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

NICOLAE DANIEL FITA[1], SORIN MIHAI RADU[2], ILIE UTU[3], MARIUS DANIEL MARCU[4], DRAGOS PASCULESCU[5], FLORIN GABRIEL POPESCU[6]

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

[1] *Ph.D., Ph.D., Lecturer, Eng., University of Petroșani, daniel.fita@yahoo.com*
[2] *Ph.D., Prof. Eng., University of Petroşani, sorin_mihai_radu@yahoo.com*
[3] *Ph.D., Associate Prof. Eng., University of Petroşani, ilieutu@yahoo.com*
[4] *Ph.D., Associate Prof. Eng., University of Petroşani, mariusmarcu66@yahoo.com*
[5] *Ph.D., Associate Prof. Eng., University of Petroşani, pdragos_74@yahoo.com*
[6] *Ph.D., Associate Prof. Eng., University of Petroşani, floringabriel82@yahoo.com*

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).

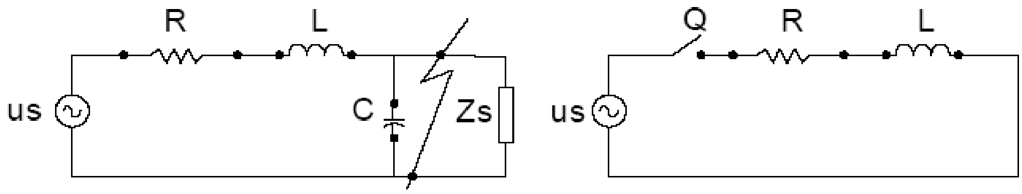

Fig.1. Short-circuit mode in a network

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].

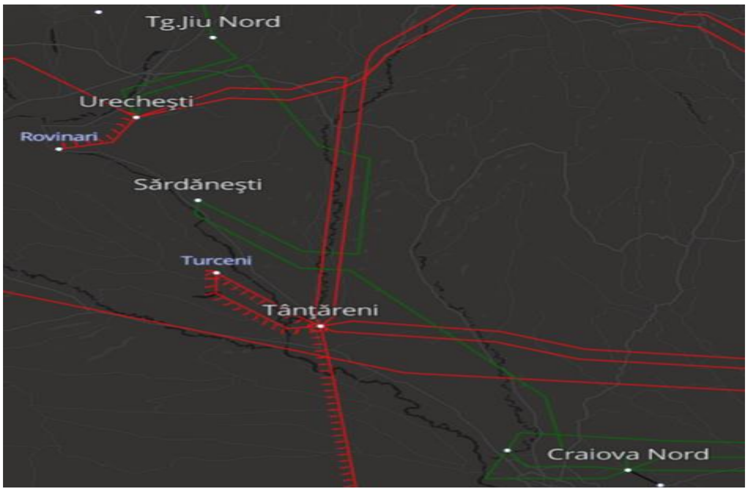

Fig.2. Single diagram of the 220/110/20 kV Sardanesti power substation (source:www.entsoe.eu)

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].

