.

A major issue that might arise in creating such an environment is developing the application in a way that inadvertently introduces security vulnerabilities. This could jeopardize the entire network, and to mitigate risks, the concept of a DMZ (demilitarized zone) must be considered.

6. CONCLUSIONS

The amalgamation of cybersecurity and artificial intelligence heralds a promising frontier, as recent studies vividly illustrate. The symbiotic relationship between these realms promises groundbreaking solutions, from robust threat detection to adaptive defense mechanisms. However, amidst this potential lies a landscape riddled with challenges. Existing problems persist, spanning from the ethical implications of AI-powered security to the vulnerability of AI systems to sophisticated attacks. Bridging these gaps demands a concerted effort, leveraging innovation while navigating the ethical and security pitfalls. As these fields evolve, a balanced synergy between cybersecurity and AI becomes not just a necessity but a pivotal determinant of our digital resilience in an increasingly complex threat landscape.

REFERENCES

[1]. Bhattacharyya D.K., Kalita J.K., *Network anomaly detection: A machine learning perspective*, Crc Press, 2013.

[2]. Fernandes G., et al., *A comprehensive survey on network anomaly detection*, Telecommunication Systems 70, pp. 447–489, 2019.

[3]. Salloum S.A. et al., *Machine learning and deep learning techniques for cybersecurity: a review*", Proceedings of the International Conference on Artificial Intelligence and Computer Vision, Springer, pp. 50–57, 2020.

[4]. Susilo B., Sari R.F., *Intrusion detection in IoT networks using deep learning algorithm*, Information 11.5, p. 279, 2020.

[5]. Ucar E., Ozhan E., *The analysis of firewall policy through machine learning and data mining*", Wireless Personal Communications 96, pp. 2891–2909, 2017.

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