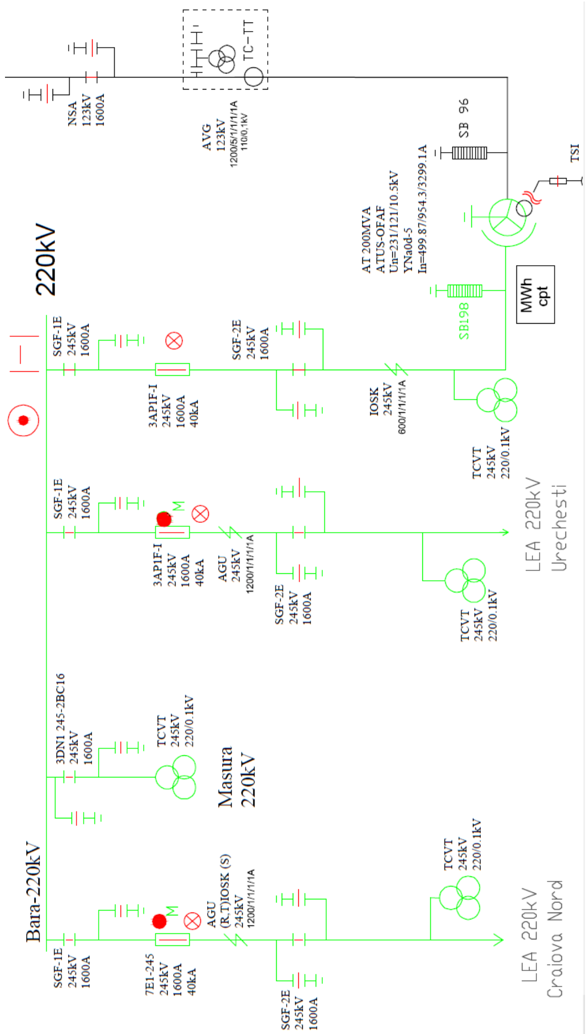

Fig.3. Single diagram of the 220 kV Sardanesti power substation

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.*

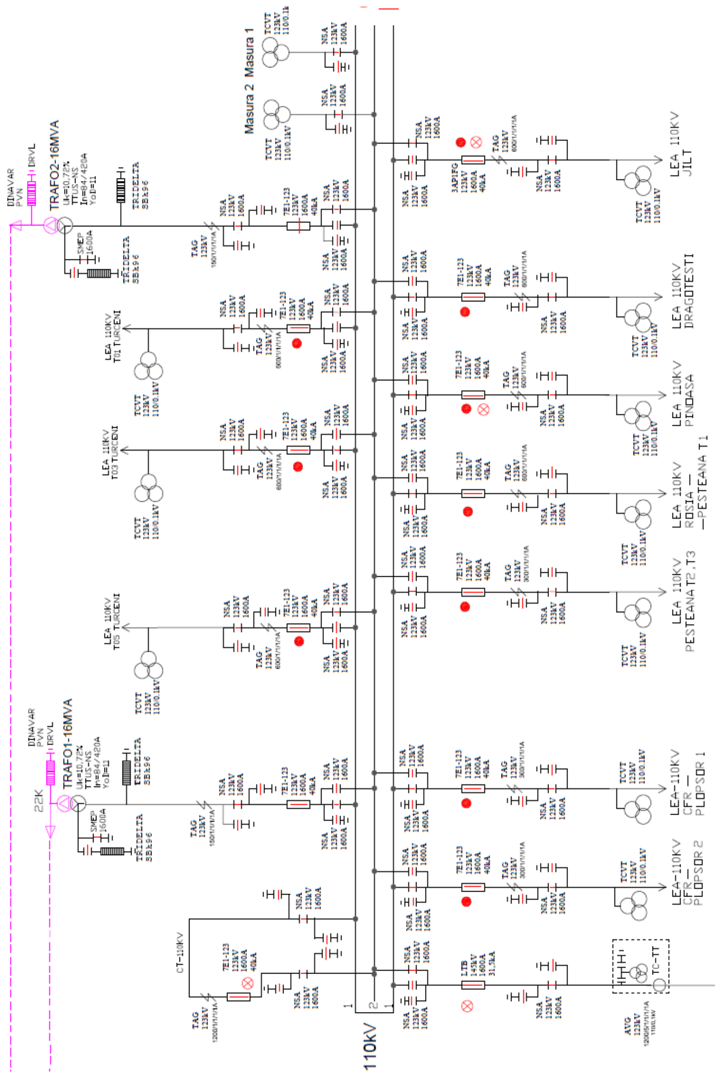

Fig.4. Single diagram of the 110 kV Sardanesti power substation

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].

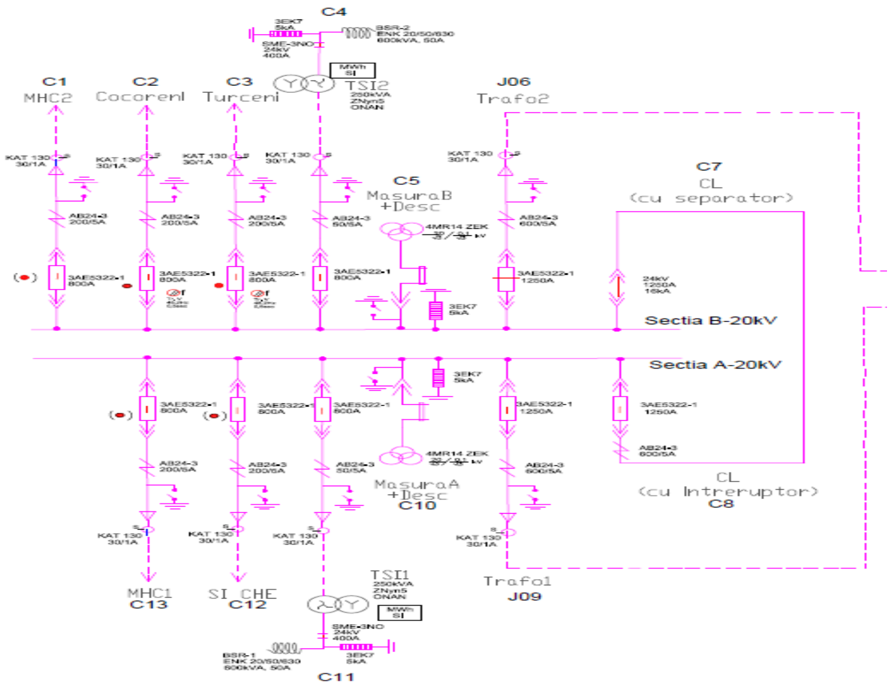

Fig.5. Single diagram of the 110 kV Sardanesti power substation

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

	Pre-Flt				--1/2-Cycle---		Steady-State--	
Bus Name	kV		I"k	ip	Isym	Iasym	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

	Pre-Flt				--1/2-Cycle---		Steady-State--	
Bus Name	kV		I"k	ip	Isym	Iasym	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

	Pre-Flt				--1/2-Cycle---		Steady-State--	
Bus Name	kV		I"k	ip	Isym	Iasym	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

	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

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-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	110	A	0	0	0	0
		B	10652	30128	10652	10652
		C	10728	30344	10728	10728

c) Short-circuit all power substation:

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

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
-------------------------------------------------
```

```
                         ------------------------------
                          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
-------------------------------------------------
```

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

```
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.